Evaluating the Operational Function of Intermediate Care using a Multimethodology of Soft Systems Methodology and Discrete Event Simulation Modelling

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSHOPHY

BY

KATHOLIKI KOTIADIS

B.Sc.(HONS) UNIVERSITY OF KENT

CANTERBURY BUSINESS SCHOOL

UNIVERSITY OF KENT

December 2003

Abstract

This thesis is about evaluating the operational function of Intermediate Care, a health and social care system for older people, by undertaking an action research project using a multimethodology of both "soft" and "hard" Operational Research. The Department of Health has invested heavily in the development of Intermediate Care systems and their services and their evaluation is worthwhile and important. A group of local stakeholders commissioned in 1999 the University of Kent to evaluate Intermediate Care for the Shepway locality in East Kent. The commissioning project was named ICON and the work described herein is allied to the ICON project.

The multimethodology used for this project is Soft Systems Methodology and Discrete Event Simulation Modelling. The Soft Systems Methodology (SSM) approach was to use primary task root definitions to understand and examine the Operational Function of Intermediate Care (IC) in Shepway. The actions resulting from SSM included to extract Service Entry Eligibility Criteria and confirmed the need to undertake a simulation study to examine the services resource utilisation and the services compliance to these criteria. For the Simulation Study four models have been built, one for each of the "hard core" IC Services and a "whole system" model that examines the decision making mechanism of allocating patients to services in the system.

The contribution of this research is multidimensional. The primary contribution is the understanding and the evaluation of the operational function of Shepway IC. The project has contributed a multimethodology that can potentially be adapted to evaluate other IC systems and their services. Other dimensions are learning about applying each of these methods to the system of interest and learning about the combination of these two methods that are traditionally associated with different paradigms.

Acknowledgments:

I would like to thank all of the members of staff from the Canterbury Business School at the University of Kent and particularly: Professor John Mingers for everything he has done to help me transform my written work into a thesis by supervising me in the last few months of my write up year. Dr John Lamb my PhD supervisor who supported me in my work and was missed when he left for the University of Aberdeen. John Bevan for helping me find a research topic by suggesting that I should go over to the Centre for Health Service Studies to see if they had any projects.

I would also like to thank the members of staff at the Centre for Health Service Studies at the University of Kent and in particular the rest of the ICON team which include Dr Iain Carpenter who helped me understand issues surrounding assessment of older people and even took me on his hospital ward round to understand older people and their health and social care needs. I would like to thank Dr Mathew Mackenzie for providing me the data from the patient data collection that he managed.

I would also like to thank all of the employees of the Intermediate Care services in East Kent who participated in the project directly and indirectly and in particular: the Community Assessment Rehabilitation Team in Shepway, the Day Hospital in Shepway, the Recuperative Care and the rehabilitation wards at the Royal Victoria Rehabilitation Hospital, the William Harvey Hospital and the Buckland Hospital. This project has made me see (with my own eyes) the dedication and caring nature of this country's health and social care professionals, who work extremely hard for few rewards, but yet enable people to regain their life.

I would also like to thank my family and friends for their emotional support when things got a bit too much for me and I felt like giving up.

Declaration of work:

I declare that the project work described in this thesis is my own. My work is allied to the ICON project, which enabled me access to Health and Social care employees, and the extent of participation of the other ICON team members in my work was clarifying health and social care terminology, helping me code the Service Entry Eligibility Criteria into assessment items, helping me verify and validate the simulation models and providing me with patient data collected through the ICON assessment forms.

List of Contents:

List of Tables:

List of Figures:

List of Appendices:

List of Abbreviations:

CART – Community Assessment Rehabilitation Teams

IC – Intermediate Care

LOS – Length of Stay

SSM – Soft Systems Methodology

DESM – Discrete Event Simulation Modelling

1 Chapter 1 – Introduction to Problem and Research

1.1 What is the research about?

This research is about evaluating the operational function of Intermediate Care, which is a health and social care system for older people. The Department of Health (2000) response to the National Bed Enquiry stated that it intended a major expansion of community health and social care services (termed intermediate care – IC) that in contrast to acute hospital services would be focused on rapid assessment, stabilisation and treatment. These would include "Hospital day units and community based services aimed at maintaining people in their home communities in good health, preventing avoidable admissions, facilitating early discharge and active rehabilitation post-discharge and supporting a return to normal community-based living wherever possible. Over time "places" in community schemes might replace some acute hospital beds". In 2001 it published guidance on service models for intermediate care, which included services with specific goals of preventing hospital admissions, enabling earlier discharge from hospital by providing rehabilitation closer to home and preventing admission to long term care (Department of Health, 2001a).

These services were to meet all of the following principles:

Are targeted at people who otherwise face unnecessary prolonged hospital stays or inappropriate admission to acute inpatient care, long-term residential care or continuing NHS inpatient care.

Are provided on the basis of a comprehensive assessment, resulting in a structured individual care plan that involves active therapy, treatment or opportunity for recovery.

Have a planned outcome of maximising independence and typically enabling patients/users to resume living at home.

Are time limited normally no longer than six weeks and frequently as little as 1-2 weeks or less and Involve cross professional working, with a single assessment framework, single professional records and shared protocols.

1.1.1 Why is a system for Older People important?

The importance of examining a system for older people is because most of the countries of the world are facing an ageing population, as life expectancy at birth is steadily increasing (Carpenter G.I., 1999). The elderly, otherwise know as older people, are those who have reached or exceeded the age of 65. The extent to which older people are ageing can be seen not just through the proportion of people aged over 65 but also in terms of the absolute numbers of older people. The World Health Organisation has produced figures to show that the world-wide proportion of people aged 65 and over is expected to increase from just over 5% in 1950 to just less than 10% in 2025. This indicates that the proportion doubles in a matter of 75 years. Another important prediction of the WHO is that the total number of older people world-wide will increase from 128 million in 1950 to 825 million in 2025 (World Health Organisation, 2003).

This increase in older people in the UK is causing and will continue to cause issues and problems for both the health and social care providers and the older people. In addition the Health and Social Care providers have limited resources to satisfy an even greater number of people and the older people are facing inadequate provision of health and social care services. There are other factors that contribute to this inadequate provision of services such as the rising cost of health and social care, current expenditure is not meeting the needs that have formed and a persistent under-funding in the NHS for a number of years. These factors have resulted in operational problems such as 'bed blocking' especially in acute hospitals and waiting lists for operations and other treatment to exceed any safe limits set.

The government has been focussed over the past few years on these increasing problems and has put health on the top of the agenda but despite efforts the problems persist. The efforts have been creative and varied and aimed at providing a relief for this over-utilised system. The action has included:

Recruiting staff such as nurses and doctors either abroad or through increasing training/university places but this will not have an effect on the system for a few years and some suggest that the numbers are not adequate.

Investing in new forms of treatment. For example, investing in new drugs and therapies.

Centralising treatments to benefit from economies of scale. For example merging hospital departments to create specialist treatment centres.

Providing local authorities with new decision and spending powers.

The above indicate a Government trend of seeking suitable cost-effective alternatives for the health and Social care of older people in place of the traditional forms of care e.g. acute hospital beds. Elderly people occupy two-thirds of general and acute hospital beds in this country, and account for over a half of recent growth in emergency admissions. Length of stay in hospital is also significantly greater for older people (Department of Health, 2000). For this age group, it has been estimated that 20% of hospital bed days were inappropriate and could have been avoided were suitable alternative facilities in place. Intermediate Care services can be considered part of the solution but funds are limited and all solutions require investigation.

1.1.2 Motivation for the Research

The motivation to conduct research to evaluate the operational function of Intermediate Care can be linked to three general PhD requirements. Firstly it was about choosing a topic that would have a wide interest, preferably National. Secondly, that it had not been done before and therefore added to the current knowledge and literature. Thirdly, that the research is feasible despite being complicated and difficult to undertake. Each of these requirements is further explained:

The first requirement was that there is National interest in this area – The Department of Health has allocated a significant amount of money and resources, specifically it has pledged to invest £900 million a year by 2003/2004 in intermediate care services (Department of Health, 2001a). The creation and evaluation of intermediate care services for older people are in order to relieve the over utilised acute hospitals and long term institutional care settings from those who do not benefit from these services.

The second requirement was about finding a gap in the literature. This is further discussed in the conclusion of the Literature Review.

The third requirement is the feasibility of the research – This was about making sure that funds were available to pay for any expenses relating to the research and that there was co-operation with information gatekeepers. A Kent Elderly Strategic Planning Group and the local Joint Planning Board commissioned an Action Research project to the Centre for Health Service Studies at the University of Kent. The project allied to this PhD was named ICON, which stands for Intermediate Care Organisation and Normalisation and was funded by the East Kent Health Authority and Social Services. This satisfied the feasibility requirements as both funds and cooperation were secured. ICON examined several aspects of IC one of which was the operational function of Intermediate Care, which I carried out.

1.1.3 The Project allied to this research

The ICON Project had four main team members including myself and I was the only person with an Operational Research background. At the start of the project I had recently graduated with a management science degree and my experience in Operational Research involved my final year project, which was modelling a final assembly cell for a manufacturing company using computer simulation modelling and I was eager to apply simulation modelling again. In fact, I joined the team because the project leader, a geriatrician, thought that simulation modelling and more specifically the conceptual model that I used in manufacturing could be useful in health care. Especially as resource requirements are also important to the health and social care managers. The other members included a geriatrician and a health service researcher.

The members of our team formally met initially every couple of weeks and we held a steering group meeting every quarter. The steering group consisted of our team and a few key members from the group of people who commissioned the project. In the steering group meetings we generally updated everyone on our progress or problems and discussed our next step. However, we spent our initial meetings trying to understand what they wanted answered and then we presented the approach and the questions that we could answer.

Once we had understood the project needs and research questions we each had our own tasks and project responsibilities. The geriatrician was responsible for the "smooth running" of the ICON project, the health service researcher managed the data collection and the "day to day" problems and I interviewed and did all the Operational Research work that is described in this thesis.

1.1.4 The initial problem situation

Initially, there was a considerable amount of vagueness about what they wanted us (the ICON team) to find out about IC. This vagueness is not unusual and it can be described as a complex societal problem as it is a large and an important real life problem, as mentioned in an article by DeTombe (2001). The article states that '*complex societal problems are often ill defined or multi-defined, hard to analyse and to handle. Knowledge and data are missing or contradictory, the causes of the problem vague and it is often not clear in which direction the problem is going. Many phenomena, many parties, private and governmental are involved. The problem often has or will have a large impact on (parts of) society*' (p.231). This description fits this problem accurately and can perfectly describe the starting point to this research. The article mentions that these complex societal problems involve interdisciplinary study and that the methodology for handling complex societal problems is multidisciplinary. The three factors that make this type of research difficult are time, effort and money. In addition, suitable methodologies can be found in the fields of cognitive psychology, sociology, computer science, artificial intelligence, mathematics, engineering, systems theory, chaos theory, philosophy and operational research.

However, they (the funders) defined part of the ICON project; they wanted a study done for an Intermediate Care service called Recuperative Care because they wanted to see if it was beneficial to older people. This was done by a case controlled study, which is not part of my work and will not be discussed in this thesis. However recuperative care is only one IC service and there are many other IC services in each of their systems (each locality is considered a system) that needed to be examined. In addition, they wanted a whole system approach, which meant that other services needed to be included in the study. This meant that traditional health care research methods such as Randomised control trials would not be appropriate for a whole system approach but methods in Operational Research could be useful. However, we did not know what they wanted us to find out about these other services or the system. Therefore, we had to go a step back and ask them for the reason(s) that they commissioned the project.

The funders wanted to improve the provision of IC in their region but they did not know what needed improving or how to make these improvements. They had been encouraged by the Department of Health to undertake or commission research to set up or improve IC services and systems. Our funders had recently introduced IC services throughout their region and they were planning on introducing more and they wanted to evaluate them. These IC services had been examples of innovation and good practice across the UK and they had been adopted and introduced in an 'ad hoc' manner across their region in an attempt to get older people out of the acute hospital beds. Therefore there was no "gold standard" because there were no examples of "good" IC systems but only examples of "good" IC services. The IC system of services had been ignored or they had simply not reached that part of the development process and therefore there was no information about how to evaluate that system. I understood at that point that what the funders were actually looking for was a guide for how an IC system should work and the evaluation was about how close their systems were to that optimum.

The Intermediate Care literature (see section 2.1) did not reveal a method for evaluating an IC system or a group of services or evidence that it had been attempted. I understood at that point that I could not promise an optimum but possibly a better way for their system to work. The problem then became about finding a way that an IC system could work and a way to evaluate it.

In fact the literature was so limited at the start of the research in 1999 that we had problems understanding IC and its role in the health and social care system for older people. We did however, find some literature exploring Intermediate Care that was essentially based on evidence from workshops by the Kings Fund (Steiner, 1997, Steiner and Vaughan, 1997). This literature provided us with one vital piece of information that shaped the research and that was that IC was a function rather than a discrete set of services (Steiner, 1997). This provided me with my first concrete questions: what could the operational function of Intermediate Care be and what and how do I evaluate it?

The operational function of an Intermediate Care system needed to be further explored. Although I was only two months into the project and still trying to understand Intermediate Care, the funders wanted to begin the project as soon as possible. Their main operational concern for IC involved the utilisation of resources which was indirectly answering the "what do I evaluate" question. One way of answering questions about resources is to apply discrete-event simulation modelling, which answered the "how do I evaluate it" question. I had some experience in simulation modelling and I believed that I could build a simulation model of the system that would include all of the IC services and that would satisfy the whole systems approach. Although this ignored the operational function I felt that examining the resource utilisation was going to be part of it so I should tackle this part of it and in parallel explore the operational function of IC.

At that time (two to three months into the project) I had a vague conceptual model for the simulation, which was influenced by my manufacturing model and it involved patients moving from one service to another depending what they looked like meaning what treatment they needed. Their IC systems worked in a way that can be described as "ad hoc" as there was no decision making mechanism that would ensure that a patient would enter the most appropriate service from the available in his or her locality. In fact the Intermediate Care services were generally not even known by health and social care professionals that needed to know about them in order to refer patients to them. This meant that many of the older people that could have gone to IC services would end up in hospitals or nursing or residential homes. This system as a whole did not seem to have any operational function but we knew that the patients that went to these services did improve because of them and in most cases went back to their own homes. Therefore even though the system did not work the services did work.

Due to pressure resulting from time constraints I had to present this potential simulation conceptual model sooner than I wanted to the funders and as it sounded plausible and a better way for their system to work they wanted it built as soon as possible. However, in the conceptual model for final assembly line I had work item characteristics that determined their pathway along the assembly line as they did not all need the same procedures. The literature (see section 2.2) also had examples of simulation models in health that require real patients' data such as age gender etc. The funders agreed that the patients' characteristics should influence which service they enter and that the system would improve if that was implemented. This new conceptual model of their IC system would require real patient data and as they did not hold any data electronically and it was unlikely that the paperwork was comprehensive they would have to collect it for us for a period of time that would be acceptable to both. The data would be used in the model and at the end of the project we would be able to evaluate the whole approach. The funders also accepted that I would need to have as much contact as possible with the IC employees as I needed to understand more about the services, the system and the operational function in order to refine my conceptual model and to construct the computer model. Of course we would need to choose an IC system from the available localities to test the simulation model as it would not be possible to do this throughout east Kent because of the inconvenience of the data collection.

Due to the general lack of understanding about the problem situation I decided to use a formal problem structuring technique. I decided that Soft Systems Methodology was suitable and this is explained in the methodology chapter (see section 3.1).

The outcome of this initial problem exploration was to decide that we should test this new model of how the system could work for a period time in the actual system and also build a model of it using discrete event simulation and compare the system with the model. This approach can be described as an Action Research Project which is explained in the following section.

1.2 What is an Action Research Project?

"Action Research is simply a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of those practises, and the situations in which the practices are carried out" (Carr,1986, p162).

The beginnings of action research are found in the forties and Kurt Lewin (1946) is generally considered the father of action research. The term action research does not suggest a method but an approach and is generally thought of as a progression from the traditional positivist and interpretative views of science in order to deal with development and learning within an organisation. This research considers action research to be an approach to the exploration and evaluation of the Intermediate Care function, which involves interaction and action and learning as a result of using operational research methods. It is however referred by some as a methodology but it is likely that the term methodology is inappropriately used as it means the principles of a method. The point of disagreement is because one can adopt a number of methods to undertake action research. An author that refers to action research as a methodology describes a distinctive feature of action research, which happens to fit with the research described in this thesis. "*Its distinctive feature as a research methodology is its requirement that the researcher actually intervenes in the organisation studied, working with organisational members on matters of genuine concern to them*" (Huxham, 2003, p240).

Hart and Bond (1995) have written about the use of action research in health care and they say that although it is not always the most appropriate approach in every setting it is particularly appropriate where problem solving and improvement are on the agenda. They have also made an interesting observation about the similarity of the action research cycle (see Figure 1.1) of enquiry, intervention and evaluation with the iterative process employed by professional staff in assessing the needs of vulnerable people, responding to them and reviewing progress. Although this does not mean that this approach is appropriate for this problematic situation it does however provide a way of explaining the research process to health care professionals and of course an argument to persuade them to take part. Basically if this approach underpins their practice philosophy then surely they can understand why this approach underpins the philosophy behind this research.

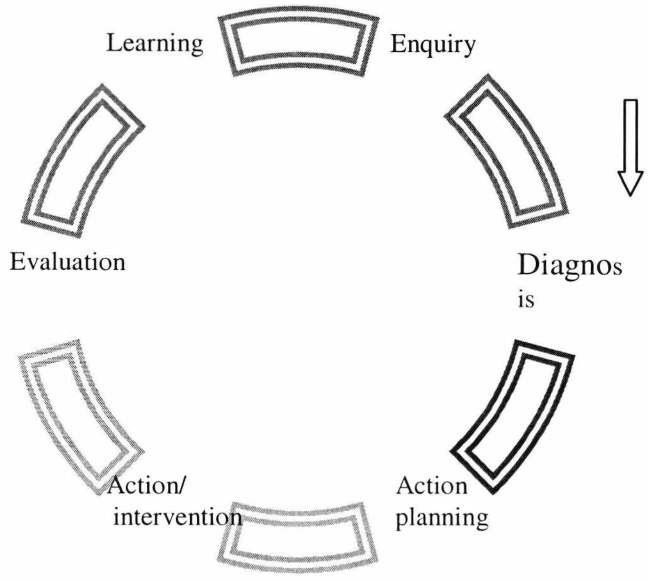


Figure 1.1 The Action research cycle

With Action Research repeatability or generalisability is a problem. Checkland (1999) in his 30-year retrospective explains how this can be overcome with the following words:

“Action research should be conducted in such a way that the whole process is subsequently recoverable by anyone interested in critically scrutinising this research. This means declaring explicitly, at the start of the research, the intellectual frameworks and the process of using them, which will be used to define what counts as knowledge in this piece of research. By declaring the epistemology of the research process in this way, the researchers make it possible for outsiders to follow the research and see whether they agree or disagree with the findings. If they disagree, well informed discussion and debate can follow. Also the learning gained in a piece of organisation-based action research may concern any or all of: the area focused on in the research; the methodology used; or the framework of ideas embodied in the methodology.”

(Checkland, 1999, p.A40)

In order to comply with the above it is important to declare what will be included in the evaluation of the operational function, which is discussed in the next section.

1.2.1 Defining the scope of the project

Stringer (1996) has developed a basic action routine framework that consists of: look, think and act and explains that it is essentially an iterative process. Therefore in order to define the scope of the project we needed to look at the problem and think about it before acting. The answers to the three questions: What could the operational function of IC consist of? What can I evaluate from it and How? were beginning to form but there still several questions regarding IC in general: Which services provide IC? What could be considered as an appropriate operational behaviour of an IC system? Surprisingly though these questions were not as important to the project funders as questions relating to bedblocking (which is essentially a bottleneck), the referral mechanism into Intermediate Care (faults with the decision-making), patients exceeding their Length of Stay and capacity (do we have enough beds and staff) and they also wanted to know if they had the right mix of services. The operational concerns provided an indication of what the people that commissioned the project wanted evaluated but the overall problem owners, the Department of Health, concerns also needed consideration.

This is because the findings will be more likely to be accepted by others outside the system of enquiry if general information is taken into account. Therefore, I examined the literature for documents that hinted about the Department of Health requirements relating to the evaluation of IC in general.

The IC literature (see section 2.1 Chapter 2) lists Rehabilitation, IC and other documents that are relevant to the Health and Social Care of Older people that mention or hint the need for evaluation. Because the IC and services are relatively new, the documents produced are still in the exploration phase and there is no specific outline of what evaluation should entail. Hanford et al (1999) emphasises the need for whole systems approach. The report by Edwards (2001) discusses the importance of Understanding, which services need improving and how, by: a. involving older people and their carers in work on evaluating, planning and developing services, b. gathering information about the pattern of needs and services for older people in the local community.

Wilson and Stevenson (2001) classify strategic and operational level functions for IC. They claim that there are functions that would ensure a better chance of co-ordinating systems and services. The functions that relate to evaluation are divided into strategic level and operational level (see table 1.1)

Table 1.1 Strategic and operational level IC functions extracted form (Wilson Keith, 2001)

Strategic level functions:
"To ensure that arrangements are in place to provide for monitoring, auditing and evaluating the quality and effectiveness of Intermediate Care".
"To map existing intermediate care provision, and check that criteria, transfer protocols and care pathways are agreed by local stakeholders and are in place"
"To develop data systems and evaluation measures to provide information on service performance trends, identify gaps and outcomes for individuals"
"To evaluate the effectiveness of the overall intermediate care system and the services within it against agreed performance criteria"
Operational level functions:
"Reviewing and developing clear admission criteria for each scheme within the locality and ensuring that there is no duplication"
"Ensuring clinical and social care input to assessment, as well as client involvement and carer involvement where appropriate, and in keep with the client's wishes"
"Monitoring intermediate care services to ensure contract compliance in all aspects of care and the environment/capacity to provide high-quality care appropriate to client needs"
"Undertaking regular planned reviews of client outcomes for each intermediate

care settings"
"Reporting data on capacity, throughput and outcomes to the commissioner on a regular basis"
"Investigating and co-ordinating audit of intermediate care services"
"Monitoring costs of services and managing a budget for problem solving"
"To ensure the efficient use of the intermediate care system by identifying clients who would benefit from Intermediate Care and ensuring their smooth transfer in accordance with an agreed care plan"

There are three points of criticism with the strategic and operational level functions in the table. The first is that many of the functions are vague and open to interpretation. The second is that they could be condensed into fewer functions. The third is that Wilson *et al* do not say how the functions should be carried out. This is probably intentional.

I have simplified the functions into the following list of evaluation tasks.

Evaluate treatment received by patients, for example treatment effectiveness

Evaluate clinical and social input to services

Evaluate economic aspect i.e. cost effectiveness

Evaluate individual services, for example utilisation of resources

Evaluate system as a whole, for example gaps in the system

Evaluate the effectiveness/suitability of data collection & information gathering.

Evaluate suitability of patients entering IC services

These evaluation tasks can be further classified into what can be addressed by Soft System Methodology (SSM) and DESM. SSM and DESM can not examine all of the above interpretations of the word evaluation. The first three tasks cannot be evaluated with this multi-methodology. The first task on the list cannot be evaluated through Operational Research as it involves some knowledge and assessment of a medical nature. This would probably best be approached as a clinical trial. The second point again is more a qualitative and clinical question that is probably best suited to a non-OR approach. The third point is best suited to a health economics approach. I will restrict my research to the last four tasks and these can be examined independently of the first three tasks. I will demonstrate in this research project that the last four tasks can be addressed with this multi-methodology. The last four tasks that will be examined, as part of the evaluation of the operational function of IC, can be put into the following order:

Evaluate the effectiveness/suitability of data collection & information gathering.

Evaluate suitability of patients entering IC services

Evaluate individual services, for example utilisation of resources

Evaluate system as a whole, for example gaps in the system

The first part of the evaluation is examining the effectiveness of the data collection and information gathering in an IC system. According to the literature Review (chapter 2) it is important to collect standardised data of older people's health and social care needs throughout a system. This is important when examining patients across services. The current data collection and information gathering will be considered effective if it also enables the evaluation of the other three tasks. If the current data collection and information gathering in the IC system being evaluated is not found to be effective a more suitable approach is proposed. If a new approach to data collection and information will be required to evaluating the other tasks it will be discussed in the concluding chapter.

The second part of the evaluation is to examine the suitability of the individuals that enter IC services. This is important and it has been mentioned in the IC literature by Stevenson (2001) with an emphasis in the availability and use of Service Entry Eligibility Criteria. This is further discussed in later sections.

The third part of the evaluation is to examine the individual IC services. The IC system chosen for the project is for a geographic area called Shepway and it is described further in Chapter 3 and 4. An important point to emphasise is that the IC services were newly introduced at the start of the research project and this was going to have some sort of impact on the evaluation as it had never been done before and there was no evidence in the literature about the evaluation of the operational function of IC systems.

Initially I thought that I would need to evaluate the individual services as part of a bottom up approach to evaluating the "whole" system but this is not exactly the case. The function of intermediate care system is more than the sum of its parts but there other factors that make it what it is. For example, the IC function involves co-ordination between the services. Nevertheless it is important that the individual services are examined, as they are vital to the evaluation of the overall system. This concept can be depicted as a (nonmathematical) formula:

Evaluation of IC function = Evaluation of function of IC system + Evaluation of function of individual IC services (1)

That is: to achieve the evaluation of the operational functions of Intermediate Care it is important to understand both the function of the system and the services within it. Although I did not precisely know what the operational function would be I did know that I would use a multimethodology of Soft and Hard Operational Research in the form of SSM and DESM to evaluate, take action and learn about:

The effectiveness and suitability of data collection & information gathering.

The suitability of patients entering IC services.

The capacity and resources available for the individual services.

The capacity and function of the system.

1.3 Lessons learnt – the contribution of the PhD

The PhD investigation is influenced by the action research cycle (see Figure 1.1) and Mingers and Brocklesby's (1997) context of an Intervention diagram (see Figure 1.2).

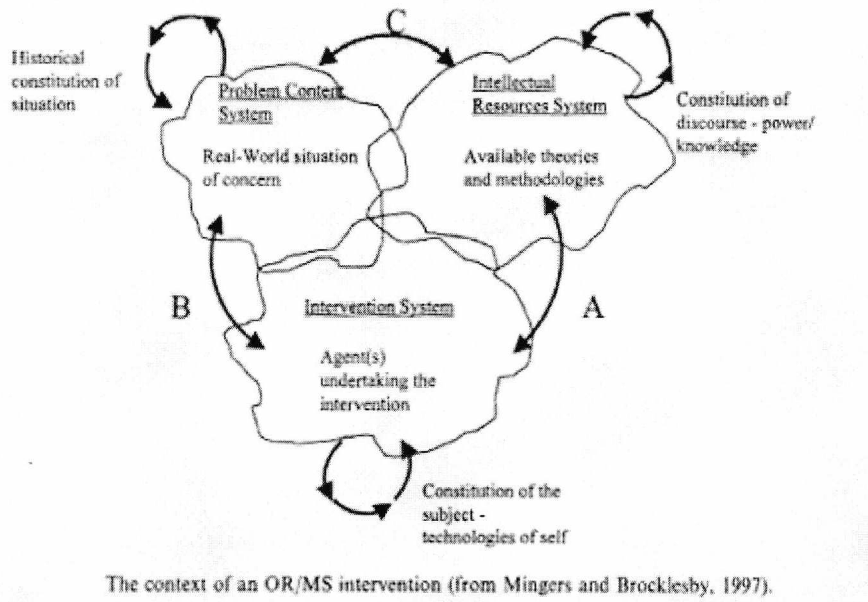


Figure 1.2 the context of an OR/MS intervention (from Mingers and Brocklesby, 1997)

The primary aim of the investigation is to better understand and to answer the action research questions about the IC function. The second aim of the investigation is to contribute to the available scientific knowledge. The investigation will further the knowledge through learning across three dimensions which is illustrated in Figure 1.3.

The first dimension (1) is learning about the methods, SSM and DESM, by applying their theory to the problematic situation. The SSM learning could include the experience of the analyst using SSM, using "primary task" or "issue-based" root definitions and adopting a mode 1 or 2 approach. The DESM learning could include learning about the simulation steps, deriving conceptual models, obtaining data for the model(s), suitable distributions for IC and validation and verification. In the diagram there is a two way loop i.e. from the theory to the specific situation through the methodology and from the specific situation back to the theory. Therefore part of the learning will be about using the two methods in the specific situation, which is Intermediate Care.

The second dimension (2) is learning about applying a multimethodology can provide learning about the combination of methods. Therefore the learning gained might involve answering the following questions: What is gained by using a multimethodology? What are the advantages or barriers and disadvantages of using a multimethodology of SSM and DESM? How can the analysts work with two methods that come from two different paradigms? Should the people in the problematic situation be made aware or exposed to the methods? As in the first dimension there is a two way loop which means that there may be specific learning about applying the multimethodology to the specific situation.

The third dimension (3) is learning about the specific situation. Therefore the learning may be about the application of OR in Health and Social care and to what extent are the findings from the project generilisable to other IC systems and services.

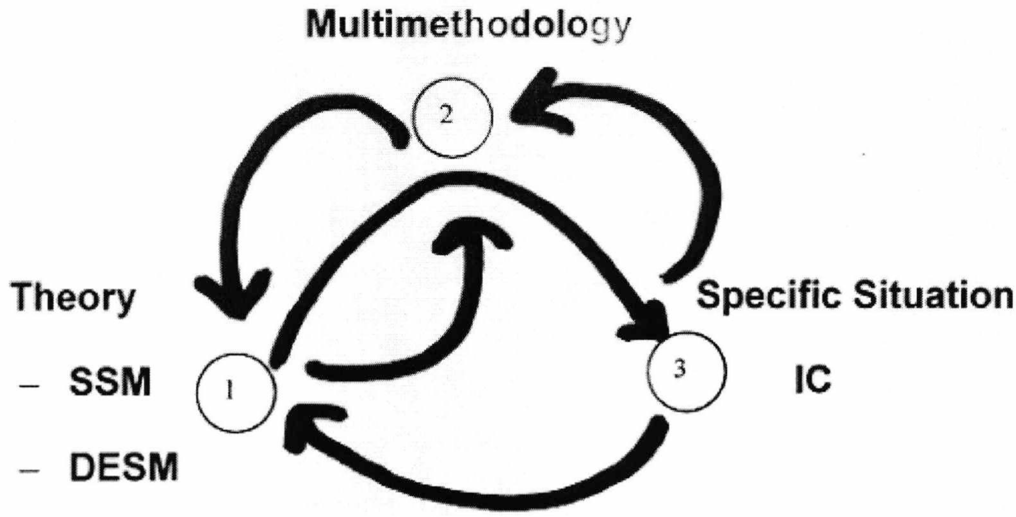


Figure 1.3 The PhD contributions

1.3.1 Overview of dissertation

The thesis is organised into the following seven chapters:

Chapter 1 introduces Intermediate Care and its importance to the Department of Health as well as the local Health and Social care authorities and it provides the initial problem situation and defines the scope of the project. The main purpose of this chapter is the exploration of the PhD contribution.

Chapter 2 introduces the available Intermediate Care (IC) literature and provides an overview of the relevant literature of Simulation in Health, Soft Systems Methodology in Health and the relevant literature relating to the use of multimethodologies in health care.

Chapter 3 initially describes the action research project and the application area, The

Shepway Intermediate Care system and services for older people. The approach to linking the two methods, SSM and DESM, for the multimethology is also described before describing each of the methods used and what parts of these were used.

Chapter 4 describes the application of Soft Systems Methodology to the problem and it also describes part of the action which was to determine the Service Entry Eligibility Criteria.

Chapter 5 describes the Simulation steps for each of the models built. Four models were built one for each of the "Hard Core" Intermediate Care services and one for the IC decision making mechanism which is called the "whole system" model.

Chapter 6 describes the results from the "what if" analysis for each of the models. The exploration for each model was determined from IC employees and stakeholders as being important to know and the changes were feasible to implement.

Chapter 7 describes the learning about the IC system in question (Shepway) and also describes the contribution of the project to the existing knowledge for each of the methods and the multimethodology.

2 Literature Review

2.1 Literature Review of Intermediate Care

Since the 1980s health and social care was provided by the NHS and the local authority social services respectively and they had a virtual monopoly over the provision of health and social care (Carpenter G.I., 1999). The NHS provided hospital based long term and rehabilitation and acute care. Furthermore it provided community based health care like nursing services. The local authority social services departments were responsible for the provision of home help, day care, meals, social work and residential and long-term care. The introduction of IC services is relatively new and literature begins in the 90s.

It is common knowledge that the majority of older people do not want to be in a hospital or a long-term institutional setting (residential home or nursing home). It is therefore important to provide older people with the opportunity to improve their quality of life in the event that they suffer from an accident or illness or disease. The National Framework for Older People (Department of Health, 2002c) in a report on IC makes the following Statement:

"There is growing evidence of the appropriateness of Intermediate Care as an alternative to traditional forms of care, in the right circumstances, and of the potential benefits for individuals and for the health and social care system, although further research and evaluation is needed".

(Department of Health, 2002, p.4)

2.1.1 Definitions of Intermediate Care?

Intermediate care services for older people (over 65) can be defined as services involved in the process of convalescence, the period of time when the person is getting better and rehabilitation, the process of regaining partial or full independence after illness or injury (Kings Fund, 2000). IC can be seen as having three main aims. The first aim is to restore older persons as much as possible in order for them to live independently or at least avoid Long Term Institutional Care. The second aim is to help older people avoid acute hospital admission and readmission. The third aim is to assist in timely discharge from hospital and thus free the much needed hospital resources. In an IC discussion paper (Steiner, 1997, Steiner and Vaughan, 1997) there are several definitions of intermediate care that have been picked out of other articles, which discuss issues surrounding intermediate care. A few of these are included in the following:

One definition (McCornack, 1992, 1996) emphasizes the need for a service to be "locally based, not essentially medically orientated, and that bridges the gap between secondary and primary care".

Armstrong (1995) defines intermediate care as "low intensity care where patients can obtain clinical input from the nursing staff and their GPs whilst being close to their own homes". There is a dispute over the accuracy of this definition in terms of the issue of "low intensity". This may be true for some types of intermediate care but there are some services where the intensity level is high as for example the care provided by the Community Assessment Rehabilitation Teams CART (Appendix A). Also the intensity depends on the individual patient's needs as well as the availability of the resources. Another issue that is that clinical input in some intermediate care settings can also be from a consultant of Geriatric Care (not just General Practitioners and nurses). The final issue that is also raised in the discussion paper over intermediate care is that intermediate care can also occur in the patient's home.

IC is also defined by Pearson (1992) as "patient centred care for those whose medical need has been replaced by the need for support, nurturing, and teaching". This definition is significant in the sense that it indicates that medical stability must be reached in order to assess and begin rehabilitation. On the other hand the use of the word "replaced" is slightly inappropriate, as many elderly patients will still need clinical input that may come in the form of outpatient care. An appropriate transformation of this definition would be "patient centred care which involves support nurturing and teaching for those who have reached medical stability".

2.1.2 What is an intermediate care system?

The intermediate care system's aim is to provide to each individual patient a plan tailored to particular health and social care needs and wants in order to aid the process of convalescence and rehabilitation. The range of services should cover all levels of requirements whether these are health or social. Intermediate care services can be provided by the NHS, the local authority social services or by the independent sector. There are many cases of jointly run and funded IC services. One difference between IC services that are NHS and social service's is that rehabilitation is free of charge from the NHS but means tested if social services are providing it (Kings Fund, 2000).

In the discussion paper over intermediate care, Steiner and Vaughan (1997) mentioned earlier, the IC system is described as a function instead of a discrete set of services. Specifically the function is "to facilitate transitions from medical dependence (experiencing one self as a patient) to day to day independence (experiencing oneself as a person)". The function is also encompassing the prevention of a relapse into medical dependence. The boundaries of intermediate care lie between acute hospital care and living independently at home and between Long term care and Palliative care.

Rehabilitation can take place in a number of settings and by a number of resources (GPs, Nurses Occupational Therapists, Speech Therapists etc). There are several models of intermediate care available in order to encompass the variety of older peoples needs and their care requirements. These models of care can take place in a number of settings and this includes home.

The Department of Health and other organizations such as the Kings Fund have produced a multitude of reports and other documents that about the welfare of older people. Hanford et al (1999), in a rehabilitation briefing produced in April 1999 by the Kings Fund, discusses the emerging policy agenda in terms of rehabilitation for older people. The document explains that "*Rehabilitation is an issue which requires 'joined-up' thinking from health and local authorities*". The document suggests that the reports, briefings etc that are included in this subsection have influenced this emerging policy. These have been included with almost the same words as in the actual document as after reading the reports themselves, one could not have produced a more concise description of them.

The first *Better Services for Vulnerable People*, published in October 1997 (Department of Health, 1997), makes clear the Secretary of State's expectations that all health and local authorities will, from April 1999, be developing rehabilitation services for older people as one of three priorities in joint work for people with continuing health care needs.

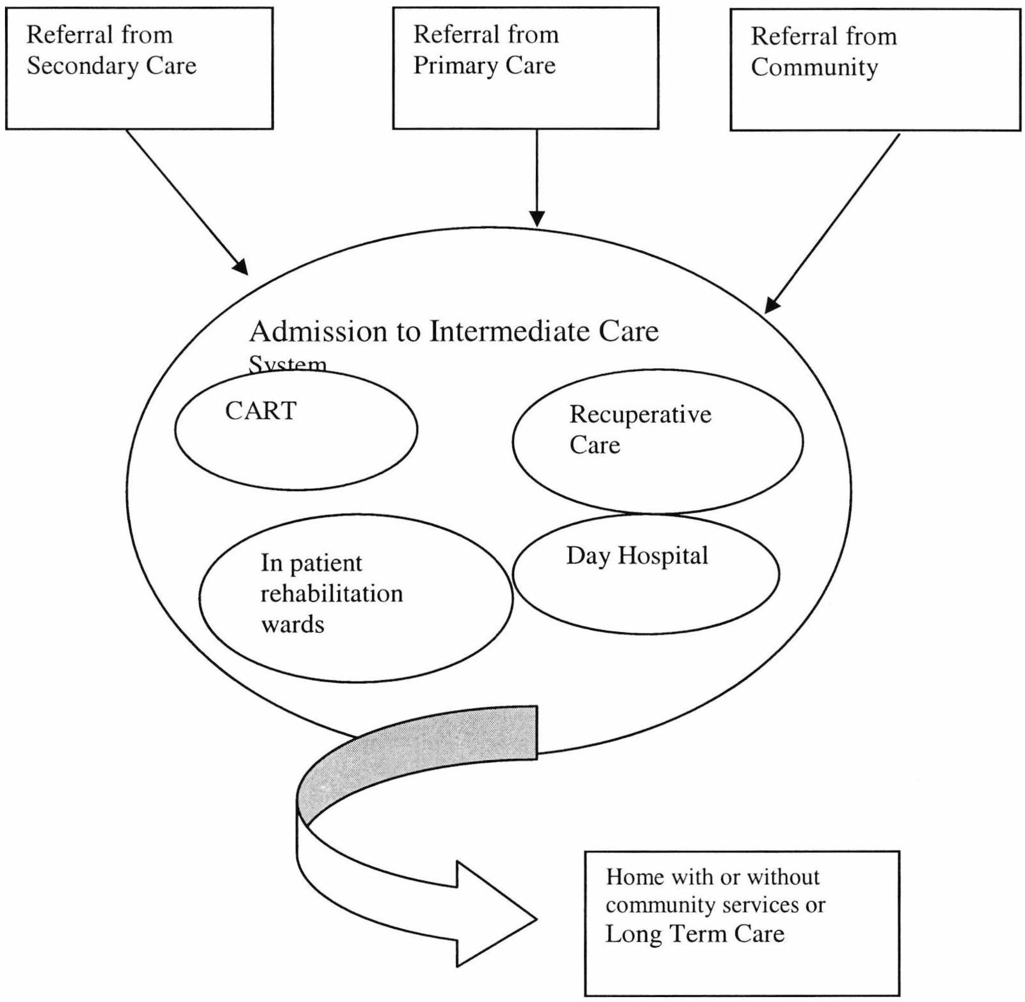
Modernizing Health and Social Services: National Priorities Guidance 1999/00 – 2001/02 (Department of Health, 1998a), produced in September 1998, develops the wider theme of promoting independence as a means of helping people *maintain* a healthy and active life. It also sets out specific joint health and social care policy goals: to reduce the risk of loss of independence in the wake of unplanned and avoidable admissions to hospital; to prevent or delay loss of independence by developing a range of preventive services; and to support carers by providing information they need both to care effectively and to maintain their health. The document requires NHS and local authorities to improve older people's opportunities for recuperation and rehabilitation, through the implementation of better services for vulnerable people.

The White Paper *Modernising Social Services* (Department of Health, 1998b), published in November 1998, explores the issues involved around promoting independence which face social services at the level of the individual user. Promoting independence for adults is defined as "*providing the support needed by someone to make the most of their own capacity and potential*" (Department of Health, 1998b). This White Paper sets out the government's view that social services authorities need to move away from a culture of providing services which "*do things for and to dependent people*" (Department of Health, 1998b), and in which staff may lack the skills, attitude or inclination to support people's efforts to care for themselves.

2.1.3 Intermediate Care system

Stevenson (2001a) in a paper for the Kings Fund discusses a whole systems approach to understanding service capacity and planning change. The whole systems approach is motivated from HSC 2001/01:LAC (2001) (Department of Health, 2001c) Intermediate Care that was issued on 19 January 2001 which requires the NHS and Councils in planning the best balance of Intermediate Care services among other things to: "Map current levels of capacity, patterns of service provision, A&E attendances, acute admissions (in particular those with very short or very long stays), bed occupancy rates and long-term care placements for older people in their area, including where referrals are generated and what sorts of conditions are triggering these referrals." The paper explains that this is important for several reasons, which include identifying gaps and "pressure points" in the service system. In order to map the services and system one should initially get a clear picture of where older people's needs are met or could be met by collecting details and information of all services including those that may not seem suitable at a first glance. The paper explains that it is also best to involve people and agencies from within the system and ask questions relating to the operational function of the system. This should include checking to see if there are any gaps in the system either in terms of availability of services or resources. In addition, it is important to understand the access mechanism into the system. For example, are the referrals appropriate? Are the right numbers of people entering the system? etc. A very important point is that made about checking the eligibility criteria for services. For example, do they exist? Do they exclude a type of need like dementia? Other information that is important to be obtained is examining bottlenecks in the system like long waiting lists. Also finding out about how people move through the system and whether these pathways are based on an assessed need is something else that needs to be considered. I have illustrated the patient flow through IC as a rich picture (see Figure 2.1). Another issue is whether there are local policies that influence patient pathways, especially those that involve charging for services etc.

Figure 2.1. Patient flow through intermediate care



2.1.4 Intermediate Care Function

Vital elements of the function of IC are Primary Care Groups that are responsible for putting IC into practice. The report entitled *Primary Care Organizations and Older People* (Edwards Margaret, 2001) suggests that there is a need to understand the factors that make the needs of older people and their carers a priority, in particular: a. the complexity of individual needs, b. that older people are the majority of users of health and social care, c. to recognize the discrimination which can occur against older people and that results in their needs not being met effectively and d. the complex and broad range of often poorly coordinated services that have an impact on the health of older people. The report also discusses that it is important to understand which services need improving and how, by: a. involving older people and their carers in work on evaluating, planning and developing services, b. gathering information about the pattern of needs and services for older people in the local community.

The document produced by Hanford et al. (1999) emphasizes the need for a whole systems approach. Specifically,

"Health, social care and housing agencies together need to analyze the whole care system, identify possible areas and targets for improvement which might also help make more beds available, and to reduce the long-term care budget. Over time, changing patterns of service delivery can potentially reduce the current heavy emphasis on bed-based health and social care. What's more, the policy directives requiring action to improve rehabilitation services for older people, the criteria and deadlines for application to the various funding incentives, and frameworks for performance assessment and management, should ensure that older people's rehabilitation remains in the forefront of health and social care". (Hanford et al., 1999, p.18)

Wilson and Stevenson (2001) in two workshops for the Kings Fund in June and July 2001 explore the role of the Intermediate Care Co-ordination function. The briefing paper was prepared in light of the comments and discussions of the second workshop. The paper contains a list of functions and tasks that need to be carried out in each IC community to ensure an effective and efficient IC system that have been mentioned in the introduction (see section 1.2.1).

2.1.5 Intermediate Care services

The National Service Framework (NSF) for Older People in June 2002 produced the most comprehensive document about the implementation of IC. The document (Department of Health, 2002c) explains that although the appropriateness and importance of IC services is now evident there are still in some places/services within a IC system that are bound by an *inconsistency, a sense of fragmentation, a lack of coherency and poor integration*. This is because IC is still in its infancy and because there is no consistent application of the IC principles.

Four principles should underpin planning and delivery of Intermediate Care according to the National Service Framework for Older People (2002). The first principle is Person-centred care, which is about *"ensuring that people are treated on the basis of their individual needs, circumstances and priorities"*. A robust assessment process must support this and older people and their carers' should be involved in decisions. The second principle is Whole systems working. *"Older people's needs often include physical, mental and social dimensions and require responses that cut across organisational and professional boundaries. There must be partnership and shared responsibility for meeting those needs. Person-centred care will only be achieved when all groups and agencies involved agree to work within a single process for assessing needs and sharing information"*. The third principle is timely access to specialist care. *"Older people benefit from high quality specialist care as much as everyone else and must not be denied access on the basis of age. Clear arrangements for assessing specialist assessment, diagnosis and treatment when needed are essential"*. The fourth principle is promoting health and active life. It is important to health and social care services that older people remain healthy and independent and IC is a vital part of this strategy. This is because it helps older people realise their full potential as well as regain health.

The NSF paper (Department of Health, 2002c) also discusses key issues that need to be examined in future developments (clinical governance, medical assessment, housing and learning from good practice). One of the key issues is the inclusion of people with mental health problems in Intermediate Care services as they can benefit equally well and that the health and social care services can also benefit by providing them with appropriate care and make appropriate use of resources. Another key issue is that of clinical governance that ensures quality of care, appropriateness and patient/user safety can be demonstrated.

2.1.6 Assessing the needs of the Elderly

One element of the evaluation of this project is about examining the effectiveness and suitability of data collection & information gathering of the IC system. In the UK the assessment of need and good care management prior to the placement in a nursing or residential home is mandatory but there is no rule to dictate the precise form that the assessment should take (Carpenter G.I., 1999). The Department of Health aimed to put in place a Single Assessment Process for older people by January 2002 (HSC 2002/001;

LAC (2002)1) and this has been extended to April 2004 LAC(2003)14 (Department of Health, 2003) due to problems of implementing a single assessment tool. Documents have been published, which provide guidance on the Single Assessment Process (Department of Health, 2001b, 2002a, b). The Single Assessment Process (SAP) is about making health and social care professional work together to assess an older person's needs and plan for those needs in an effective and coordinated manner. The health and social care providers must ensure that three factors are taken into account during the implementation: a. the scale and depth of assessment is kept in proportion to older peoples needs, b. agencies do not duplicate each others assessments and c. professionals contribute to assessments in the most effective way.

The Single Assessment Process (SAP) will be an important element of the IC operational function and is taken into account in this research. An important element of the SAP is the use of an Assessment Tool which is further discussed in the following papers:

Carpenter and Calnan (1997b) report on the benefits of a standardised assessment of individual needs. The requirement for local authorities to assess individuals' needs was formalised with the NHS Community Care Act of 1990. They explain that the need for assessment comes from the lack of certainty that resources are used efficiently and equitably. The article also reports the misuse and unsuitability of many of the current assessment instruments. For example many authorities have included in their assessment form scales or parts of scales that have been developed for research rather than determining service provision. In fact a 1993 review of assessment procedures, which was undertaken by the Social Services Inspectorate (SSI), found that there was *"a considerable duplication of paperwork by health and social services because due to difficulties in information sharing different assessment standards were not reconciled*". The paper reports that the 1995 and 1996 SSI reported some improvements but overall it was a clear that variability remained high and comparability and the capacity to generate standardised information was low. This Poor assessment would inevitably lead to "*poor targeting and delivery of care quite apart from the difficulties in determining the benefits*".

Carpenter (1997a) reports on an international project, interRAI that has developed a standardised assessment tool for use in any hospital or long term care setting. InterRAI has developed a series of standardised assessment instruments for use in community care, hospital and long term care institutional care settings. The assessment tool, the Minimum Data Set (MDS)/RAI has two components: a. the MDS and b. the Resident Assessment Protocols (RAPs). The RAPs guide the assessor to develop an individual's care plan for their identified problems. Carpenter explains that the MDS covers "*all the domains one would need to consider in determining an individuals care needs*". The standardised structure allows for knowledgebases that can be used to transfer, share and compare information that will enable a more effective and efficient interface between health and social care. Sturdy and Carpenter (1997) suggest that the introduction of eligibility criteria as a standard for assessing people for continuing care can be assisted with a standardised assessment form. A modified version of the MDS has been used to collect the patient data used in the simulation models.

2.2 Operational Research in Health and Social Care systems

2.2.1 Historical Review of OR in Health

The operational research community can indeed take pride in its accomplishments and in the fact that since the early 1960's (Bailey, 1952) the amount of research effort in health has increased dramatically. By the mid seventies operational researchers had developed some central ideas about the health service (Valinsky, 1975). The *first central idea* that operational researchers have introduced into the health field has been that it is important to view the health services as a stochastic process. A stochastic process is not a fixed process but instead varies randomly over time. To some extent health administrators have long known that they where dealing with uncertainty in a system largely dominated by chance factors.

A *second central idea* that followed as an outgrowth of the first is the generalisation that patient needs, although variable, can nevertheless be identified quantitatively, and models based on patient classification schemes can be developed that predict requirements for care. These predictions can be used in turn to form the basis for a more logical and effective assignment of health manpower and other health resources. This idea was originally developed for acute care inpatient units but can be valid and applied to long term care and ambulatory care.

A *third central idea* that was still evolving in the mid seventies is the tendency to view the health services delivery process as being composed of a collection of hierarchically interrelated goal-seeking response systems. Goals and Objectives are derived from sets of demands to which various component levels (health service areas) of the total system must respond in an adaptive manner for the optimal allocation of resources and services.

2.2.1.1 What is Simulation Modelling?

Bellinger (2000) defines simulation as the manipulation of a model in such a way that it operates on time or space to compress it, thus enabling one to perceive the interaction that would not otherwise be apparent because of their separation in time or space. Another definition is that by Pidd (1998), which states Computer Simulation modelling is the use of a computer model as a basis for exploration and experimentation. In addition, computer simulation is about mimicking a system over a period of time. The use of a computer enables speedy mimicking (Guilbert, 1999) (Oakshot, 1997).

A paper by Jun et al. (1999) defines Discrete event simulation in terms of health care applications as an operational research technique that allows the end user to assess the delivery of existing health care delivery systems, to ask "what if" questions and to design new systems. Discrete-event simulation can also be used to forecast the impact the changes in patient-flow, to examine resource needs (either staffing or physical capacity) or to investigate the complex relationships among the different model variables (for example rate of arrival). This allows managers to reconfigure existing systems, to improve system performance or design, and to plan new systems without altering the present one.

The simulation models are developed to investigate improvements to the real system or to discover the effects of different policies on that system. The choice of simulation model depends on **(1)** the system classification (static or dynamic, discrete or continuous) and **(2)** whether the model of the system is said to be deterministic or stochastic.

2.2.2 Historical Review of Computer Simulation in Health Care

Using computer simulation in health care and more generally in the social sciences is not a new idea as the literature begins in the 1960s (Shuman, 1975). In the mid seventies simulation applications could be found within the full spectrum of health care, ranging from hospital admissions procedures, through facility utilisation and design, to the development of conceptual frameworks for a total national health care system. In a effort to achieve new breakthroughs in these areas, health care investigators turned to computer simulation models rather than relying on the standard analytical techniques as a method of analysing the many complex processes in various health care systems of the mid seventies. These investigators were convinced that by means of simulation they were better able to study and describe the properties of these systems and that the simulation approach is not nearly as restricted by the limiting assumptions, which bind the analytical model. The conclusions from these investigations were that using simulation means that one can afford greater flexibility in experimentation and the testing of hypotheses and alternative policies, as well as increased flexibility in altering and modifying values and parameters in the model during the course of the investigation. Also, simulation frees the investigator from having to classify and interpret system processes only in terms of standard analytical techniques (Shuman L.J., 1975). This period of time was about exploring the potential of simulation modelling. However, the thought process surrounding simulation modelling advanced rapidly during the seventies and other uses apart from a decision making tool were found for simulation modelling. David Valinsky (1975) argued that there are at least four general categories of simulation usage that are applicable to the field of health care. These include simulation as a research tool, an educational device, an aid to decision-making, and a planning model. Valinsky explains that while it is possible for any of these functions to constitute the full purpose of any particular model, it is common for models to incorporate two or three of these functions simultaneously, and sometimes all four. In the late seventies England and Roberts (1978) gave an extensive and comprehensive survey on the application of simulation in twenty-one health care areas. They cite ninety-two simulation models out of twelve hundred models reviewed, including all published models developed through 1978. This demonstrates how extensively simulation modelling was used by the late seventies and is possibly related to the emergence of microcomputers.

In 1980 Tunnicliffe-Wilson (1980) provided a review of population health care problems, which are tackled by computer simulation. The review initially divides the use of simulation in health care broadly into three levels that can also form a hierarchy:

a. the health care of a population (looking at the future provision of health professionals and facilities), b. health care within a particular institution (e.g. examining the operation of hospital and outpatient clinics) and c. health care of an individual patient (mainly for teaching purposes). This can be seen in table 2.1. The paper groups and describes the first simulation category according to the problems that it has set out to tackle. Like Valinsky (1975) in the mid seventies Tunnicliffe-Wilson (1980) was aiming to further the philosophy behind simulation applications in health care and explain the potential benefits of simulation modelling.

Table 2.1. Tunnicliffe-Wilson (1980) simulation categories in the health care hierarchy.

Population	Institution/ Facility	Patient
A. Resources needed	A. Emergency care	A. Teaching models
B. Cost implications	B. Size of facility	B. Medical research
C. Disease prevention and control	C. Organisation of resources	
D. Location of services	D. Delegation of tasks	
	E. Organisation of patients	

The development of visual interactive modelling in the eighties meant that simulation modelling began to flourish in health care but Smith-Daniels et al. (1988), suggest that this was mainly for the inpatient facilities. Smith-Daniels et al. (1988) reviewed the literature relating to capacity management in health care services and determined its relevance to the changing health care industry. They reviewed all articles relating to capacity management even those that had not used simulation modelling. They provide a review, classification and analysis of the literature on this topic as well a discussion of the future research needs that are not dealt in the existing literature. The authors report that the literature that they reviewed was not as useful for future research directions for several reasons. Firstly, because researchers had shown the most interest in problems that exist in inpatient facilities but current trends are towards increased use of ambulatory care facilities as a substitute for hospitalisation. The second reason is that capacity management objectives (minimising operating and investment costs, maximising resource utilisation, minimising patient waiting time, minimising the number of patients receiving inappropriate care, minimising the distance travelled by patient etc.) are not enough and more objectives (e.g. organisational goals, quality of care issues etc) need to be incorporated. Thirdly, demand is presented as a function of the demographic characteristics of a population in the geographic region served by the health care facility. This function should also include membership in an integrated health care system and the competitor's location and service mix. The final, reason is the lack of interconnection between work force and facilities resources, which are vital components of a health care delivery system. The authors' analysis demonstrates that methods that were used at that time (in the late eighties) for capacity management including simulation modelling were not meeting the needs that had been formed in health care.

2.2.3 The current direction of OR in Health care

Geoff Royston (1998) explains that the balance of care has changed and that there are five shifts in care, the *First Shift* is from "*diagnose and treat disease and illness*" to "*prevent and treat*". The *Second Shift* is about the movement between Institutional Care and Care in the Community with a greater emphasis on community care. The shift is not absolute as both are needed and there is movement between the two. The paper also mentions that the goal must be *"to ensure that people are maintained in a care setting that is most appropriate to their needs and makes best use of the resources available"*. The *Third Shift* is from a *professional-centred care* to a *patient-centred care* as the future role of the professional will change from looking after patients to enabling people to look after themselves. The *Fourth Shift* is from providing treatment from habit to providing treatment though knowledge. The article says that a substantial amount of medical treatment is ineffective and is still in use because of habit. The shift is therefore about having Evidence Based Medicine, which can be achieved through research and medical audit. The *Fifth Shift* is about devoting a higher proportion of health and social care resources from one group to another depending on needs. For example the increase of resources devoted to the care of the elderly. The article suggests that ORMS (Operational Research Management Science) can help with managing the important shifts in the balance of health care by:

- Scanning for emerging issues

- Formulating and diagnosing problems
- Setting goals and objectives
- Designing and developing options
- Appraising options and making choices
- Persuading others and gaining acceptance for solutions
- Implementing solutions
- Monitoring and controlling implementation
- Evaluating results

The methods that can be used include the following:

- Analysis and meta-analysis of literature
- Brainstorming, delphi, nominal groups
- Soft Systems Methods, Cognitive Mapping
- Forecasting, Scenario Analysis
- Expert systems neural networks
- Complex adaptive system modelling, cellular automata
- Statistical modelling, mathematical modelling
- Simulation, System dynamics
- Multicriteria decision analysis, data envelopment analysis

- network analysis
- management games
- control trials, natural experiments

The article describes the issues involved in the area examined and lists both the main methods that are selected as suitable for Health Care research. The extensive use of simulation modelling in Health Care over the past decades can be seen throughout the remainder of this Literature Review.

2.2.4 Computer Simulation Applications in Health Care Systems

The following papers fall under the category of simulation health care surveys, literature reviews and bibliographies. Klein et al. (1993) provides an annotated bibliography on simulation modelling and health care decision making. The review does not have simulation articles that are similar to the simulation work presented in this thesis.

Lagergren (1998) writes about the role and contribution of models to management and research in European health services. The paper initially discusses the nature and objectives of modelling and then it examines some applications of modelling in health care, which it divides into four categories. The first category is epidemiology, health promotion and disease prevention. The second category is Health and Care systems design. The third category is health and care systems operation and the fourth category is medical decision-making. The author expresses the view that the choice of model category, method or programming system is partly determined by the problem under study but is also a matter of subjective choice. He reports, "*many authors in the health care system seem to agree that simulation models permit more flexibility and enforce less unwanted simplification than analytic models*". He also mentions the ability of simulation to describe complicated interactions.

Given the many potential simulation applications in healthcare, Lowery (1998) claims that they tend to fall into *two main categories*, analytic decisions with uncertain components and comparison of alternative systems for determining resource or scheduling requirements. This research is only concerned with the second category.

Lowery (1998) writes that simulation is an extremely useful tool for modelling these types of complex systems. The use of simulation for these purposes is different to using it for modelling analytic decisions, in that the analysis of operational systems requires a comparison of alternative systems to obtain the desired information. In addition the model is defined not in terms of a series of equations but in terms of the physical movement of a transaction (e.g. patient, lab tests) over time through different facilities or resources. For example when using simulation to determine how many resources (e.g. hospital beds, operating rooms, examining rooms, x-ray machines, nurses, physicians, etc.) are needed for a healthcare facility, there is no formula that combines different variables (e.g. demand, utilisation etc) to equal "number of resources required".

Jun et al. (1999) have written a survey on the literature of the applications of discrete-event simulation modelling in health care clinics. The paper focuses on articles that analyse single or multi-facility healthcare clinics. Examples of multi-facility healthcare clinics include outpatient departments, emergency departments, orthopaedic departments and surgical centres. The authors comment that they have found very few articles that use simulation to study complex integrated systems that "*may be due to the extensive data requirements that are needed to support such studies and the prohibitive expenses associated with such a data collection*"(p.109). Their survey of the literature is extensive (approximately 117 articles) as it classifies and covers articles from the past twenty years and also refers back to some earlier ones.

The paper is of great importance to this research and we will look at it in detail. The authors organised their paper by separating the articles into three areas: articles that relate to patient flow, articles that relate to the allocation of resources and articles relating to future directions. The following subsections follow the same classification system. There are three elements of organisation that need to be mentioned. Firstly only very relevant articles will be discussed due to the magnitude of their numbers. (A number of less relevant articles will be included in Appendix B). Secondly other articles that have not been cited in their survey will also be included in this classification, for example recent articles that were not available at the time of the survey. Thirdly some of Jun et al. (1999) relevant comments will be included in italics.

2.2.4.1 Papers on Patient Flow

There are papers on patient flow because of increasing competition facing hospitals and health clinics for their services (fast and efficient health care). Effective and efficient patient flow is "*indicated by high patient throughput, low patient waiting times, a short length of stay at the clinic and low clinic overtime while maintaining adequate staff utilisation rates and low physician idle times*" (p.110). Jun et al. (1999) divide the articles on patient flow into three further categories. These three categories are: a. Patient Scheduling and Admissions, b. Patient Routing and Flow Schemes and c. Scheduling and Availability of Resources.

2.2.4.1.1 Patient Scheduling and Admissions

Tuft and Gallivan (2002) simulate three years operations of different admission strategies of a cataract waiting list. A computer simulation method called Priority Admission STrategy Analysis (PASTA) is used as a research tools for investigating operational consequences of different booking or admission systems. The admission strategies included a first come first served booking system, a triage booking system, and a waiting list system in which admissions were strictly ordered according to priority stratum. They compare these three different strategies for determining admission dates for patients awaiting cataract extraction after scoring for visual impairment and need. The data for each patient, which is generated through randomisation and comprises of the following: the date of the referral, the date of the outpatient assessment and priority weighting. The priority weighting is a number between 0 and 100 and is central to the model. The model results showed that there is a considerable scope in reducing high priority waiting lists. This article demonstrates the use of scores for patients as a way of moving entities through the model which is something that has also been used for the simulation models in this thesis.

2.2.4.1.2 Patient Routing and Flow Schemes

Henderson and Mason (1999) estimate ambulance requirements in New Zealand, which involves decisions about how many ambulances are needed as well as where the ambulances should be placed in order to meet the service targets efficiently. The simulation is written in a high level programming language and not specialist simulation software. The model uses historical data (real calls) that are fed through it rather than artificially generated data (calls). The ambulances are routed according to attributes relating to the call that include call arrival time, call priority, call location, time spent by ambulance at the scene, destination to which the patient was transported and time spent at the destination. This conceptual model is similar to the one used in the DESM phase of this research. It is encouraging to see that others have successfully applied this conceptual model even if it is in a different application area.

Moreno et al. (2001) present a Knowledge Based System (KBS) for aiding in the decision-making tasks carried out in hospital management. The KBS has been designed following a KADS methodology, which enables a structured representation of knowledge. Initially the authors divide the decision-making process into 4 subtasks: *monitoring, diagnosis, prediction of the possible solutions for the stated problem, and design of the solution.* The prediction subtask is performed through a simulation program, which simulates the patient flows. This is again a similar concept to the one adopted in this research and once again demonstrates a move towards incorporating the decision making process in simulation models.

2.2.4.1.3 Scheduling and Availability of Resources

Taylor and Kuljis (1998) simulate an outpatient clinic with CLINSIM a simulation package that enables managers to gain an insight into the behaviour of a particular system. The model is “general purpose” and “data driven” so it is capable of modelling a range of outpatient clinics and caters for clinics with certain specifications that have been obtained through lengthy discussions with representatives of outpatient clinics. The specifications are that the clinics have up to six doctors, up to two receptionists, and up to three consultation rooms to operate simultaneously. The CLINSIM model was also used to attempt improve the state of the outpatient clinic at Leeds General Infirmary.

2.2.4.2 Papers on Allocation of Resources

Papers on allocation of resources originate from the rise in the cost of providing quality healthcare. The authors of the survey, (Jun J.B, 1999) divide this section into three general areas: **a**. Bed Sizing and Planning, **b**. Room Sizing and Planning and **c**. Staff Sizing and Planning.

2.2.4.2.4 Bed Sizing and Planning

Jun et al. (1999) suggests that demand for hospital or clinic beds can be divided into both routine (scheduled) and emergency (unscheduled) admissions. They explain that *"Both these types of admissions impact how many beds are needed to meet demand, while maintaining reasonable bed utilisation rates. In the literature, most bed planning simulation models attempt to overcome bed shortages or policies that lead to patient misplacement bumping, or rejection. Hospitals are faced with the trade off between having available beds to service patient demands vs keeping bed occupancy (utilisation) rates high"* (p.113). This issue is of direct relevance to the research in this thesis.

Butler (1992a) used simulation to study *"patient misplacements"*. Patient misplacements occur when patients are sent to an alternative hospital because of bed shortages in the preferred hospital area. The article "*examined the sensitivity of patient misplacement to various modifications in their bed allocation policy, which included patient transfers, bed scheduling and assignments*". In another study designed to reduce patient misplacement (Butler T. Reeves G., Karwan K., Sweigart J.,, 1992b) a two-phase approach was adopted. This involved "*a quadratic integer programming model (for scheduling) and a simulation model to evaluate bed configurations and to determine optimal bed allocations across a number of hospital service areas"*. This is another example of the use of a multimethodology to solve a problem.

Papers by Lowery (1992) and Lowery et al (1992,1993), (Lowery J.C., 1992a, Lowery J.C. and Martin J.B., 1992b, Lowery J.C., 1993) studied the use of simulation in a hospital's critical care areas in order to determine critical care bed requirements. Critical care areas refer to operating rooms, to recovery units, to intensive care units and to intermediate care units. One of the findings of these papers is that most models "*do not fully consider the interrelationships between different units and few models have been validated using actual hospital performance data"*. The authors focused in these deficiencies and showed improvements in their methodologies over previous models.

Dumas (1984, 1985) studied the interrelationship between different hospital rules in terms of bed availability and planning. Dumas examined this interrelationship through the comparison of two bed-planning rules for the purpose of providing the patient with a bed when he or she could not be allocated a bed in their preferred unit. The first bed-planning rule is vacancy basing that uses "*a ranked list of alternative misplacement possibilities*". The second bed-planning rule called "home basing" does not allow misplacements. These pieces of research showed "*that home basing policies resulted in better overall performance but less patient days and therefore less revenue*".

Cohen (1980) approached the problem from a slightly different angle to the others and introduced the idea that patients can be moved to between units of a hospital as their condition changes. This study demonstrates that "*the probability of inappropriate patient placement is a function of the capabilities of all the units, as well as the policies for handling priority patients and bumped patients*".

Bagust et al. (1999) examined the daily bed requirements arising from the flow of emergency admissions to an acute hospital. The setting was a hypothetical acute hospital in England and the simulation model. The purpose of the paper is "*to identify the implications of fluctuating and unpredictable demands for emergency admission for the management of hospital bed capacity, and to quantify the daily risk of insufficient capacity for patients requiring immediate admission*". The main conclusion is "*that there are limits to the occupancy rates that can be achieved safely without considerable risk to patients and to the efficient delivery of emergency care. Spare bed capacity is therefore essential for the effective management of emergency admissions, and its cost should be borne by purchases as an essential element of an acute hospital service*". This conclusion is also of great importance to the research in this thesis as the aim of the average bed utilisation in the simulation models is eighty five percent which allows for some spare bed capacity.

Kim et al. (1999) describes the analysis of capacity management of the intensive care unit (ICU). The decision process in an ICU is described as being mainly subjective and lacking in clear criteria upon which to base any given decision. The study analyses the admission and discharge process of a one particular ICU in a hospital in Hong Kong by using queuing and computer simulation models built with actual data from the ICU. The paper explains that the admission process is largely dependent on two judgements regarding which patients are suitable for admission and when the patients should be admitted. The ICU's admission decision takes two factors into consideration: the *patient's attributes* and the *state of the ICU.* The patient's attributes include factors such as the severity of the illness, age, expected length of stay and probable outcome. The state of the ICU refers to bed availability and the possibility of a speedy discharge of any of the current patients whose recovery has been better than expected. The study's questions are 1. How often will full capacity arise?, 2. How long will patients have to wait? 3. To what extent might an increase in beds relieve such delays? The data used in the model was collected over a continuous six-month period and the belief is that the shapes of the arrival and discharge distributions for these six months would not mirror a different or longer period. The authors explain that in this case it is important to justify the feasibility of the approach through this preliminary study and to report the intention to conduct a more extensive study that will extend to two years.

In the past thirty years, the dramatic increase in the cost of health care has compelled researchers and health care professional to examine new ways to improve efficiency and reduce costs. Lange et al. (1999), discusses the benefits of simulation modelling in medical planning and medical design and shows a particular interest in a project for an outpatient service. The paper makes some interesting points that are somewhat related to this research. One point is about having an aim for the utilisation of an outpatient unit. The example provided indicates the difficulties in creating outpatient services and mentions that the unit is designed for around 75% utilisation. Another point that is made is about the "mentality" of doctors and nurses. The paper says that they have developed a very acute sense of "correctness" or "incorrectness" about decisions. Specifically *"they may not know precisely why a decision seems correct or not, but this "intuition", is one of the most valuable tools of the clinical practitioner".* The author also reports that the simulation model of the outpatient unit showed that it would not work as the beds would not be enough due to the small amount of space and that this was a much more efficient method than averaging based methods. The author also provides some valuable information about the chaotic conditions that one may encounter in planning and suggests that simulation is suited to dealing with these chaotic states. These chaotic states include the following:

Chaotic Condition 1 – is that not all hospital departments or hospitals themselves are co-operative and may not respond in a neat and predictable way.

Chaotic Condition 2 – no two hospitals or hospital departments will respond in the same way to any given change and therefore it is not possible to transfer "best practice" planning methods across hospitals.

Chaotic Condition 3 – if you attempt physical re-design of any hospital area or department without process re-design, it will almost always be necessary to re-design the process in the future and vice versa.

Chaotic Condition 4 – the stakeholders' different agendas can "slow things down" and create huge costs. Modelling can allow a reconciliation of differing view and agendas into a clear objective.

Chaotic Condition 5 – changes in physical layout and process can create problems or inconvenience in the working practises of staff. Modelling allows one to identify these issues in advance.

Chaotic Condition 6 – Re-engineering is always "painful" and will always yield some unpleasant results. Also in some cases small changes "reverberate" so that the actual impact is much larger than anticipated. This again is best examined through modelling as it allows for the whole picture to be predicted.

Chaotic Condition 7 – if one thing goes wrong it is possible to erase all previous good work. The author describes this as: "*one Aaaa has the power to erase ALL previous pats on the back*". This is again something that can be avoided with the use of simulation.

Vasilakis and El-Darzi (2001) model the winter bed crises that usually arises two to three weeks after Christmas. Among other factors the bed crises is usually attributed to factors such as bad weather, older people getting influenza, and nurse and bed shortages and the consequences include patients waiting on trolleys in hospital corridors. The paper is about modelling the stream like movements of patients through hospitals. The key concepts of the simulation model are that: a. patients arrive randomly of each other, b. length of stay in the acute (short stay), rehabilitative (medium stay) and long stay beds is exponentially distributed, c. acute beds are blocked when no beds (server units) are available for patients identified as needing rehabilitation, d. rehabilitation beds are also blocked when there are no available beds in long stay. The basic parameters of the simulation models were obtained through BOMPS, which generated performance statistics based upon the fit between a mixed exponential curve and bed census data. The conclusion is that delay in discharge rather than an increase in admissions could be the main cause of the crises.

Ridge et al. (1998) describe a simulation model for bed capacity planning in Intensive Care. The length of stay of emergency and planned patients is described using either the negative exponential curve or a Weibull curve fitting routine. The model demonstrates a strong non-linear relationship between the number of beds and the number of transfers.

Harper and Shahani (2002) model the planning and management of bed capacities in hospitals. The simulation modelling work considers various types of patient flows and the individual's patient level and the resulting bed needs over time. An important feature of the model is that it is linked to the hospital's patient management system. The paper proposes that detailed hospital bed capacity models should incorporate monthly, daily and hourly demand profiles and meaningful statistical distributions that capture the variability in patient lengths of stay. The project team consisted of a steering group of hospital managers and clinicians that guided the work and facilitated the gathering of hospital data and any other information needed. The project spanned over 16 months and an integrated bed capacity simulation model was developed. The work highlights the need to evaluate hospital bed capacities in light of both bed occupancies and refused admission rates.

2.2.4.2.5 Room Sizing and Planning

Davies and Davies (1995) and Davies and Roderick (1998) use DESM to explore the overall demand for planning resources for renal services throughout the UK over the next 15 years. The study is mainly concerned with end stage renal failure and the aim is to determine how many patients will require treatment in the future and what facilities will be needed for their treatment. The data used was obtained from national and international data sources.

2.2.4.2.6 Staff Sizing and Planning

Klafehn (1987) simulated patient flows of non-admission and in-house patients going through a radiology department of an acute care hospital because the patients Length of Stay exceeded the desirable level. The simulation model was built to trace the flow of patients through the system, to observe where waiting lines existed and to determine the length of time individuals spent waiting for scarce resources. The arrival rate of eight types of patients as well as the number of each type of patient that had to be serviced by the radiology department had to be created from "day sheets". The day sheet is a daily log of the type of patients along with the type of procedure the patient received. The model's scenarios included varying the number of radiologists in order to reduce the Length of Stay (LOS) of the non-admission patients. The simulation runs indicated that an extra radiologist would accomplish this requirement. This article reflects the approach taken for the individual models for each IC service described in thesis.

Alvarez and Centeno (1999) examine enhancing a simulation model of an Emergency Room with Visual Basic Application (VBA) routines so that it can use real world data. The simulation model has been "complemented" with a series of decision-making routines. Each category of decision requires a different set of data. The data may be available from the hospitals information system department or it may reside in a database of an external information system supplier to the hospital or it may be in the ER databases. The authors developed a library of routines written in Visual Basic for Applications (VBA) that are able to transform the extracted data from the database and the user in the proper format required by the model. These routines use a hierarchical approach to organise the various scenarios under which the model may run and aid in partially reconfiguring or customising the model without having to access the simulation language or software at any time. The importance of this model is that it uses on line data from the ER information system and that the model is so user friendly that the user does need to have knowledge of simulation modelling techniques. This approach to modelling will be something to aim for in the future of this research presented herein once patient data is systematically collected.

2.2.5 Simulation literature of Complex Integrated Multi-Facility Systems

Jun et al. (1999) write that "a limited number of simulation models have been developed that analyse complex multi-facility health care delivery systems... Simulation models can depict the interaction of major service departments and support services in a hospital, and the information that can be gained from analysing the system as a whole, can be invaluable to hospital planners and administrators" (p.116). Jun et al. (1999), report that the lack of literature is attributed to two factors. The first factor is the level of complexity and the resulting data requirements of the simulation model and the second factor is the resource requirements, which include time and costs.

Stafford (1976) who is also mentioned in the Jun et al. (1999) survey developed a multifacility simulation model of a university health centre as part of his PhD research. The simulation model incorporated fourteen separate stations, which included the cold clinic, X-ray, mental health, team physicians facilities, injections, dentist, gynaecology, physical therapy, radiology and pharmacy. The model views an outpatient clinic as a complex queuing system in which the patients enter the system at various facilities receive the treatment offered at these facilities and leave the system. The available arrival data for the university health centre was insufficient in determining the individuals interarrival times. The arrival process that was observed during a three-week period fitted the negative exponential distribution. Stafford (1976) has used transitional probabilities to move patients to treatments but in this project, the system model will use actual patient data to determine the service needed.

2.2.6 Simulation Models that include elements of Human decision making

One very important element of the simulation modelling of this project has been to simulate decision-making. Robinson et al. (1998) have written about simulating the human decision maker. They write that most simulation models represent human activity systems as opposed to "purely automated systems" and can present two problems to the simulation modeller. The first problem is that the modeller must determine the way in which the human decisions are made and the second problem is that he or she must then model them as accurately as possible. They write that:

"The typical approach to representing human decision making in simulation models is to try to elicit decision rules from the decision maker. In some cases, this amounts to little more than a guess on the behalf of the modeller. Following this, the rules are included in the model using the constructs of the simulation language or simulator. This normally requires the use of a series of "if", "then", "else" statements. This can result in large amount of code that is difficult to interpret and even harder to change."

(Robinson et al., 1998, p.1542)

The authors suggest that one approach to overcome this problem is to use an expert system to represent a human decision maker and link it with a simulation model and they suggest two ways of doing this: The first way is to extract the decision rules from the expert and represent them within an expert system and the second way is to "use the simulation model to prompt the expert to make decisions, building up a set of examples from which an expert system could learn". The authors describe linking an expert system to a simulation model using Object Linking and Embedding (OLE).

2.2.7 Computer Simulation Literature in Healthcare that include a cost or Economic Analysis.

Baldwin et al. (1999), Eldabi et al. (1999) and Taylor et al. (1998), discuss how simulation can support decision making by helping health economists develop a deeper understanding of the relationships involved in a clinical trial. The example used is based on modelling the clinical trial for Adjuvant Breast Cancer using a tailor made simulation package called ABCsim. A group of economists evaluate the economic implications of the ABC trial to determine the cost effectiveness of the various treatment combinations by comparing the additional resource use with the survival gains and quality of life effects. The collection of data regarding quality of life is done through questionnaires and interviews which are both costly and time consuming. The authors report that there are problems involved with this type of data collections which include: a. limited data collection resources, b. the use of clinical staff to perform the data collection therefore removing them from their own work, c. disturbing the clinical process by interruptions for data collection, d. the effects of people saying what the questioner wants to hear rather than what they might actually feel and e. the difficulties of collecting data on quality of life both during and after treatment. The basic structure of the economic factors was captured in the model in terms of treatment pathways and health states.

Campbell et al. (2001) examine whether a cost analysis of a Hospital at Home service was cost saving compared with conventional inpatient care using discrete event simulation. The hospital at home scheme was introduced as an initiative to cope with winter pressures in a health authority in West London. It involves treating elderly patients with a variety of conditions in their home environments. The choice of the method was explained as driven by circumstances. The authors believe that *as the service was already in place it was not feasible to design a formal evaluation such as a randomised control trial. Instead, prospective and retrospective observational data were collected on two groups of patients: an intervention group receiving hospital at home and a comparator group receiving conventional inpatient care* (Campbell, 2001, p.14). The data was analysed using DESM package, Simul8. The baseline simulation performed with 1000 patients in each group showed the mean cost per patient for Hospital at Home care and 3 months follow up care was cheaper by three-fifths than the mean cost per patient of inpatient care and follow up.

2.2.8 Modelling using real patient data

One element of this research is the use of patient attributes for the simulation models. There is literature on simulation modelling that supports the use of real patient data and demonstrates benefits for using it. The need for high quality data can be seen in a variety of contexts in health care in the majority of articles that have been previously cited as well as in the following articles:

A paper by Cromwell et al. (1998) describes using simulation to educate hospital staff about casemix classifications like Diagnosis Related Groups (DRGs). DRGs were originally developed in the USA to assist quality assurance and they involve classifying grouped patients who are expected to consume similar levels of resources. This enables differences in casemix of hospitals to be minimised and could therefore allow the efficiency of hospitals to be compared. The Illawarra/St. George educational group received Commonwealth funding to create educational material and part of this was the development of a computer based management game, built around a simulation model of a hospital. The individual patient is the main entity and its "condition "attribute determines its clinical path. In total there are 40 simulated conditions. This model can be described as largely needs driven rather than the usual resource driven models.

2.2.8.1 Modelling the elderly using real patient data

Forte and Bowen (1997) describe the Balance of Care system as a decision support system (DSS) that is designed to address strategic planning issues involving a range of different agencies including health and social services and the private and voluntary sectors. The authors make some valid points regarding care for the elderly. Specifically, "*the settings of services for elderly people are predominantly community based and are characterised by the large number of commissioning and provider organisations, the potential range of services provided, and the often poor quality, compatibility and availability of information on needs and service levels*" (Forte and Bowen, 1997, p.71). The authors explain that the Balance of Care was developed to assist managers in handling the complexity involved in the provision of care for the elderly. The Balance of Care computer model is dependent on data regarding existing service levels and their costs, and how these relate to the needs of the elderly population. The vital element in this sort of model is the ability to relate information on services to levels of dependency in the population. The authors report that the dependency in the population is reliant on two factors, the incapacity of the individual and the level of informal support. In terms of the individual there are three important characteristics: physical ability (mobility and the ability to carry out daily living tasks), mental ability (dementia or behaviour disorder), and incontinence. Most importantly different combinations of these will generate different service requirements. In terms of informal support the authors report that it is much more difficult to assess but can have a significant impact on the response demand of other formal services. The system model comprises two components a population model and a care options model. The model can be described as static and does not change over time like a discrete event simulation model and it works with a number of simple, built in routines and allocates the population of a particular dependency group to care option. The process is done automatically on the basis of specified preferences or lower costs. Finally, the authors explain that the purpose of the computer model is not to give precise answers but to help others develop strategic thinking.

It is very likely that without the use of real patient data some of the simulation models cited in the literature review of this thesis would not be as effective. The majority of articles talk about collecting data mainly about their patients: gender, age and dates of admission and discharge. These can be described as essential information and that can be considered adequate especially if decision-making processes have not been included in the model. None of the article discusses using data from a comprehensive and validated data collection instrument.

Obtaining real data from health and social care is a difficult task if the data is not hospitals. Hospitals have been required by law to collect patient data systematically but community services have eluded this requirement up to now. This is reflected in the large amount of work done for acute hospitals and the small amount of work done in the community. This means that Smith-Daniels et al. (1988), the article mentioned earlier in the historical review, is still relevant even though almost fifteen years have past.

2.2.9 Validation and Verification of simulation models

An important stage of every simulation modelling project is the validation and verification of the simulation models. Sargent (1987, 1998) describes validation and verification techniques that have been taken into account for the validation and verification of the simulation models for this project. Kleijnen (1995) demonstrates in a case study that validation and verification have "elements of art as well as science". The case study discusses validation issues that arise such as screening, risk analysis, Gaussian approximations, Type I and II errors, less stringent statistical validation and animation. In another article Kleijnen (1995) surveys verification and validation of models especially simulation models in OR. For verification it discusses: 1) general good programming practice, 2) checking intermediate simulation outputs through tracing and statistical testing of final simulation outputs against analytical results and 4) animation. For validation he discusses 1) obtaining real world data, 2) comparing simulated and real data through simple tests such as graphical, Schruben—Turing, and t tests 3) testing whether simulated and real responses are positively correlated and moreover have the same mean, using two new statistical procedures based on regression analysis, 4) sensitivity analysis based on design of experiments and regression analysis and risk or uncertainty analysis based on Monte Carlo sampling and 5) white versus black box simulation models.

Jenkins et al. (1998) examines validation and verification issues for a case study carried out in the health sector. The paper argues that the health sector is characterised by a level of complexity in handling resources, which makes validation and verification a difficult and challenging task. The paper proposes that by describing the level of interaction among the three key modelling constructs: entity, resource and workcentre one can understand the likely level of complexity of the model. Their modelling environment assumed that "entities will move from workcentre to workcentre depending on the attributes of the entity, the state of the workcentre and the state of the resources. The entity is essentially passive and does not take decisions about routes and destinations". The scope of the model is defined in the paper through a table of five levels of complexity, based on two dimensions: Entity and Resource (see table 2.2). The paper suggests that as the scope of the model increases its range, the numbers of workstations will also increase to capture the necessary behaviour.

Table 2.2 Scoping the model. Adapted from Jenkins et al. (1998)

	Description	
Range	Resource	Entity
1	The system has been modelled without the use of resources.	No entities are required for execution of the model. This is likely to be a trivial case.
2	The system has been modelled using resources, which are able to be called single workcentres by whatever entity is being processed at a particular time. These resources will not have time constraints placed on them.	Entities are passed through the various workcentres with a fixed route, with no choice of path.
3	The system has been modelled using resources, which are able to be called single workcentres by whatever entity is being processed at a particular time. These resources may have time constraints placed on them.	The entity will pass through the process, choices on the particular route will depend only on attributes of the entity. The state of the workcentre, and the state of the resources will not impact on the route of the entity.
4	The system has been modelled using resources which are able to be called by multiple workcentres. The resources may have down times and shift structures which also influence their availability for tasks at the workcentre.	The entity will pass through the process, choices on the particular route will depend on attributes of the entity and the state of the workcentre. The state of the resources will not impact on the route of the entity. The pattern of resource requirement by the entity will remain constant.
5	The system has been modelled using resources which are able to be allocated to multiple workstations and multiple entities. The resources are able to be pre-emptive from a workcenter and are able to work in teams with variable composition.	Entities are able to use multiple workstations, and multiple combinations of resources in order to effect the transformation required to pass through the full process.

The case study by Jenkins et al. (1998) involves Verifying and Validating a model of an A&E department in an Australian hospital. When building the model the project team asked the stakeholders to initially comment on flow charts and verbal descriptions of policy rules and eventually on the animated interface. Two techniques were used to achieve acceptable levels of verification for their project. The first technique was to conduct close observation of the animated interface during extended runs of the model to identify conflicts or inconsistencies in the behaviour of the model. The second technique involved showing the model to system experts. Although the model was shown to system experts this did not lead to significant levels of feedback that would have contributed to model verification. This was even more surprising as there were errors in the code that led to visible inconsistencies in the resource and entity behaviour. However, the use of verbal description of behaviour in the model helped the system experts note inconsistencies. The paper also described the use of two validation techniques. The first technique was the use of visualisation/animation. This process involved running the model for extensive periods and system experts and members of the modelling team observed the pre-emption behaviours of entities and resources such as examining whether the queues were sensible. To facilitate this stage of validation, patients with different categories were presented with different coloured icons, which allowed a detailed account of each resource, entity and workcenter. The second validation technique was a graphical presentation of the model's behaviour. This was done through collecting statistical data for extended periods of hospital history and this data was analysed by patient category. The model was instrumental in order to provide data in the same format. The frequencies of service levels by patient category were compared to establish validity levels for the model. There was consistency between the historical data and the model output. This paper has influenced the validation and verification phase of the simulation models described in this thesis.

Robinson (1999) reviews the literature regarding the accuracy of simulation studies and raises the following common factors: support from senior management, the skills of the modeller, the relationship between the modeller and the end user, involving the end user, correct formulation of the problem, the accuracy of the data, using the right simulation software, the soundness/credibility of the model and communication and timeliness of the work. In another article, Robinson (2002) describes the concept of quality in DESM through a model consisting of three quality concepts: 1. the content, 2. the process, 3. the outcome of a simulation study.

2.2.10 Implementing a simulation project in Health

Mahachek (1992) introduces the basic concepts of patient flow simulation to health care managers. The paper suggests two approaches to organising a simulation project. The first approach is to draw resources that form an in house team only from within the organisation with detailed knowledge of the day to day activities. This group will benefit from a computer simulation environment that inevitably promotes "brainstorming" and a deeper understanding of cause and effect relationships. The second approach is to secure the services of an outside consultant with simulation experience. The consultant despite having a lack of specific departmental knowledge will have a general understanding of health care environments. The paper also explains that by choosing a consultant led approach the simulation modelling will "*reduce the natural suspicions of an outsider*". This is mainly due to the goals of simulation modelling that is to potentially create a beneficial working mechanism rather than having a manager give unfounded orders regarding organisation changes. The paper also provides useful information about the practicalities of implementing a simulation project. A very important message that is presented in the paper is that the usefulness of a simulation depends more on the motivation and participation of the health employees than the analyst's talents. This means that a significant amount of effort should be spent to get the employees to "buy in" to the project.

2.3 SSM in Health Care literature

Checkland (1990, 1999) developed Soft Systems Methodology (SSM) in 1981 because he felt that hard OR had certain limitations in its use in terms of system analysis. Checkland worked for many years as a senior manager and recognised that "Management Science" could not deal with all aspects of his work. His concern was increased by the term "Management Science" and specifically with the term "Science" which he believed was not justified. When he moved to Lancaster University for an academic career he developed other system approaches that could be of value to managers. The methodology underwent some modifications over the years. The first model of the methodology is the Seven-Stage model in 1981, then came the Two Streams model in 1988 and the final version is in 1990 the Four Main Activities model (Checkland, 1999).

SSM has been applied to health care by Checkland (1990) himself in a project for the East Berkshire district in order to investigate and recommend ways of measuring the performance of their community medicine. He identifies the "*need to understand not only the ideas (and controversy) of community medicine but also the basic mechanisms operating at district level in the NHS in the provision of health care*". The description of the finding out phase involved interviews attending local meetings, reading and applying Analyses One, Two and Three. Checkland (1990) also writes that it was useful to produce a basic structural picture of the problem situation and a rather detailed model of a general (primary task) system to plan and organize (but not deliver) health care to a defined population. The use of a primary tasks model had been adopted in this thesis and this is explained in the methodology chapter. Checkland (1999) in his thirty year retrospective also described using a model to structure open ended interviews with a large number (sixty) professionals. The material generated from the interviews was used to construct an activity model which was described as an innovative SSM move and the outcome was ten pieces of action research work in the NHS.

Rose and Haynes (1999), who were part of Checkland's team at Lancaster University, wrote about an innovative evaluation design for the NHS using the epistemological differences of Soft Systems Methodology. They were commissioned by Yorkshire regional health authority to design a process that Resource Management (RM) sites could use to evaluate their own projects. They describe the difficulties involved in evaluations in NHS RM such as measuring improvements in patient care and that it is often perceived as time consuming and potentially threatening. They list the following problems presented in their evaluation:

> RM developments are not discrete or separable from other concurrent change initiatives;
>
> IT/IS developments are not discrete or separable from wider organisational goals;
>
> Measurement and quantification techniques are difficult to apply and potentially extremely misleading;
>
> Goals and objectives differ widely in different parts of the organisation and evolve over time;
>
> Evaluation is politically sensitive and requires emphasis on learning and moving forward rather than assessing damage and apportioning blame;

They write that SSM is evaluatory in nature potentially well suited to evaluation of complex public service change initiatives. They explain that SSM can be used as a problem-structuring tool, where the result of the study may be a set of research questions to be answered by other means. This observation is particularly useful as it describes the project herein were SSM was used mainly to problem structure and it produced a set of questions/issues that were answered mainly using DESM.

Checkland (1990) describes a study for social services to ascertain what resources would be required to enable a substantial number of mentally handicapped people in Borough to be placed in "open" (as opposed to Sheltered employment). The authors reports that the system was complex with several organisations involved that had limited communication. This finding is interesting as Intermediate Care, which is also linked to social services, is also complex with several services involved with limited communication.

Connell, (2001) evaluates soft OR by reflecting on a successful structuring that led to an apparently "unsuccessful" implementation of SSM that was used to help in the design of an information system for health service users providing care in the community in a part of the south and west health region in the UK. The author application of SSM was towards Checklands (1999) "mode 2" although the project team were encouraged to go through the SSM sequence of steps but some of the systemic ideas were "translated" into jargon free language. However, the author describes that a particular group of stakeholders, the service providing groups, did not participate directly which created problems and were therefore less equipped to make an evaluative judgement on the process, yet still make a judgment that may have had an effect on the perception of implementation success. The author says that because some stakeholders viewed the project as a "failure" rather than a success he felt that there should reflect on the process. Because of this reflection the author developed a process to assist in judging the success of an SSM project, which is further discussed in the conclusion chapter (section 7.4.1).

2.4 Papers using a multimethodology of SSM and DESM

2.4.1 Clarifying the multimethodology terminology

Method comes from the Greek word Methodos that is defined as a systematic approach to solving problems (Dimopoulou, 1982). Mingers (2000) defines method "as a structured set of processes and activities that includes tools, techniques and models that can be used in dealing with a problem or problem situation". For the purposes of this research the term method and methodology have the same meaning. Combining two of these methods is called a multimethod or multimethodology.

Simulation modelling is usually described as a technique but in this research it is considered a methodology. Technique, which is also a Greek word, is defined as a skill (Dimopoulou, 1982). The reason that it is considered as a methodology is because in order to solve a problem one undertakes a number of activities before and after the specific modelling simulation technique is used. A technique is thought of as a procedure that if properly applied will produce a guaranteed result (Checkland, 1998) but building the computer model is not enough when conducting a simulation study. For example in order to simulation study of patient flows in an A & E department one initially will need to understand the problem, obtain a conceptual model of the system of interest then begin the data collection and then build a DES model, verify and validate the model and finally perform a what if analysis. In this research a simulation modelling study is a methodology although discrete event simulation is considered a technique.

In the review, we have seen several simulation papers that stand-alone with no other method and answer question or provide solutions, which demonstrates its power. Simulation modelling is part of a group of methodologies that typically fall under the heading of hard OR and SSM is part of another set of methodologies that fall under the heading of soft OR. The combination of a hard and soft methodology is less common than that of two hard or two soft methodologies (Mingers, 2000). Both hard and soft methodologies can be individually applied to some problem situations without the need of another methodology. This of course depends on the problem situation. In some situations there is a need for both methodologies.

In recent years some have found benefits in mixing methodologies and have attempted to create a framework to smoothly enable the use of multi-methodologies (Mingers and Brocklesby, 1997, Mingers, 2000, 2001, 2003). The use of multimethods comes from the need to deal with real life problems that do not fit neatly into one particular methodology and therefore need some groundwork usually in the form of a soft methodology. The article also expresses the view that a mutlimethod does not represent a specific way of combining methods but it refers to the plurality of methods or techniques both qualitative and quantitative, within a real problem intervention.

The term Multimethodology is closely associated with various terminologies such as pluralism, coherent pluralism (Jackson, 1999), critical pluralism (Mingers, 1997), pragmatic pluralism (White and Taket, 1997) and a term that is emerging is complementarity (Pidd, 2004). The adjectives in front of pluralism describe the philosophical approach or position that each author adopts. The reason that many positions are put forward by OR/MS is the belief that it is essential to take a position on the philosophy and the practice of mixing methods for the credibility of any argument for methodological pluralism (Midgley, 2000). A few words will explain some of these positions on pluralism:

Critical pluralism recognizes two types of continual activity: "actual actions within the problem situation some of which may draw on particular methodologies and techniques; and critical reflection about the intervention determining the particular combinations of actions and methodologies that are employed" (Mingers, 1997, p.419).

Pragmatic pluralism is about "A strategy of mix and match, adopting a flexible and adaptive stance, and operationalising "doing what feels good" (White and Taket, 1997, p.386).

Pidd (2004) has edited a book on systems modelling that largely discusses complementarity and focuses on complementarity in terms of Flood and Jackson's (1991), Total Systems Intervention (TSI), which examined six different systems approaches (system dynamics, viable system diagnosis, strategic assumptions surfacing and testing, interactive planning, SSM, Critical system heuristics) and suggested how they might be fused under a single approach. Pidd acknowledges the difficulties in working concurrently with hard and soft approaches and presents three relationships between hard and soft approaches: a. hard and soft are incommensurable, b. hard and soft approaches feed off each other in an eclectic and pragmatic way and c. soft OR/MS methods are seen as containing the hard OR/MS methods. However, he does not advocate one philosophical position (or relationship) but suggests that the divide may not be a great as some imagine but the reader should make his or her own mind up and that "the journey is more important than the destination" (p.19).

Jackson's (1999) "coherent pluralism", is about using methods and tools under one methodology. His view is best explained in his own words: "Only by using the methods and tools under the control of a methodology which clearly serves one paradigm can we test them and discover how to improve their effectiveness in supporting an intervention conducted according to that rationality. We can find out if system dynamics models developed originally to serve a hard methodology are indeed useful in the context of a soft methodology. This consideration rules out, for me, the option of "multiparadigm multimethodology" apparently proposed by Mingers and Brocklesby" (Jackson, 1999, p.18).

However, "Pluralism, interpreted in the broadest sense as the use of different methodologies, methods and/or techniques in combination is a topic of considerable interest in the applied disciplines these days." (Jackson, 1999, p.12)

Although pluralism and multimethodology are similar in their meaning, pluralism is the wider term as it incorporates multimethodology. In fact, Mingers (1997) describes multimethodology as a particular form of methodological pluralism and believes that most interventions if not all should be dealt with more effectively with a blend of methodologies from different paradigms. Similarly, Midgley (1997) believes that, in most research, the situation is perceived as sufficiently complex to warrant the need of a number of methods and that it is therefore more important to think about the design of methods than simple choice between "off-the-shelf" methodologies. Midgley (2000) reports on an alternative approach to mixing methods to the System of Systems Methodologies (Jackson and Keys, 1984) (that received much criticism and was later abandoned for the Total Systems Intervention mentioned earlier) which he calls "creative design of methods". He explains,

"This involves understanding the situation in which an agent wishes to intervene in terms of a series of systemically interrelated questions, expressing the agent's purposes for intervention. Each purpose might need to be addressed using a different method or part of a method. The purposes are not necessarily determined as a complete set in advance, but may evolve as events unfold and understandings of the situation develop. In this sense, it is important to acknowledge that interventions take place over time, and that different purposes may emerge at different "moments" of enquiry, requiring the use of different methods" (p.226).

He also places importance on the role of intuition and the intervener in the creative design of methods.

The multimethodology adopted for the case study is SSM, associated with the soft paradigm, and DESM, associated with the hard paradigm. Authors that discuss pluralism and multimethodology also discuss paradigms, otherwise known as philosophical assumptions, because methods and methodologies tend to be associated with or applied under a particular paradigm. Mingers (1997) explains that there are three different paradigms: the first is the hard (positivist) that treats the organizational world as objective, the soft (interpretivist) treats human organisations as fundamentally different, and the critical that accepts the place of both hard and soft but emphasizing the oppressing and inequitable nature of social systems. This paper is only interested in the soft and hard paradigms. The hard paradigm is considered the dominant paradigm; it is associated with problems and puzzles and there are also six key characteristics that can mean that a problem is perceived as "hard" OR (Rosenhead, (1999)). These characteristics are:

1. Problem formulation with a single objective and optimization. Multiple objectives if recognised, are subject to trade-off on to a common scale.
2. There are overwhelming data demands, with consequent problems of distortion, data availability and data credibility.
3. Scientization and depoliticization, there is an assumption of consensus between stakeholders
4. People are treated as passive objects.
5. There is a single decision maker with abstract objectives from which concrete actions can be deduced from implementation through a hierarchical chain of command.
6. There is an attempt to abolish future uncertainty, pre-taking future decisions

The soft paradigm is considered the alternative paradigm and is associated with messes and also can have some or all of these six characteristics (Rosenhead, (1999)):

1. Non-optimizing; seeks alternative solutions, which are acceptable on separate dimensions, without trade-offs.
2. Reduced data demands, achieved by greater integration of hard and soft data with social judgements.
3. Simplicity and transparency aimed at clarifying the terms of conflict.
4. Conceptualises people as active subjects.
5. Facilitates planning from the bottom up.
6. Accepts uncertainty, and aims to keep options open for later resolution.

In social theory, the paradigms are thought to be incommensurable, which means that they are mutually exclusive, unable to be combined or linked, although there is little agreement with this view from management scientists and operational researchers. In the following paragraphs, we will briefly explore some beliefs about mixing methods and mixing hard and soft paradigms.

Ormerod (1997), a practitioner that moved into academia, believes that mixing methods is possible and that switching between paradigms was not an issue for him and that the limitations lie in the competence of the consultant and the participants rather than the methods themselves.

Brocklesby (1997) acknowledges shifts in paradigms and that they can be a "painful experience" for the individual concerned but that it is possible for a person to become multimethodology literate given sufficient determination. He believes that "the process of transforming an agent who works within a single paradigm into someone who is multimethodology literate is perhaps unlikely, although by no means impossible" (p.212). However, for this to occur, a number of obstacles must be overcome:

First, the agent must become paradigm conscious. Secondly, the agent must believe that the new paradigm offers something worth having and fits with the agent's personality and beliefs. Thirdly, effective performance in a paradigm necessitates learning its propositional and commonsense knowledge. Brocklesby uses Varela, Thompson and Rosch (1991) work that identifies two types of knowledge, propositional and commonsense, needed for someone to act effectively in a "new paradigm". He explains that in soft MS the propositional knowledge needed to create rich pictures, produce root definitions can be acquired from textbooks but in order to be effective in soft MS one must work directly with people, and respond to developing situations which cannot be captured in a propositional format. However, to become proficient in a new paradigm the newcomer has to acquire relevant propositional knowledge but this is only the first step and that "really" knowing the paradigm and acting effectively in it means active bodily involvement, experience and practice. He also says that acting effectively within a new paradigm requires both learning and unlearning.

2.4.2 Papers reviewing the literature of the multi-methodology of SSM and DESM

A paper by Mingers (2000) reviews the general use of multimethodologies to real life problems. A table listed in his article has been partly included (only for Health Services) as it provides some indication about the literature of practical soft ORMS applications (see table 2.3). The table shows that other authors have chosen this combination, SSM and Simulation, for application in Health Services. The contribution of these papers to this research is in presenting evidence of a previously developed philosophy of a structured approach to multimethod design that incorporates the various frameworks previously developed. The article concludes with some suggestions for further research that would contribute to the practical use of a multimethodology. The suggestions are:

- More case studies showing both the successful and the less successful mixing of methods.
- Empirical and theoretical analysis of how particular methods can best be decomposed, and which combinations are most fruitfully linked.
- Consideration of the importance of the personal characteristics of the practitioner in both choosing and using multiple methods. In particular, how difficult is it for individuals to work across paradigms combining technical, quantitative analysis with soft facilitation skills?
- Consideration of the impact of project teams (rather than individual practitioners) on multimethod. How do the benefits (such as a wider range of skills and experience) compare with the costs (possible disagreement about which methods to use)?

Table 2.3 A list of published papers in which practical application of soft MS/OR are reported as of analysis interventions.

Application area (Health)	Methods/techniques used	Reference
Outpatient clinics	Systems thinking + data analysis, queuing, simulation	Bennett and Worthington (1998)
Problems of disabled users	Systems Thinking	Thoren 1996
Modelling Outpatients Services	SSM + Simulation	Lehaney and Paul(1994, 1996)
Nurse Management	SSM	Wells (1995)
Contract Management in the NHS	SSM	Hindle, et al. (1995)
Health Care information System	SSM	Maciaschapula (1995)
Resource planning and allocation	SSM + simulation	Lehaney and Hlupic (1995)
Employment for those with mental health problems	Critical Systems	Midgley and Milne (1995)
Planning hospital organization	Interactive planning	Lartindrake and Curran (1996)

Robinson's (2001) paper discusses using Hard OR in soft interventions. The purpose of the paper as described by the author is to demonstrate that DESM can be used to support soft OR interventions. The article presents a case study that describes the use of DESM to aid the improvement of a user support helpline service at Warwick Business School. The methodology steps were examined in detail and the most striking difference to most traditional DESM uses is that the model was used as a focus for debate, a means for learning about the problem situation and for reaching an agreement to act. The reason for this was because of the lack of accurate data making it impossible to validate the model and being confident that it was an accurate representation of reality. The article also compares the steps and outcomes with system dynamics and SSM. The article also demonstrates the power of the simulation methodology and the DESM technique as it concludes that a lack of accurate data does not need to be a hindrance to DESM.

One of the few articles that attempts to link SSM and DESM is that Lehaney and Hlupic (1995) that review the use of DE simulation for resource planning in the health sector. The paper provides case examples of simulation and the modelling problems are explored. The paper examines the successes and failures of simulation modelling and the use of SSM is suggested as an approach for improving the process and project or research outcomes. The authors explain that the "*messy nature of problem situations within the NHS makes SSM a very suitable way in which to tackle the development of these problem situations into logical models*" (p.384).

Another article about combining SSM with DESM is again from the same first author Lehaney and Paul (1996) that examines the use of SSM in the development of a Simulation of Out-patient services at Watford General Hospital. The paper is concerned with the hypothesis that simulation can be developed using SSM and that the acceptability of the final model may be increased through the participative nature of SSM. In this case, the aim was to see if SSM could be used in the model building process even though simulation had been selected as the tool of analysis. The SSM approach was to develop primary task root definitions. The framework was developed for the care of the elderly clinic (an outpatient clinic) because "the attributes of the patients necessitate the use of a number of supportive activities: X-Ray, Blood Test, ECG, Weighing." Although this article can be compared to the project in this thesis there is one major difference is that the framework is created for one service unlike the framework for the IC system that incorporates several services. One of the main conclusions was that by applying CATWOE to the system experienced by patients reveals that there is no system owner and hence no monitoring or control of that system. The use of this multimethodology allows the modelling of the actual patient experience and the participation of the staff in the modelling process. This participation paves the way for acceptance of the conceptual model and gives rise to the final simulation being credible.

Lehaney et al. (1999) also describe an intervention that utilised simulation within a soft systems framework and they call it soft-simulation. The project was for an outpatient dermatology clinic and the analysts also used primary task root definitions. The article also includes a lengthy discussion on critiques, challenges and responses to issues about SSM or DESM or their combination. One of these challenges is:

Challenge 10: "A framework which attempts to encompass simulation and SSM suffers from paradigm incommensurability, and this is insurmountable."

Response 10: "Within this case work, meetings involved discussion of both hard and soft issues and were successful in generating agreement for actions, which in turn proved useful in shaping operational policies. If simulation and SSM are viewed as completely different approaches, they might be incommensurable. However, our view is that they are both useful in facilitating debate and decisions, and are therefore both useful in similar areas, with each strengthening the other. The intervention system proposed is issue based (soft?), and does not match any functional or organisational boundaries of the hospital. However, in the early stages, it is likely to result in primary task models of the systems being studied (hard?). The approach advocated helps develop confidence through the use of primary task analysis and the hard results may arise from them. Without such results it is unlikely that participants will be interested in anything further. With such results clients may be 'led in' to the issue based analysis and more likely to consider it credible. Therefore it may be argued that there is a smooth transition across paradigms, or that, in this case, the notion of different paradigms is inappropriate." (Lehaney, 1999, p.889)

Many authors that advocate the use of multimethodogies have understood the conflict between real life complexity and the need to be able to implement the appropriate methodologies in order to satisfy the research or projects needs. Many OR academics and practitioners are guided in their choice of OR methods and techniques by their knowledge and experience or even lack of it. The combination of Hard and Soft OR methods are such that one must have a variety of talents: e.g. communication skills for SSM and imagination for DESM. In addition, one would need to have a great deal of knowledge and experience in both areas, which very few possess or have been given the opportunity to develop. One may consider this as one of the reasons that such few articles are available with a multimethodology of SSM and DESM.

2.5 Literature Review Conclusion

I have scanned the literature relating to the research in this thesis to see what research has already been carried out and the following must be kept in mind:

1. The Department of Health want to evaluate IC
2. The operational function of an IC system has not been evaluated
3. The need to have a whole system approach to Health and Social care problems.
4. Simulation Modelling is suitable to examining health care problems.
5. Real patient data can enhance a simulation model. Patient data should be collected through a standardised assessment tool.
6. SSM has been used to structure problems.
7. SSM and DESM have seldom been used together and never in the context of IC.
8. SSM and Simulation Modelling are well suited to each other, especially in health care.

3 The methodology for this research

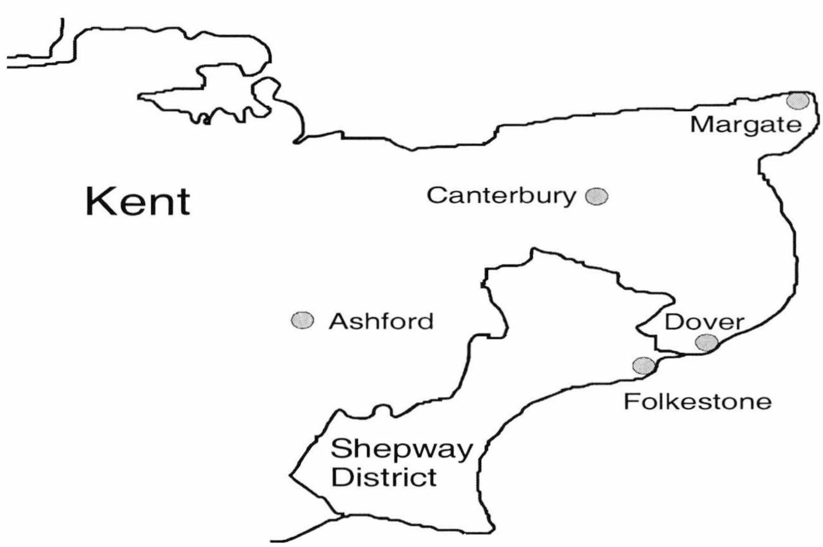
3.1 The action research project

The Shepway locality is a discrete area with a discrete population that generally use a discrete set of IC services (see Figure 3.1). The IC system chosen as the testing ground is in Shepway District in East Kent. The system encompasses rehabilitation wards in acute and non-acute hospitals, as well as intermediate care services. The starting point was to find out about the area and its population as well as all health and social care services relevant to older people in Shepway along with the resources currently available to each.

3.1.1 Shepway – information

Shepway District, whose principal town is Folkestone, covers an area of 90,000 acres. At the time of project implementation, demographic data from the 1991 census were available. A population of 93,500 was recorded, with this figure forecast to increase to 106,300 by 2011. At the time, approximately 20,000 people aged 65 years or over were living in Shepway, with 61% of these being female. Aside from Folkestone, this population is divided between the smaller towns of Hythe, Dymchurch and New Romney, and numerous villages within the mainly rural areas of Romney Marsh and the North Downs.

Figure 3.1 Shepway District, East Kent



The scope of the evaluation included the services, which are considered part of the Intermediate Care function as they provide rehabilitation and convalescence for older people resident in Shepway. These services are:

- The three "hard core" intermediate care services in Shepway. CART, Day Hospital and Recuperative Care.

- The rehabilitation wards at Royal Victoria Hospital. These are the Edinburgh (General rehabilitation) ward, The Fitton ward (Orthopaedics) and the Richard Stevens (Stroke) ward.

- Two Elderly rehabilitation wards at Buckland Hospital in Dover that mostly take non-Shepway admissions although they do have number of patients that live in and around the Shepway border. These are Montgomery ward and Ramsay ward.

- Two older people's rehabilitation wards at William Harvey Acute Hospital in Ashford that take Shepway admissions. These wards are Bethersden ward and Brook ward.

Ranges of services in Shepway that are not included are the voluntary services that also provide post-acute support for these patients and long term institutional care. Older people in Shepway may also receive post-acute physiotherapy from the community health centre based in Folkestone. A wide variety of voluntary agencies also exist to provide additional care and support. These include: the Red Cross; St. John Ambulance; Age Concern; the Stroke Association; Crossroads; DIAL; and Home from Hospital. Also at the time of project implementation Shepway had seventeen nursing and forty-nine residential care homes. The decision to exclude them from the evaluation rests on the difficult balance between accuracy and practicality. Also, the law of diminishing returns applies to the inclusion of ever smaller and more subtle influences on patient care. When considering that a persons social support network – family, friends etc, as well as their financial, social and cultural background can have some affect on care planning, it is clear that the line has to be drawn somewhere. As it stands, the evaluation incorporates all significant elements of the Intermediate Care system.

Shepway District in East Kent, UK was chosen as the discrete area upon which to test the multi-methodology. Shepway was chosen for the following reasons:

Its links with the authorities that commissioned and funded the ICON project. This work as mentioned in the introduction is allied to the ICON Project, which has been commissioned by the Elderly Strategic Services Planning Group and the Joint Planning Board for Care of the Elderly.

Its inclusion of three "hard core" intermediate care services: (1) a Community Assessment and Rehabilitation Team (CART); (2) an Elderly Care Day Hospital; and (3) a Recuperative Care Centre (described in Appendix A).

Its proximity to the University of Kent and the research team.

3.1.2 Who was involved?

The projects collaborators included managers from following health and social services:

1. East Kent NHS Hospitals Trust
2. Shepway Social Services
3. Shepway Community Assessment and Rehabilitation Team (CART)
4. Shepway Elderly Care Day Hospital (Folkestone)
5. Lawrence House Recuperative Care Centre (Folkestone)
6. Shepway Healthcare Research Co-ordinator

As the ICON project developed, the steering group was expanded to encompass ward managers from the Royal Victoria, Buckland and William Harvey hospitals, district nursing managers, and Managers from Social Services Older People's Intake and Long-term teams.

In the course of the project I interviewed at least twenty individuals on at least one occasion that either worked with or for the various services. I was also involved in at least seven group meetings with a mixture of IC managers, employees and system owners. The project involved as many people e.g. IC employees, managers etc as possible that had a range of roles e.g. collecting data or for interviews. For each service

I interviewed the manager and one or two employees of different profession e.g. a nurse and a rehabilitation worker. The people interviewed were made to feel that their opinions were of equal worth and they were not judged. The aim of the project was to create an atmosphere of openness and cooperation and I encouraged participation. Therefore, at the start of each interview I explained what sort of information I needed and why I needed it in a language that was not academic or intimidating or filled with jargon that they would not understand. This formed part of the communication philosophy. The other part of the communication philosophy in this project was about listening attentively to all those interviewed and accepting their view of the operational function and encourage them to provide their opinion in terms of improvements. The communication philosophy was also about making them feel comfortable which meant that I did not use a Dictaphone because there is a prevalence of a "blame" culture in health and social care and I soon understood that if I wanted them to open up to me I would have to listen and take a few notes. This approach encouraged participation and cooperation.

Mahachek (1992) suggests that a consultant (medical) led approach reduces the fear of an outsider and this project was led by a Geriatrician, which probably did help as he made an effort to attend many of the group meetings with IC employees that occurred throughout the project.

3.2 Multimethodology

3.2.1 What methods are included in the multimethodology and why?

The first phase of the multimethodology involves Soft Systems Methodology (SSM) and the second phase involves Discrete Event Simulation Modelling (DESM). The purpose of using SSM is to understand the system to capture its essence and determine what the operational function of IC could be. DESM main aim was to answer questions about the resources and capacity.

3.2.1.1 Why Soft Systems Methodology?

Soft Systems Methodology is considered appropriate in this project for three reasons. The first reason was that we needed to understand the operational function of IC and SSM is suitable in enabling a better understanding. The second reason was that no one in the system had a total understanding of what the IC function should incorporate or what the system could incorporate or even an understanding of the services. This meant that it was a puzzle of various interpretations of how the system should work or could work and this information was held in the minds of various health and social care professionals that were involved with IC either directly or indirectly. SSM is good staring point to structuring this information collection process. The third reason was that this evaluation was of genuine concern to them and they seemed committed to take action based on its findings and the SSM cycle involves taking action based on its findings.

3.2.1.2 Why Discrete-event simulation modelling?

Simulation, according to Lowery (1998), is an extremely useful tool for modelling healthcare systems because of their characteristics of uncertainty and complexity. Uncertainty is a major characteristic of illness and hence makes simulation attractive for modelling healthcare systems. In addition simulation enables the modelling of complex systems with lots of interacting parts.

Another reason for advocating the use of simulation to health care services is that waiting times for treatment are too complex to be analysed theoretically. By modelling Health and Social care services using DESM one can also understand and evaluate their function, assess their current efficiency (bottlenecks, throughput times, number of patients etc), examine resource use, assess patient eligibility to IC services and ask 'what if' questions (Pidd, 1996). Service organisation and delivery are being scrutinised in order to: improve effectiveness and efficiency in terms of resource utilisation, to reduce patient waiting times and identify 'bottlenecks' in the system.

Other advantages include the ability to use simulation models as tools for communication of issues or problems that are easier to explain in a dynamic and graphical manner. Increasingly health care workers have to prove information and knowledge about problems as part of a drive for Evidence Based Management.

However, there are some potential pitfalls of using discrete event simulation modelling. Lagergren (1998) reports some of the disadvantages of modelling that can be applied to simulation modelling. One of the more obvious disadvantages is that the model reflects the modeller's view of reality, which may be biased. However, this disadvantage is not applicable because of SSM, which takes into account various views of realities. Simulation modelling is also considered to be time and cost consuming especially when there is a large data collection involved.

Lagergren (1998) presents an advantage of using simulation modelling which is a disadvantage in our case because of the action research approach. The advantage is that one can model and examine various changes on health system without interfering in the daily routine but because we made them collect data for a period of time we did interfere with their daily routine.

3.2.2 Reflections from choice of multimethodology?

The article by Mingers (2000) expresses a view that there are two principal arguments for using multimethods. Mingers's (2000) first argument states that '*all real-world problems no matter how technical and well-defined they appear they exist within complex organisational context that has both social and personal dimensions. Therefore combining methods to deal with all these characteristics should be more effective'*. The second argument is that '*a typical ORMS intervention passes through several stages, from an initial exploration and appreciation of the situation, through analysis and assessment, to implementation and action. Individual methods and techniques have their strengths and weaknesses with regard to these various stages*." (Mingers, 2000, p.679)

The reasons that this multimethodology was chosen are:

a. These methods were considered suitable for the requirements problem situation.

b. SSM is suitable for problem structuring and DESM is good with complexity and uncertainty.

c. The combination of SSM & DESM has proven successful in other areas (see section 2.4.18).

The best description of the suitability of SSM and DESM is found in an article mentioned earlier by Mingers (2000) and an application by Lehaney and Paul (1996). The article by Mingers lists a generic set of four activities associated with research and intervention. The first activity is *Appreciating the problem situation as experienced by the agents involved and expressed by the actors in the situation.* The second activity is *Analysing the underlying structure/constraints generating the situation as experienced.* The third activity is about *Assessing the ways in which the situation could be other than it is; of the extent to which the constraints could be altered and desirable changes brought about. The fourth activity is Acting to implement and bring about the changes.* (Mingers, 2000, p.682) Mingers (2000) says that there are many methods and techniques available for an analysis of the general process of research and intervention that do not all perform equally well at all these activities. In fact, some activities are best suited to certain methods and techniques. He goes on to provide the following examples: "*Collecting data, administering questionnaires and surveys, developing rich pictures and cognitive maps, and employing the twelve critical systems heuristics questions all contribute to finding out about the different aspects of a particular situation. Whereas building simulation or mathematical models, constructing root definitions and conceptual models, using role-playing and gaming, or undertaking participant observation helps to understand why the situation is as it is, and to evaluate other possibilities*". (Mingers, 2000, p.683)

3.2.3 The Philosophical differences between SSM and DESM

Having discussed the desire for this multimethodology it is also important to explore its feasibility. One of the concerns at the start of this project was how to apply this multimethodology. For example, would I combine, or link, these methods or would they be used as mutually exclusive? The main concern is because they belong to different paradigms; SSM is from the soft paradigm and the DESM from the hard paradigm. Mingers (2003) distinguishes between paradigms using three philosophical principles.

The first principle is ontology, which is about "*the types of entities that are assumed to exist and the nature of that existence*". The second principle is epistemology that is "*the possibilities of, and limitations on, our knowledge of the world*". Mason (1996) defines epistemology as the "*theory of knowledge and should therefore concern the principles and rules by which you should decide whether and how social phenomena can be known and how knowledge can be demonstrated*". The third principle is about praxiology which is "*how we should act in an informed and reflective manner*".

DESM traditionally requires a positivist attitude and approach and examines the current physical structures and processes and SSM takes into account various perceptions of the world and can move outside the current structures. Soft operational research requires a different way of thinking about a system to hard operational research. Checkland (1999), the father of SSM, explains the term system and then goes on to talk about the difference of Hard and Soft systems thinking with the following words:

"System is simply used to label something that can exist in the world outside ourselves. The taken as given assumption is that the world can be taken to be a set of interacting systems, some of which do not work very well and can be engineered to work better. In the thinking embodied in SSM the taken as given assumptions are quite different. The world is taken to be very complex, problematical, mysterious. However, our coping with it, the process of inquiry into it, it is assumed can be organised as a learning system. Thus the word 'system', is no longer applied to the world, it is instead applied to the process of our dealing with the world. It is this shift of systemicity (or systemness) from the world to the process of inquiry into the world which is the crucial intellectual distinction between the two fundamental forms of systems thinking 'hard' and 'soft'...In the literature it is often stated that 'hard' systems thinking is more appropriate in well defined technical problems and that soft systems thinking is more appropriate in fuzzy ill-defined situations involving human beings and cultural considerations. This is not untrue, but it does not define the difference between 'hard' and 'soft' thinking" (Checkland, 1999, p.A10).

This creates questions about the using the method in this instance and also about the possibility of combining them. These questions include: Can SSM and DESM be combined for the purpose of a single intervention? Or is it a case of using the SSM to investigate the project and gain understanding and apply DESM independently of SSM to answer other questions? Or Perhaps SSM needs to be applied initially to get information to include in the simulation model by linking the paradigms? Can these methods that have evolved from completely different paradigms be dependent on each other to satisfy the project?

Mingers and Brocklesby (1997) discuss three different levels of problems arising from the use of mutlimethodologies:

The first one problem is philosophical and it arises when there is paradigm incommensurability, which means that the paradigms are mutually exclusive. This is because the paradigms "*differ in terms of the fundamental assumptions that they bring to organisational enquiry*" (Mingers and Brocklesby, 1997, p.496). Mingers and Brocklesby (1997) report that the theory suggests that the agent(s) must choose the rules of practice within an organisational enquiry and that "*they must commit themselves to a single paradigm, although sequential movement over time from one paradigm to another is permissible*" (Mingers and Brocklesby, 1997, p.496). The project must determine the extent to which these two paradigms, hard and soft, are mutually exclusive and whether the theory is correct.

The second problem is cultural and involves the extent to which organisational and academic cultures militate against multi-paradigm work. Mingers and Brocklesby (1997) explain that this is a potential problem because the agent's culture such as his or her values, beliefs and basic assumptions about the world might stand in the way of moving from one paradigm to another. Mingers and Brocklesby (1997) also provide an example that fits with my research:

"*Take for example, the case of someone wishing to move from hard to soft systems. A key operational premise of hard systems is that it is geared towards designing new (ontologically) "real" systems, or in making existing systems work "better". Success in this task domain is contingent upon the agent processing high levels of technical expertise, which he or she must apply according to prevailing standards of rigour. Soft systems embody markedly different operational premises. The stock-in-trade of soft systems is the construction of notional – not ontological real – system and technical rigour is secondary to relevance. The primary goal of agents working within this* *paradigm is to "connect" with people – to facilitate intersubjective understanding –and to help them reach accommodation and a commitment to action.*"

(Mingers and Brocklesby, 1997) (p.498)

The above example prompts questions about whether I could move between paradigms because of my hard OR degree. The assumption is that it would be very difficult especially for me to move between paradigms because of my previous hard OR mindset due to my experience e.g. final year project. The questions that arose are: How difficult is it to move between the soft and hard paradigms if your background is Hard OR? If it is possible then what are the difficulties? Are there any lessons learnt about moving from one paradigm to the other?

The third problem is cognitive feasibility and involves the problems of an individual agent moving easily from one paradigm to another because of the personality type. Mingers and Brocklesby (1997) elaborate by explaining, "*There is prima facia evidence that there is correspondence between certain "personality types" and the sort of work that characterizes some of the key management science paradigms*" (Mingers and Brocklesby, 1997, p499). He illustrates this point by describing two personality types. The first personality described is the analytical scientist personality type, who prefers quantitative, aggregate data and has distaste towards qualitative data because he or she values precision accuracy and reliability. The second personality is described as the "particular humanist" and prefers to conduct research via personal involvement with other humans and prefers qualitative data. Furthermore he or she is consultative and zealously promote consensus and acceptance. Mingers and Brocklesby (1997) suspect that most management scientists overlap the various categories but there will be some that will fit into one category more than the other and he writes that "*for such people it may be surmised that they will experience some difficulties in moving from one paradigm to another, and/or experience a certain internal tension or discomfort if they are compelled to work in a paradigm that calls for actions and behaviours that do not "fit" their cognitive processing preferences"*. (Mingers and Brocklesby , 1997, p.499)

This potential problem creates questions about my cognition (mindset and personality) as the agent for the intervention. I have successfully completed a hard OR project so does that mean that I am an analytical scientist type and therefore my personality type interferes with my ability to use SSM or is it possible that I am a particular humanist that has learnt to successfully apply hard OR but would be better at soft OR? Would the answer to this question be the level of discomfort that I would feel whilst undertaking one of the two methods? Then again hard OR consultants must have both personality types in order for them to be precise yet also manage the client and promote acceptance of the results. These issues are considered in the final chapter (Chapter 7).

3.2.4 How are SSM and DESM linked in this intervention?

In this thesis, I have described the desire for SSM and simulation and I described my initial thoughts as to which part of the problem each method would tackle. I have not described though how these methods would be linked and the reasoning behind it, which will be described in this section.

At the start of the research, I had to make some initial assumptions because of the lack of clarity in terms of the problem and actual IC system of investigation. The starting point was to explore further the right-hand side of the nonmathematical formula: "Evaluation of the function of the IC system" and the "Evaluation of function of individual IC services" (nonmathematical formula section 1.2.5).

Firstly, I started exploring the function of the IC system. Based on the definitions and the existing literature at the time I thought that there would be a decision-making mechanism in the system about which service a patient enters and it would be purposeful and hopefully logical. I also thought that there would be a number of managerial activities to manage, coordinate and improve the systems operations. Otherwise, the only link between the services would be the target population of older people. These activities could be considered as the primary tasks of the IC function. (Primary tasks are explained in the SSM section 3.3)

Therefore, the function of IC system (from the nonmathematical formula (1) p.33) would be equal to evaluation of the decision making mechanism and evaluation of primary care tasks of system.

Therefore, we have a new nonmathematical formula:

Evaluation of function of IC system = Evaluation of decision-making mechanism + Evaluation of Primary Care tasks of System (2)

This evaluation of the decision-making mechanism would be through simulation modelling and the evaluation of the primary care tasks of the system would be done with SSM. I decided that I would start by obtaining the primary tasks. There was no documentation for the actual system to assist in this process so I spoke/interviewed a selection of IC employees and owners to find out about their IC function and system and services. The aim was to eventually get consensus about what to include in the primary tasks of the system. If primary tasks were missing from the real system then action should be taken by the system owners to put these tasks in place. The process of understanding would also assist me to form my conceptual models for the simulation. Therefore, I was using a soft approach in order to satisfy the needs for my hard paradigm method. This would enable me to build a model of the services to assess the resources and a model of the system that would examine the decision making process and the system resources.

When the SSM phase began and I spoke to various IC employees and owners I discovered that there was no formal decision making mechanism in place for patients to be sent to the most appropriate service and what was going on could not be described as purposeful and was certainly not logical. This would make it impossible to create a conceptual model for the system simulation model. I therefore moved into the soft OR paradigm and decided that I would build a simulation model for the "whole system" that was not depicting the actual situation but the most agreeable conceptual view of the decision making process. This meant that I was going to apply a hard OR method with different paradigm assumptions. This new decision making mechanism would be desirable and culturally feasible and it would be evaluated in a virtual environment.

The second part of the exploration was about the function of individual IC services. The individual services would be examined with a hard paradigm using DESM and the conceptual model could depict the actual situation. Of course there was a general agreement that each service was doing what it was suppose to so.

Therefore, the methods were used through a mixture of the soft and hard paradigms.

3.3 Soft Systems Methodology

The aim of this section on Soft Systems Methodology is to describe the elements of Soft System Methodology that are used in this research.

3.3.1 What can SSM do for this problematic situation?

Checkland (1999) provides "4 key thoughts" about SSM which are used to explain how I will use the method to help me tackle the problem.

The first key thought is that SSM is helpful in grasping "*purposeful and meaningful action*". Checkland (1999) elaborated on this issue by writing that "*people attempting to take purposeful action meaningful to them leading to the idea of modelling purposeful "human activity systems" as sets of linked activities which together could exhibit the emergent property of purposefulness*" (p.A7). This is very important as it provides the basis of using SSM, which is to capture the essence and fundamental phenomena of a system.

His second key thought is that SSM is helpful "to select an appropriate world view" and his third key thought is that SSM can be formed as an organised learning system. The inquiring /learning cycle of SSM can be as follows:

> Real world: the starting point is understanding that the real world is formed by complexity of relationships.
>
> The Relationships are explored via models of purposeful activity based on explicit world-views.
>
> The Inquiry is structured by questioning perceived situation using the models as a source of questions.
>
> 'Action to improve' is based on finding accommodations (versions of the

situation which conflicting interests can live with).

The Inquiry in principle never-ending; best conducted with wide range of interested parties; give the process away to people in the situation;

The learning cycle steps are intended to guide action but do not guarantee success. Both Checkland (1990) and Pidd (1996) write about issues that must be taken into account when using the learning cycle for SSM. The first is that the modeller should think of it as a cyclic approach as real life usually involves backtracking and iterating around the loop. The second issue is that in principle at least the modeller can start at any of the points in the cycle, which ties in with the first issue. Another issue is that the modeller using SSM must think in two different ways, one in terms of the "real world" and another in terms of systems thinking. In terms of the real world, the modeller must investigate it by working with at least some of the people in the system, hoping to be of use to them and hoping to understand how they interpret the world. In terms of systems thinking the modeller must withdraw from the real world and use system concepts to try and understand what is happening in the real world. This means that the modeller will think of the system in a different way to those who are part of the system itself.

In this research, I was able to talk to people in the system, hear their opinions, and understand their problems, thoughts and concerns about the future. I was able to visit them in their environment and get a "feel" of what it is like to be part of that system. On many occasions, I was able to observe the culture, the politics and the disagreements amongst members of the system. The SSM process helped me put together a plethora of information into a puzzle that provided a clear picture of what the operational function of IC involved.

This in fact is one of the reasons for selecting SSM as it provided a structured process for inquiry. This learning cycle is also the basis of the "Four Main Activities Model", which is the version used in the SSM Analysis (see section 3.3.9).

The fourth key thought is that SSM models of purposeful activity can provide an entry to work on information systems. This is not in itself important to this research but it does mean that Checkland (1999) considered this method as suitable for combining with other methods. This fourth key thought confirms SSM's nature of being a suitable first step to a project.

3.3.2 Description of the SSM methodology

Checkland (Checkland, 1993, 1998) uses a figure to illustrate the learning cycle steps involved in a diagrammatic form. The use of diagrams, otherwise known as purposeful activity models, is central to this methodology as it is about lessening the communication issues involved in the process of obtaining a viewpoint or understanding of the operation of a system. He regards the purposeful activity models used in SSM as "devices - intellectual devices – whose role is to help structure an exploration of the problem situation being addressed". Checkland's (1999) own words are best used to explain their purpose:

"*They do not purport to be representations of anything in the real situation. They are accounts of concepts of pure purposeful activity, based on declared world-views, which can be used to stimulate cogent questions in debate about the real situation and the desirable changes to it. They are thus not models of...anything; they are models relevant to debate about the situation perceived as problematical. They are simply devices to stimulate, feed and structure that debate.*"

(Checkland, 1999, p.A21)

In 1990 Checkland improved upon this model of enquiry by refining it and adding a few steps to it. The literature describing the 1990 model is heavily dependent on understanding the 1981 model and therefore I will initially describe the older version and then the new version, although the more comprehensive new version has been adopted for this research. Each of the 1981 SSM stages will be examined in the following sections as they formed the basis of the exploration.

3.3.3 The problem situation unstructured expressed

A problematic situation that is thought of as "fuzzy" by the problem solver (system analyst) because of conflicting or varied views is an indication of an unstructured problem situation. Checkland (1993) defines an unstructured problem as "a feeling of unease but which cannot be explicitly stated without this appearing to oversimplify the situation" (p154). The problem is that the situation has not been expressed and therefore there is not enough understanding to warrant a set of objectives. Checkland (1993) also explains that traditionally in order to express the problem situation a sequence of events must take place; recognition of the problem, definition of the problem, action to solve the problem, problem solved. Although a problem can be recognised, it is not always easy to define it due to the subjective influences that will emerge from the people within the system. In these "fuzzy" situations, it may not be possible to fully define and solve a problem but instead to alleviate the condition.

3.3.4 Root definitions of Relevant Systems

The essence of the model is captured through a set of root definitions. A Root Definition according to Checkland (1990) is a verbal account that has at least six components, which are summarised in the mnemonic CATWOE. CATWOE is created from the initial letters of the following six words: Customer – this is the direct recipient of what the system does. The recipient can be a person or several people or groups etc. Actor – this is a person(s) that carries out the system's activities. Transformation process – this is the process that something is converted to output and then passed on to the customers. The process is an activity and its description therefore requires the use of verbs. Weltanschauung – this is the outlook or worldview of the root definition. Ownership – this is the individual or group with the system's responsibility. Environmental Constraints – these are the constraints that the system operates under.

Traditionally SSM is used to obtain a variety of relevant systems (problem areas or areas of interest) to be examined through root definitions and conceptual models. For this research only one relevant system is considered and the aim is to formulate Primary task definitions of it. This approach has been taken by other SSM practitioners and more importantly Lehaney (1995, 1996) used primary task root definitions when linking SSM with DESM. The next step is to build a model of it and then compare it to the real world.

3.3.5 The SSM conceptual model or purposeful activity model

Checkland (1993, 1999) initially refers to the purposeful activity models as conceptual models. The change in name is part of Checklands (1999) thirty-year retrospective on SSM. Purposeful activity models are part of the process of describing a system. Checkland (1993) suggests that there are two possible approaches to describing a system: the first is to describe elements that comprise it, their current condition, their relationship with external elements, which affect the system and the condition of those external elements. The second approach is about thinking of a system as an entity that transforms inputs in order to produce some outputs. The second approach is the one chosen to describe the system in this research. In his thirty-year retrospective (Checkland, 1999), he advises that one should not think only in terms of models, which map existing structures, as this will encourage a new way of thinking.

In order to build a conceptual model it is usual for the modeller to write down verbs covering the activities in the system. Conceptual models are intended as minimal descriptions of the subsystems or components that would be necessary in any embodiment of the root definition (Checkland, 1990, Pidd, 1996). Conceptual model in terms of SSM, is a diagrammatic representation of the interconnections of the activities that must be present for the root definition to make sense. The purpose of a developing the conceptual models is to ensure that the system as defined through people's perceptions is captured in terms that fit the notion of open system (Pidd, 1996).

3.3.6 The process of comparison

An important element of SSM is the process of comparison between the real-world situation and that indicated by the conceptual model in order to generate new interpretation relevant to improving the situation. Checkland (1993) suggests fours ways of doing this:

The first method is *using the conceptual model to support ordered questioning*. The conceptual model is used as a source for a set of questions, which can be asked of people involved in the actual situation. Checkland believes that with this method only the analyst need be aware of the conceptual model. Basically, he or she should keep the conceptual model "under wraps" and should use it to open up debate about change, to get people to think whether it is needed and if so, in what form. This method had a major advantage as it allows the analyst to work with the people in developing possible changes and it avoids the accusation that: *he or she doesn't really know what goes on here*. This method is very helpful in developing a good relationship between the analyst and the interviewee.

The second method is about *walking through the conceptual model with sequences of events that have actually occurred in the past.* This method is about investigating the effect that the system of the conceptual model would have if it had existed at some point in the past and how would it compare with what actually happened in practise. There are certain issues/disadvantages associated with this method and the first is that people's memory of the past is not always accurate and can be selective. Secondly, some of the people interviewed may have been involved in the sequence of events and may feel threatened.

The third method is about conducting a general discussion about the high level features of the conceptual model vis-à-vis its comparison with the present situation. This requires the analyst to spend time with the major actors/system stakeholders explaining the model to them and discussing with them the differences and similarities. This method is different to the first method, as the actors are being made aware of the conceptual model.

The fourth method is about *examining model overlays,* which requires the existence of a previous model. In this method, an attempt is made to compare the detail of the conceptual model with the detail of the current model. It may be the case that for better results the conceptual model should be built without seeing the current model.

The approach chosen in this research is a mixture of the first and third method. The second and the fourth method were not especially useful. It is important to point out that several IC employees were asked about the conceptual model. This is because none of the IC employees knew enough about the whole system and its services to be able to provide all of the answers. Therefore, everyone in the system contributed to the understanding. In addition, the available literature was not comprehensive enough to obtain a complete picture of an IC system (see IC Literature Review in Chapter 3). In terms of the first method, all of the IC service managers in this IC system were asked questions about their IC system without a conceptual model being present. This was especially useful as it made the employees feel that their opinion of "how things work there" was important to my research. In terms of the third method I was able to arrange to spend time with some of the senior IC system managers. The process involved examining the high level features of the conceptual model of operational function of IC which they knew about. The outcomes of this process of comparison are described in Chapter 4.

3.3.7 Implementing Feasible, desirable changes

Implementing feasible and desirable changes relates to stages 6 & 7 in the seven-stage SSM model. Implementing feasible and desirable changes is a result of the process of comparison. The changes can take three forms: changes in structure, changes in procedure and changes in 'attitudes'. Checkland (1993) defines the first two changes with the following:

"Structural changes may be to organisational groupings, reporting structures, or structures of functional responsibility. Procedural changes are changes to the dynamic elements: the processes of reporting and informing, verbally or on paper, all the activities which go on within the relatively static structures. Changes of both of these kinds are easy to specify and relatively easy to implement, at least by those having authority and influence."

(Checkland, 1993, p.180)

Checkland (1993) defines changes in attitudes as the "intangible characteristics which reside in the individual and collective consciousness of human beings in groups" (p.180). Changes in attitudes are not as easy to implement as the other two forms of changes because of the complexities that characterise attitudes. For example, the term attitude includes changes in influence, expectations, roles and behaviours.

The purpose of stage 6 is to look at the comparison between the conceptual model (purposeful activity model) and the current state of the system and generate a debate with those interested in the problem (usually owners and actors) about the three types of changes. This debate about the comparison between the real world and the systems world is in chapter four (see section 4.3-4.4).

3.3.8 The Multidimensional SSM

Criticisms of the first SSM representation of 1981 led to a second representation shown in Figure 3.2, which was before the 1990 four main activities model (Checkland, 1999). This representation of SSM illustrates that the approach must be multi-dimensional throughout its application. The three dimensions are the Political System Analysis, the Social System Analysis and the Role Analysis and are otherwise called Analyses One Two and Three. Checkland suggests that the three linked analyses should run in parallel as shown in Figure 3.2. The three analyses are primarily concerned with taking into account all the possible linkages between the real world and the world of systems thinking. Although Multidimensional analyses have not been adopted formally the three dimensions are considered with respect to the relevant system. Each of the dimensions is briefly introduced:

The analysis of the Roles people are playing or might be expected to play. This is an attempt to think about intervention in which the analyst and others will engage in the future. By getting to know the people involved in the actual system I was able to understand what action they were prepared to get involved or what action they would be allowed to get involved in.

The analysis of the Social System in terms of the roles, norms and values that are evident. Roles are taken to be the social positions people occupy, which might indicate an institutional position (e.g. patient) or behaviour (e.g. stroke patient). Norms are the expected or normal behaviour, in this context to be admitted to a rehabilitation hospital. Values are the local standards used to judge people's norms. In this context, a value of the norm might be to admit the patient to the stroke unit of the rehabilitation hospital. The idea of this analysis is that the analyst should try to understand how people play out their roles. Because there are many roles norms and values and they all influence the IC system, it is important to understand as many as possible. In fact, this analysis has been beneficial for the simulation modelling phase, for example one could think about the roles as types of entities for a simulation model.

The analysis of the Political System is an attempt to understand the power-weight of the different people in the system and how different interests could be accommodated. This is an explicit recognition that power play is occurs in organisations and must be accounted for. This type of analysis needs to be undertaken discreetly as it is not realistic to ask people directly about their powers.

In terms of the research, this analysis was not done consciously but instead the process was internalised and a product of observation and communication with IC employees. This stage was about making sure that there was enough understanding to create a conceptual model of the operational activities, taking place in the IC system that is acceptable amongst the diverse group of employees and endorsed by the system owners.

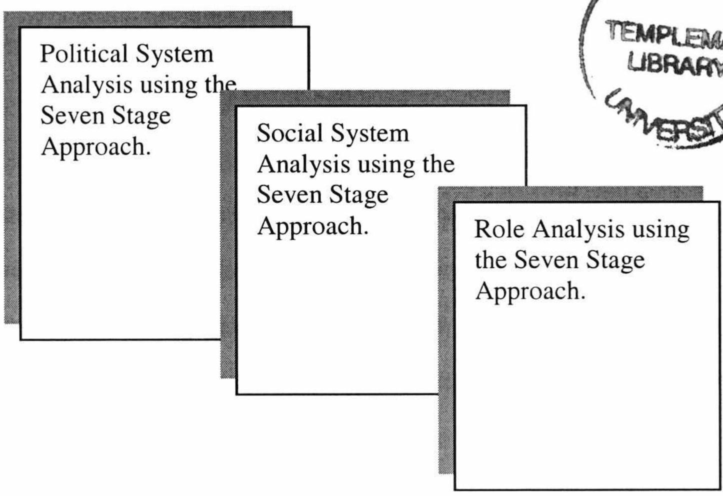


Figure 3.2 SSM – The Three Dimensional Analysis.

3.3.9 Four main Activities model

In 1990 Checkland, improved upon the 1981 seven stages model and produced the Four main activities model (Checkland, 1999). The use of the newer SSM version is dependent on the understanding of the older one and in fact, the main differences are the additions that have been made.

The new model has the following activities:

1. Finding out about a problem situation, including culturally/politically;
2. Formulate some relevant purposeful activity models;
3. Debating the situation, using the models, seeking from that debate both
   - Changes which could improve the situation and are regarded as both desirable and (culturally) feasible and
   - The accommodations between conflicting interests which will enable action-to-improve to be taken
4. Taking action in the situation to bring about improvement

Step one and three combine elements of the multidimensional analysis described earlier (see section 3.3.8). However, in step two, the aim is to get all the interviewees to think about the same relevant system (operational function of IC) and formulate a primary task root definition of it, build a model and then compare it with the real world.

3.3.10 The additions to the SSM framework

When selecting a system to model it is often found that there are several layers available and it is necessary to decide which layer will be used in the root definitions. An addition to the methodology is to cast root definitions in the form: do P by Q in order to contribute to achieving R. This answers the three questions: What to do (P)? How to do it (Q)? and Why do it (R)?. The PQR definition takes place before building the purposeful activity model (conceptual model) to ensure clarity of thought. This research has cast a root definition in this form to make sure that the main questions about the operational functions of IC are explored.

Additionally to the root definitions, we have the introduction of criteria to measure the system's performance. The system's performance can be described by exploring three issues: checking that the output is produced, checking that minimum resources are used to obtain it and checking at a higher level that this transformation is worth doing because it makes a contribution to some long term aim. Therefore the main criteria otherwise known as the 3Es are: the criteria for efficacy (E1), efficiency (E2) and effectiveness (E3). Another two optional criteria that can be also used are for ethicality, which is about asking, whether what is transformed is morally correct and for elegance. The criterion for elegance is whether the transformation is aesthetically pleasing. This research has mainly concentrated on the main criteria, which are described in chapter 4.

Another addition is a dual way of thinking about the SSM process. The first is prescriptive way of thinking and is referred to as Mode 1 and the second is internalised and is referred to as Mode 2. Checkland (1999) describes the reason for this distinction as an evolution. When SSM emerged it was methodology driven rather than problem driven but as its assumption, process became clearer and better understood the process became internalised. By internalising the SSM process it was easier to focus on the complexity of real life and subsequently focus on the problem. Checkland (1999) writes, "*the process of internalisation is a very real one for those for whom it is happening, but it is not an easy process to describe certainly not as a series of steps recognised at the time they occur for the steps are often not so recognised*"(p.A35). In terms of this research the process of internalisation is applicable mainly to the multidimensional analysis described earlier in this chapter.

The SSM phase of this research has the following aims:

1. To enable fast and complete understanding of IC.

2. To help define the operational function of IC.

3. To create a conceptual model of the operational activities that should take place in an IC system.

4. To examine if the appropriate operational activities are taking place in the chosen (Shepway) IC system.

5. To determine what action needs to be taken in order to evaluate the operational function of IC. Some action will be specific and will not need further exploration and other action will require further exploration i.e. through simulation modelling.

3.4 The methodology for the Simulation study

3.4.1 Introduction

The simulation steps involved in a standard simulation study can be identified as the following:

Express the real problem – this stage is about obtaining a clear definition of the problem at hand and the system that surrounds it. This stage is very important for the whole system simulation model as it is dependent on the findings from the SSM phase.

Extract a conceptual model of the situation – this is about capturing the essential elements of the system being modelled that have a relevance to the problem at hand. This stage is also about deciding what data or information is relevant and at hand or whether it needs to be collected.

Collect data and any other information that is required in order to satisfy the conceptual model's requirements.

Build Computer Model – this is about either building the model with a programming language or using an "*off the shelf*" simulation package.

Perform Validation & Verification – this stage is about whether the computer model is correct (no bugs etc) and whether the model does what the modeller intended it to do.

Perform Experimentation – This stage is about examining the outcome of various changes to the real system. This sort of analysis is also called "What if" as it involves looking at various scenarios usually to improve the current situation.

Some authors have a slightly different set and number of steps for a simulation study but essentially, there are few differences. This is the set of steps undertaken in this simulation study and the following sections explain in more details how each step has been approach in this research.

3.4.2 Express the problem situation

This stage can also be about formulating the problem and planning the study (Oakshot, 1997). The problem to be addressed and the purpose of the results and findings must be defined. Other things such as the boundaries of the system must also be defined. In this research, this step is mainly described in the SSM chapter, as it is a result of applying that methodology.

3.4.3 Extract the Conceptual model

In this research, this stage involved extracting several conceptual models. I found that in order to answer the questions four conceptual models were needed: three of the conceptual models were needed for the "hard core" (main) IC services (Recuperative care, CART and Day Hospital) and one conceptual model was needed for the IC system (whole system model). These conceptual models are described in chapter 5. The IC wards are examined in the whole system simulation model and are therefore part of that conceptual model. Each of the models is designed to answer different questions relating to the operational function of the IC system and services.

The method of extracting the conceptual models relating to the IC services was through interviews with each service manager and in most cases with a service employee. I was also able to observe a working day of the Day Hospital and Recuperative Care.

3.4.4 Collect Data

The majority of the data collected is stochastic and was collected mainly for the wider ICON project. The data requirements for the project are explained in more detail in chapter 5. The data collection of the ICON project spanned over a period of six months although collecting data concurrently was only for three months. The data collection options were discussed and agreed with the system owners, as they wanted to ensure minimum disruption to the staff and patients.

In many simulation models, the lack of data dictates the need to generate distributions that best fit the data requirements to be used to capture the essence of the system. Generating data is not uncommon in simulation studies and many of the simulation software provide a function to generate data with the most commonly used distributions. The lack of data in a simulation study can be attributed to many reasons e.g. the system does not exist (not in this case). In this situation, the main reasons for needing to generate distributions with the available data are gaps in the data collection. It will also ensure that the system is modelled capturing the essence of the system, which is that patients arrive randomly and stay for a random amount of time, and a model should depict this element of randomness. The third reason is because if you know the distribution you can change the parameters in the "What if" analysis.

The run time for the models is five months and the concurrent data collection was only three months and that meant that it was better to use probability distributions. The procedure to obtain a suitable probability distribution is described in the subsequent sections.

The majority of simulation studies require some form of data collection and analysis. In order to be able to build the computer models for this project it was necessary to obtain data and information about the Shepway IC system and its services. There are two basic types of data that need to be collected, the deterministic-type data and the data that is stochastic in nature (Oakshot, 1997). The first type is easier to collect as it mainly concerns elements of the system that can be counted such as beds in a ward or nurses etc. The second category of data is "any data which is known to vary in a random fashion" and are the inter-arrival days, the patient's length of stay and the patients clinical and social characteristics. The interarrival data in this project are the days between consecutive arrivals and the length of stay is the time (in days) between the patient's admission and discharge from each service. The patient's characteristics are formed by the items on their assessment form that are used to determine a score for the Services Entry Eligibility Criteria (see section 5.4.2).

The interarrival days and Length of Stay data were analysed and fitted to appropriate probability distributions using a software package called Stat::Fit (Geer Mountain Software Corporation, 2001). The approach for the patients characteristics was different as I decided to sample from the collected data, which is called sampling from observed data. This means that the simulation package obtains values from this distribution by sampling directly from it, e.g. data in an Excel file. This means that the simulation model only uses values that have been observed but the use of a theoretical distribution means that the simulation will use values that fall in the tails of the distribution (occur rarely). This project will mainly use theoretical distributions for the interarrival and length of stay but patients' characteristics are sampled from observed data. This is further explained in chapter 5.

3.4.4.1 The patient data collection tool

In the Literature Review of this thesis I described an article by Carpenter (1997) reporting on an international project, that has developed a standardised assessment tool for use in any hospital or long term care setting. The tool to collect the patient characteristics was a modified (shortened) version of the MDS by interRAI (www.interrai.org). The reason for choosing this assessment tool was mainly that it was a comprehensive and validated assessment tool.

3.4.4.2 Fitting the variables to Theoretical Distributions

The variables that required theoretical distributions were the interarrival days and the length of stay. The main requirements were that these distributions were whole positive numbers because the aim of the whole systems model is to examine gaps in the system and capacity and for this particular system it is not necessary to examine the system changes in hours, minutes or seconds. The utilisation of staff is not also not included in the whole system model. This meant that I was looking to fit the data to discrete distributions bounded by a minimum. A discrete distribution bounded by a minimum and extending indefinitely in the positive direction can be represented by a Geometric, Negative Binomial, or Poisson distribution (see Appendix C).

The approach to fitting the variables to theoretical distributions has been adopted from Law and Kelton (1991) who suggest that in order to carry out a simulation using random inputs such as interarrival times we have to specify their probability distributions. This process requires the use of statistical techniques such as Maximum Likelihood Estimation (MLE) and Chi-squared tests (see Appendix D), which assume that the observations are an independent (or random) sample from some underlying distribution. If the assumption of independence is not satisfied then these statistical techniques may not be valid but heuristic techniques such as histograms may still be used.

In order to be as thorough as possible I used Stat::Fit to determine the above techniques and the most appropriate theoretical distribution for the interarrivals and the Length of Stay for each service. The procedure undertaken for each service is described in Appendix E.

3.4.5 Build Computer Model

Cacciabue (1998), like many other simulation-modelling authors, explains the importance of using simple models to represent complex systems. Also the major goal of simulation is to reduce the complexity of the analytical model. Oakshot (1997), who also shares this belief, provides two main reasons to justify simple models. The *first reason* is that a complex model is more difficult to build and therefore will take longer to develop, with a greater chance of errors. The *second reason* is that a simple model may be adequate for the intended purpose and any further complication may make experiments on the model difficult. Modelling can be thought of as an iterative process where by the modeller starts with a simple model and increases the complexity according to the question that needs to be answered.

The simulation software used, simul8 (Simul8 Corporation, 1993-2001) that has a typical simulation structure (see Appendix F), requires that the model is built by drawing it on the screen. The simulation entities consist mainly of work centres (work facilities), storage bins (queues), resources (employees) and work items (product or clients). The workcenters and storage bins are joined up with routing arrows to describe the default route the work items will take as they move through the model.

The software has certain facilities necessary to build the simulation models for this research. These are a. using a logic-enhancing program called Visual Logic, connecting to other software to obtain external data, using attributes to record an objects individual feature and using probability distributions. Visual Logic lets you add detailed rules into the simulation model in the form of commands that relate to operations. In addition, Simul8 allows the use of databases such as excel sheets with external data etc to be connected with the simulation model. Finally, attributes are additional pieces of information that that are recorded in the model to describe the entities (Brooks et al., 2001). This facility is particularly useful for distinguishing between different types of a particular entity because they describe characteristics such as gender. This information may be essential to the model logic, for example they can be used to determine the route the object will take.

3.4.5.1 Determining the warm up time

Many simulation models pass through an initial transient period before reaching steady state. Although other behaviours do exist, where a model does not reach steady state. For models that do reach a steady state "the analysis should ignore the transient period in order to ignore any bias in the results. The modeller has two options for achieving this. The first option is to run the model for a warm up period before collecting any results. The other is to place the model in a realistic starting condition, at the beginning of the run, completely removing the transient period (Brooks et al., 2001) (Law and Kelton,1991).

A warm up time is required for the simulation models for this research as the services always have patients on their "books". This is because they never get rid of all of their patients and start from the beginning. Law and Kelton (1991) describe a number of procedures to obtain a steady state. However, in this research I found it more convenient to use the process recommended in the Simul8's users manual. The Manual recommends the following procedure to find a suitable warm up time:

Firstly, the modeller must decide the measures of performance that are of interest to him or her. These can be the number of work items completed, the utilisation of a workcentre or the length of a queue. If there are several measures of performance then the procedure must be carried out on all and the longest time to be taken as the warm up time. In this research, the utilisation of a workcentre is the main measure of performance. This is because capacity is of importance.

Secondly, the model must be run for a short period of time that will allow the model to complete work on some items. For example, until patients start leaving a service. The service managers reported the usual length of stay spanning from 2 to 6 weeks so an adequate starting point would be to start with 4 weeks. The procedure can be seen in Table 3.1. Then the model must be run for other amounts of time for example one week whilst recording each time the number of patients leaving the service. This data collection process is automated in simul8.

Thirdly, the modeller must construct a graph of the table and should notice a point that the model has warm up. This is usually better observed on a graph. Some authors suggest that once the warm-up time has been determined it is worth adding about 20% to it as a safety margin.

Table 3.1. Table taken from simul8 manual

Time in weeks	Number of patients
Week 1-Week 2 = 2 weeks	2
Week 3 = 1 week	3
Week 4 =1 week	6
Week 5	0
Week 6	2
Week 7	1
etc	

A warm up time was found for each of the services and the highest of these was used for the system model. This is further described in chapter 5.

3.4.6 Validation and Verification

An important part of every simulation study should be whether the simulation model and its results are reasonable. This stage is known as verification and validation. Two questions can summarise the aim of validation and verification:

Is the simulation model an accurate representation of the system?

Does the computer program perform as intended? (Law and Kelton, 1991)

Validation Definitions

Schlesinger et al. 1979 [(Sargent, 1987)]defines validation as "substantiation that a computerised model within its domain of applicability posses a satisfactory range of accuracy consistent with the intended application of the model".

Robinson (1999) defines validation as:

"the model being sufficiently accurate for the purpose at hand (Carson, 1986). This suggests that the modeller and decision maker have some clear objective for developing and using the model, and that there is a level of accuracy that is required from the model if it is to achieve this objective. Because many simulation studies are carried out to predict the performance of a real world system, the level of accuracy required is often relatively high, say 90% or more. The level of accuracy may be less stringent when the model is primarily used for improving the understanding of the real world system."

(Robinson, 1999, p1701)

The simulation models of the individual services for this research need to be as accurate as possible because they are supposed to mimic the services and their purpose is to evaluate their resources, capacity etc.

The accuracy for the system model is difficult to define because it portrays a complex decision making process of patient referrals into the various services. It has been difficult to adapt the conceptual model into an accurate enough computer model. Another problem is that the system's decision making mechanism as it currently stands is not be as it should, so even if the computer model is an accurate representation of the conceptual model it may not necessarily behave like the actual system. This will be because the real system does not perform and operate as it should. The evaluation will involve some form of comparison between what the system owners want the system to be doing and what the system is actually doing. Therefore, the simulation model of the system has a primary objective of improving the understanding of the real world system and its accuracy cannot be defined in numerical terms. It will be accurate enough if it is able to inform the system owners about the system and help them make decisions based on it.

Kleijnen (1995) explains the importance of validation by saying, "a false model may generate output that is sheer nonsense, or worst, it may generate output subtle nonsense that goes unnoticed. Such a model may lead to the wrong decision" (Kleijnen, 1995, p.22).

Verification Definitions

Sargent (1987) defines verification as "ensuring that the computer program of the computerised model and its implementation are correct"(Sargent, 1987, p.33). He believes that, "A model should be developed for a specific purpose (or application) and its validity determined with respect to that purpose" (Sargent, 1987, p33). He also says that it is unlikely to achieve absolutely validity over the complete domain of its intended applicability because of the usual constraints of time and costs. In fact, in most cases the development of a model reaches a point that further improvements are marginal. Therefore the aim of the modeller is to perform tests and evaluations until there is sufficient confidence in the model for its intended application. This has been the approach adopted in this research.

In order to ensure the validity (validation and verification) of the models various techniques have been adopted and applied to the models. These techniques are described in the Appendix G.

A table is included of what techniques have been applied and to which models. The individual models have been combined in the table as they have the same simulation goals (see table 3.2).

Table 3.2 The Verification and Validation techniques used

Type of Test:	Whole System Model	Individual Models
Animation	✔	✔
Degenerate Tests		✔
Event Validity	✔	✔
Extreme Conditions Test	✔	✔
Face Validity	✔	✔
Fixed Values	✔	✔
Historical data validation		✔
Historical Methods	✔	
Internal validity	✔	✔
Operational Graphics	✔	✔
Traces	✔	✔

3.4.7 Sources of Simulation inaccuracy

Robinson (1999) discusses three sources of simulation inaccuracy that involve the modelling of the system, the data and the experimentation. Each of these is discussed in turn and what has been put in place in terms of this research to ensure that they do not occur.

3.4.7.1 Modelling the system inaccurately

The first source of inaccuracy involves the modelling of the system. This is largely dependent on the skills of the expert simulations and his/her ability to understand the problem to be embarked upon and correctly identify the model that is required. This in turn can create the following three types of problems:

Firstly, if the problem is not understood properly then a model of the wrong problem will be developed. This requires the modeller to work closely with the client organisation to develop a good understanding of the problem situation. Problem structuring methods such as Soft Systems Methodology (Checkland, 1993) used in this instance can remedy this problem.

Secondly, if the wrong model is developed for the problem situation as a results of poor conceptual modelling. Validation of the conceptual model acts as an aid to ensuring that the conceptual model is adequate. In this project the aim is to enable good communication and use SSM to ensure that the appropriate conceptual model are developed.

Thirdly, if the conceptual model is not properly converted into a computer model. This will mean that the computer model has errors. Mixed Testing discussed in Appendix E is used to ensure that the computer model does, as it should.

3.4.7.2 Inaccuracies from the data

The second source of inaccuracy is from the data. This can be due to two reasons, inaccurate data and poor data analysis that can result in inaccuracies in the results obtained from a model. The first reason, collecting inaccurate data, can be a result of poor data collection methods leading to errors in the data or that the sample size is inadequate and it is not possible to make accurate inferences about the full population of the data. If the sample is inadequate the data is estimated which leads to uncertainties concerning the adequacy of the estimates. The data was collected by the IC employees in each service. The person within the ICON team responsible for getting the "filled in" assessment forms from the IC services felt that on the whole the fields on the assessment forms were filled in correctly but there were plenty of gaps. Although efforts were on a continuous basis to motivate IC staff to fill in all assessment fields it did not alleviate the problem.

Poor analysis of the data that has been collected is a second cause of modelling inaccuracies. Poor data analysis can be in the form of simple mathematical errors or the use of incorrect probability distributions. Inaccuracies in the data can lead to errors in the results of the model so it is therefore imperative that efforts are made to ensure that the data is accurate. Robinson (1999) suggests the following ways of overcoming these inaccuracies:

Firstly, "if the data has already been collected and given to the modeller then the source of that data is investigated and with particular reference to the possibility of errors entering the information. The modeller should ascertain who collected the data, how they where collected and for what purpose. It is useful to draw graphs of the data such as scatter charts or histograms to look for any unusual patterns or outliers. The modeller must ensure that the data are in the right format for the simulation and as such needs to be aware of how the simulation software interprets any data that are entered".

(Robinson, 1999, p.1705)

Secondly, "*Where the data needs to be collected careful consideration should be given to the data collection exercise*" (Robinson, 1999, p.1705). Sample sizes should be adequate and efforts should be made to avoid errors or to be able to recognise them if they occur. For example, checking the data against a second source (e.g. patient checklists and hospital information system). The data collection exercise was dependent on funds and the system owners. We decided that it was imperative to have at least three months of concurrent data collection across all IC services and that was acceptable by the system owners. The decision for three months was because services have a maximum length of stay of six weeks so by doubling that amount we felt that we would get adequate numbers of patients going through the system. Of course, as the data collection was extra work for the staff and in some services it proved to be too much work. In addition, the service managers and system owners were adamant that there was practically no seasonal variation, which meant that the three months were adequate. In some services like recuperative care, the data collection spanned over more than six months because of the small numbers of patients entering the service at the time.

Thirdly, where the data cannot be collected, one option is to estimate the data. Robinson suggests that one approach in this situation is to regard these data as experimental factors and to ask the question: what values do these data need to attain to achieve the desired result? He also suggests that this is appropriate where the decision-maker has some control over the values of these data. Robinson's suggestion was very useful for the gaps in some of the patients characteristics because we (a geriatrician and I) were able to estimate some of the gaps based on the other information in the assessment forms. This was very useful, as the simulation models require the patient to have a value for all attributes. This is further explained in Chapter 5.

Finally, to ensure that correct statistical distribution is used it is necessary to have accurate data. However, there are techniques that can be used to identify the best fitting distributions such as P-P plots Q-Q plots and the chi-square test. This can be done by simulation analysis packages such as Stat::Fit (Geer Mountain Software). In this research, all these factors have been taken into account and Stat::Fit has been used for data analysis to ensure that manual mistakes are not made.

3.4.7.3 Inaccuracies from experimentation

The third source of inaccuracy is through experimentation. The experimentation can lead to inaccuracies in four ways. The first inaccuracy through experimentation is when the initial transient period is ignored. In this research, the initial transient period is not ignored, as a warm up time has been determined for each service and the system.

The second inaccuracy occurs when the run length is too short or there are insufficient replications. It is generally preferred that models are run with multiple replications which means re-running the model with different random number streams. In multiple replications the runs are independent and so confidence intervals can be easily calculated. The downside to multiple replications is that they tend to add a significant amount of time to the simulation run time. The number of replications required is normally determined by continuing to perform replications until a sufficiently narrow confidence interval is obtained (Law and Kelton, 1991). In this research, the simulation software used (simul8) enables multiple replications and this facility is used to obtain confidence intervals. I found that for the system model only one replication was needed in order to have an acceptable confidence interval whilst not make the model too slow. Fifteen replications were adequate for the individual models as the service managers found that the confidence intervals for more replications were not as realistic.

The third inaccuracy involves insufficient searching of the solution space. The aim of simulation experimentation is to change the parameters to obtain a better understanding of the model's behaviour and to seek out target or optimum level's of performance. If only a limited number of experiments are performed then the quality of the findings are limited. The aim of this research is to select a limited number of scenarios from the total set available and to use these to learn about the performance of the system. These scenarios are influenced by discussions with IC employees and system owners.

The fourth inaccuracy is about not testing the Sensitivity of the results. This involves changing the data in the model (e.g. sampling from a distribution) to determine at what points the solution is likely to alter. For example, increasing the number of arrivals to see when the model resources exceed the required level of utilisation. These sorts of changes can indicate the sensitivity of the solution. It is important that the model run time is as short as possible and it is generally preferred to have a simpler model (less detailed) that allows for more experimentation. This inaccuracy has also been taken into account by making sure that each model does not have any excess detail in order to allow for experimentation.

3.4.8 What if Analysis

This stage is about finding out about desirable changes whether or not culturally feasible and testing those changes in a virtual environment. This stage is further explained in Chapter 6.

3.5 Chapter Conclusion

In this chapter, I have briefly described the methodologies that I have used for my research. I have also provided an insight into what techniques from these methodologies I have used and why. The following two chapters (Chapter 4 and 5) will provide a description of the application of these methodologies to the problem.

4 Soft Systems Methodology

4.1 Introduction to SSM process – 4 main activities

The SSM approach in this research is to apply the four main activities model to the Shepway IC system. Each of the activities will be examined in the following sections.

4.2 Activity 1 – Finding out about the problem

The first activity is finding out about the problem situation culturally and politically. This provided a good starting point to an area that was foreign to me and by talking to health and social care professional I discovered that the meaning of Intermediate Care was largely unknown to them as well. The concept was still in its infancy and the people that knew about it were mainly the people that either funded or managed the IC services besides some of the people that used the services and a selection of health and social care researchers.

Within those circles of people who knew about IC it was recognised that the management of IC is affected by the political and cultural situation at both the local and national level. The remaining section is divided into two categories. The first category involves finding out about the political and cultural situation at the National Level as this forms the foundation for the second category. The second category is about finding out about the Political and Cultural situation locally (in Shepway).

4.2.1 Finding out about the Political & Cultural situation at the National Level.

Finding out about the Political and Cultural situation at the National Level involved discussing with a wide range of health and social care professionals (within and outside Shepway) about the current political climate. It was also useful to consult a wide range of literature especially relating to care of the elderly. In addition, the East Kent IC providers held a National Conference on IC in 2000 that provided an understanding of the current climate.

The function of Intermediate Care is affected by changes, such as Department of Health initiatives to decrease the number of acute hospital beds. This is because fewer beds in acute hospitals lead to reductions in the patients Length of Stay, which means that older people will need to enter IC services to complete their convalescence or rehabilitation. Hospital nurses (sisters) reported that stricter regulations for Nursing Homes have also had an impact on the Intermediate Care system. For example, many of the nursing homes could not comply with the stricter regulations without raising the fees involved significantly which has meant that many of them have had to close. In interviews, hospital staff reported large queues for Long-Term institutional care and especially for nursing homes. They also said that there is a greater need for patients to improve their health outcome through IC even if that means that they will enter a Residential Home instead of a Nursing Home.

The changing attitude to patient care, which is about remaining healthy and as independent as possible, can be considered as a cultural change. This attitude has been mentioned in National Service Framework for Older People (2002), which is included in the Literature Review. This point about the changing attitude to patient care was also made in an interview with the CART service manager. Therefore, IC will target a population that will also include those who are at risk of an acute admission and those in long term institutional settings that could potentially improve and require fewer resources.

4.2.2 Finding out about the Political and Cultural situation locally (in Shepway).

In order to understand the culture and attitudes in the Shepway IC system and services several steering group meetings, visits to IC settings and interviews were arranged with IC staff and people with power and authority in IC. The system managers were shown diagrams of the flows between the services, as it was easier to focus the discussion and communicate IC operational mechanisms. These diagrams could be considered "rich pictures" by end of meetings as we drew on them to clarify and enable understanding. Their initial simplicity encouraged the people attending the meeting or interviews to think about all the services in the system as a "whole". We also discussed issues surrounding the primary task root definitions such as: What are the older people like before and after receiving IC? How older people could move around the system? Moreover, what would prohibit them from entering a particular service? In addition, services mangers provided all patient assessment forms and service documentation.

One of the findings was that the political situation at the local level affects the management and function of the Intermediate Care operational function. For example, throughout the course of this project the Elderly Strategic Planning Group in charge of the local IC system and services has been re-named and reconfigured. Each time there are such drastic changes, powers are distributed differently that inevitably complicate things.

The operational management of Intermediate Care is also affected by local cultural differences of the NHS and Social Services employees. This is because the majority of the IC staff are either NHS or social services employees. IC services are mainly NHS but a few fall under Social Services e.g. *Recuperative Care*. Despite this, the funding of the set up of IC services is "a joint effort" as their performance affects both the NHS and Social Services. It was evident in interviews that NHS IC employees and Social Services IC employees had a different view of certain issues, for example who pays for the treatment of a patient? Treatments in NHS run services are free of charge to patients but are not always free in IC services run by Social Services. In fact Social Services will means test each older person that qualifies for their services and will only provide the service free of charge if the person is eligible for financial assistance. This of course was the situation at the time of the project, which may have altered since then. This culture of "means testing" creates problems in the IC function. For example, Recuperative Care, which is one of the IC services run by social services, was under-utilised. The Recuperative Care staff could not explain this phenomenon. However, the NHS staff that referred patients to the service reported that patients were not keen on going there if a payment was required. When mentioning this to the recuperative care staff they said that they did not believe that payments would affect a client's choice, as they would be means tested. This is one example of the division and lack of communication between these services.

I consider the problems discussed above as general local problems and some are inevitable but there are other problems in Shepway, cultural and political, that can be improved and improve the operational function. These will be explained in more detail:

The first issue is autonomous way that the IC services operated and the lack of an identifiable centralised Intermediate Care management to coordinate all the services and systems operation. An example of the services' autonomous culture was that patients were assessed with different assessment forms in each setting. However, the initial problem exploratory meetings helped to slightly change this autonomous culture by explaining that each service was part of the same system. The aim was to get them to accept that they were part of the same system and agree that a standardised assessment form was needed throughout that IC system. This was also important to the simulation modelling stage as the consolidation of the assessment forms (described in a later a section) paved the way to creating a whole system model. If this had not taken place it would not be possible to readily obtain patient data that was comparable and that could be used for hard OR.

The second problem was the lack of information about some of the services. The basis for this finding was that service documentation and information for patients and their carers was available in very few settings. For example the rehabilitation and convalescence wards did not have any documentation at the start of the project. Furthermore there was no document for patients, carers or referrers that provided information about all of the settings. This was an indication to an unstructured and limited referral process. This lack of suitable documentation and clear guidelines hinted to inappropriate patient referrals and admissions. Of course, none of the people in authority had considered to produce such documentation, which suggests a reactive approach to management rather than a proactive one. This could be an extension of general medical philosophy, which is treating the symptoms rather than preventing the cause.

The third problem is the inability of the people in authority to provide clear guidelines about how the system should operate. The power to make changes was dependent on these authorities that did not seem to understand the services or be able to explain any situation when asked in interviews in any detail. This was most probably because the people in authority that made decisions for IC were usually overworked by having to take on several responsibilities outside IC. One can only assume that this lack of time would handicap the understanding and decisions being made.

The fourth problem was that it was difficult to identify the problem owners. The initial sentiment was that problem owners were not the local IC system but the Department of Health who passed down funds to local authorities for IC research projects. On the other hand, the local authority commissioned the project to the research group at the Centre for Health Service Studies at the University of Kent. Throughout the interviews and meetings the IC service managers did not express views or anything else that would make them the problem owners. In fact, they could all be considered as problem owners: the local Strategic Health Authorities (that made strategic decisions for the services) and the Department of Health. The system managers clearly wanted improvements for their part of the system but they did not appear to have an in depth understanding of their role.

The fifth problem was the IC staff's fear of the research outcomes because of the "blame culture". This meant that is was initially difficult to get them to express themselves without hesitation. The researcher's role was someone from the outside looking for "dirt" instead of the person here to help. This was because of the initial lack of understanding of the role of this research and that their performance individually was unimportant in the large scale of things.

This activity of understanding the issues that shape the IC system involved a fair amount of thought and consultation with the various stakeholders. The benefit of this activity is that by finding out the problems of this system it has produced activities that are required in the purposeful activity diagram. This activity was also important in understanding the factors that would potentially adversely affect or shape the research. Checkland (1999) in his 1988 version of SSM recognises the "*crucially important role of history in human affairs...in working in real situations we are dealing with something, which is both, perceived differently by different people and is continually changing.*" (Checkland, 1999, A15)

4.3 Activity 2. – Formulate some relevant purposeful activity

models.

This stage is about creating a primary task root definition of the relevant system that was acceptable to enable the purposeful activity to be modelled. In this research, I am interested in one relevant system, which needs to be investigated to satisfy the project needs. The relevant system is the function of the Intermediate care system. Determining the primary task root definition and the purposeful activity model was a joint effort of actors and owners although I did not disclose that I was using SSM or that I was using a formal methodology for my exploration because of the "fear culture" described earlier. This point is further discussed in the concluding chapter (Chapter 7). The sort of questions asked were: Do you agree that the customers are the older people? Who is the ultimate authority and owner of this system? Etc. The system owners including the Clinical Services Manager and Head of Older People in East Kent and the IC service managers were shown the purposeful activity model and they all felt that it represented their view of how the IC function should be and what they are working towards.

The mnemonic CATWOE was used to define the Customer, Actors, Transformation Process, Weltanschauung, Ownership and Environmental Constraints. The definitions are as follows:

Customers: *Older People over 65 that require rehabilitation or convalescence.* The IC customers are the older people that are deemed to require convalescence or rehabilitation in order to improve their current state of health. These older people may come from a number of settings or services including acute hospital settings and the community.

Actors = *Intermediate Care employees i.e. nurses therapists etc.* The number and combination of health care professionals that can be involved in IC services differs from service to service. However, the majority of these resources are nurses, occupational therapists, physiotherapists, doctors and rehabilitation workers.

Transformation Process = the need to support Intermediate Care in Shepway is met by designing and operating a system of strategic and operational level activities to enable IC.

Weltanschauung = a belief that these strategic and operational level activities are important in providing effective care for the older people.

Ownership = the local health and social care authorities.

Environmental Constraints = local IC funding, Department of Health guidelines.

The above definitions lead to the following root definition:

Root definition = A local health and social care owned system operated by IC staff that supports IC in Shepway by designing and operating a system of IC strategic and operational activities in order to provide effective care for the older people whilst recognising the constraints of local IC funding and Department of Health guidelines.

4.3.1 The 3 Es – Measure of Performance

Checkland's (1999) says that it is necessary to "*define the criteria by which the performance of the system as a whole will be judged*" (Checkland, 1999, A25). In terms of this research the measures of performance are the following:

El: the criterion for efficacy is to check that IC function is supported through IC operational activities.

E2: the criterion for efficiency is to check that the minimum IC resources are used to support operational activities.

E3: the criterion for effectiveness is to check that the operational activities enable older people to be rehabilitated in the most appropriate service for their needs.

These definitions are incorporated in the purposeful activity model of this IC system and are used to monitor the actual system. By doing this we are able to determine if these criteria are satisfied and if not to provide standards to achieve them.

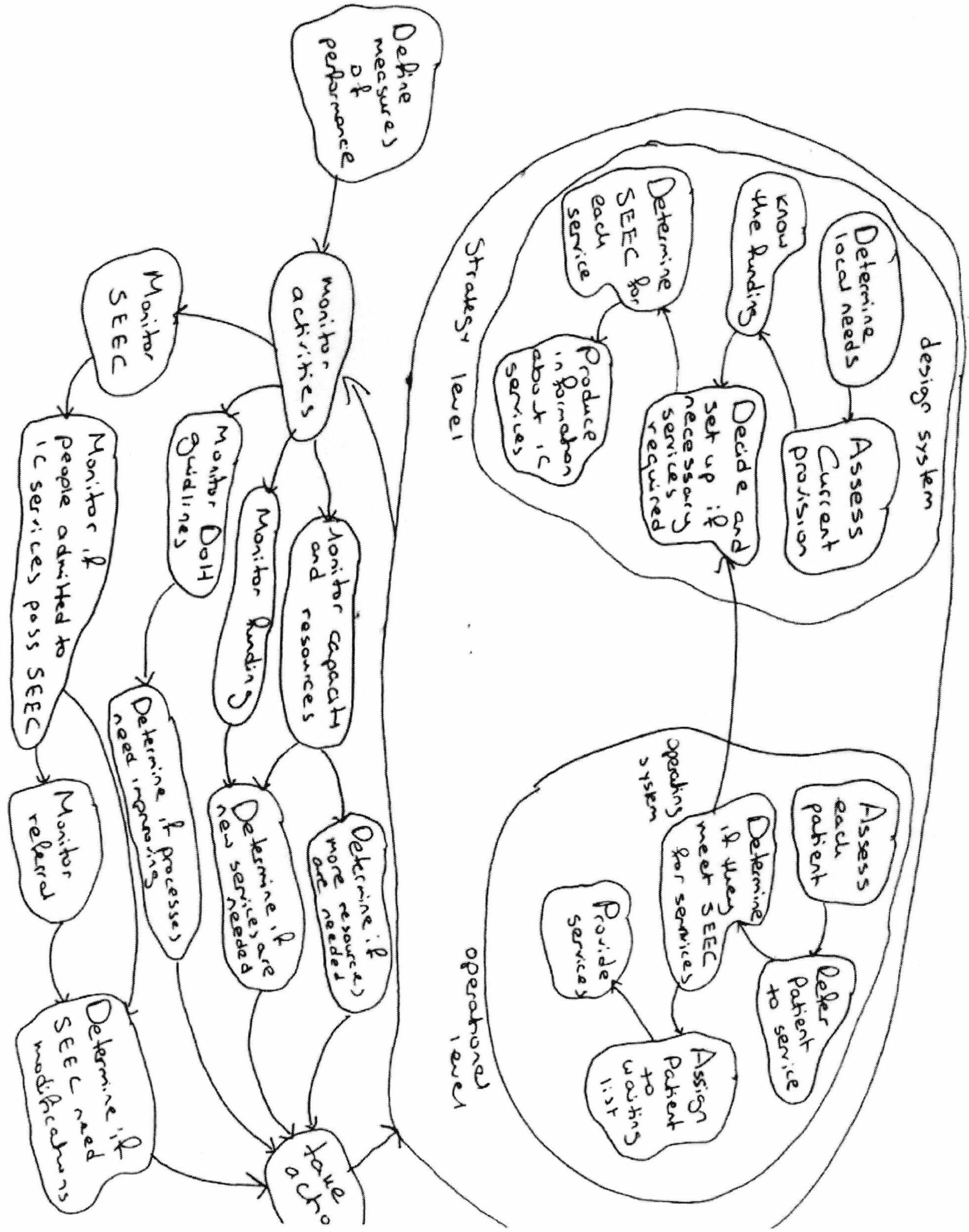
4.3.2 Model Building

With the construction of the Root Definition, CATWOE, and the three Es, it is now easier to construct the activity model that shows the transformation process T.

"The model building process consists of assembling the verbs describing the activities which would have to be there in the system named in the RD and structuring them according to logical dependencies."

(Rosenhead, 1999)(p.89)

Figure 4.1 Activities of IC system



4.4 Activity 3 – Debating the situation, using the models

In order to debate the IC operational situation it is necessary to compare the "real world" situation with the one constructed in the "systems world". This is achieved through a comparison of the activities in the activity model with the ones taking place in the real world. The main findings from the analysis showed that:

- Provision of information and communication about services to referrers and service users was not systematically addressed.
- The Service Entry Eligibility Criteria as existed were not explicit, and assessment against criteria was not systematic.
- Performance measures were limited to recording the numbers of people referred and average length of stay in the service.
- There were very few service monitoring and evaluation procedures in place.

The process of comparison is shown in the following tables (4.1, 4.2, 4.3):

Table 4.1 Comparing the real world with the purposeful activity model at the strategy level

IC strategic Activities	Does it exist? Yes/No	How is it done?	How could it be done?
Determine Local Needs	Yes	The services have been set up to cope with the service gaps in primary and secondary care. The service set up is more reactive than proactive to the local needs.	The local needs should be assessed and determined in regular intervals and should be proactive.
Assess current provision	Yes but not formally	The owners tend to examine the average number of people in services for each month.	They need to take into account service managers opinions about improving provision and should examine provision with formal methods such as simulation modelling.
Know the funding	Yes	Services are set up with funding for a number of years.	
Decide and set up if necessary services required	Yes the IC system explored has a variety of IC services.	Services are established in an "adhoc" manner without necessarily covering all patient needs in that locality.	Patient's needs should be identified and mapped to existing services through SEEC and if there are needs that are not being met then new services should be introduced.
Determine Service Entry Eligibility Criteria for each service	Yes formal criteria exist in some services.	The criteria do not reflect the service purpose and patient focus.	Each type of Service should have clear patient focus distinct from other services in order to determine SEEC
Provide information on IC services	Yes for some services, for example CART, Recuperative Car and Day Hospital.	The services have their own leaflets obtained at the service's headquarters.	A comprehensive leaflet that encompasses all services should be readily available by all health and social care providers.

Table 4.2 Comparing the real world with the purposeful activity model at the operational level

IC Operational Activities	Does it exist? Yes/No	How is it done?	How could it be done?
Assess each patient	Yes older people are assessed usually upon entry to a service.	With different assessment forms in each service.	With one standardized assessment form to be used by all IC services. Also there should be a single assessment framework for access to these services.
Refer patient to service	Yes	Anyone can refer to IC services (including the patient) but referral paths are not formally identified.	Formal referral paths should be in place so only suitable referrals are sent to each service as unsuitable referrals are time consuming.
Determine if patients meet SEEC for services	Not always	In some services this done with rigour and in others anyone can enter the service.	This should be a formal and transparent procedure done for each patient.
Assign patient to waiting list	Not always	Some patients wait for a particular service but others are referred on to other services without waiting lists.	Patients should not be sent to the shortest queue but the most appropriate service.
Provide Intermediate care services	Yes patient are referred to IC services.	Patients are sent in an "adhoc" manner without necessarily covering all patient needs.	Patient's needs should be identified and mapped to existing services through SEEC. The patient should be sent to the most appropriate service for his or her needs.

Table 4.3 Comparing the real world with the purposeful activity model at the monitoring level

IC monitoring Activities	Does it exist? Yes/No	How is it done?	How could it be done?
Monitor Capacity and resources	No		By examining resource utilisation and length of queues for each service and this can be done using simulation modelling.
Monitor funding	Yes		
Monitor DoH IC guidelines	Yes	Not all DoH documents are read by service managers but system managers read most literature.	The service managers consult Department of Health circulars and reports such as NSF
Monitor if older people admitted to IC services pass criteria	No		This should be done in audited regularly and done in a transparent manner.
Monitor IC services	No		Monitor IC resources and Capacity
Monitor SEEC	No	SEEC for the services that have them were determined when the service was set up.	SEEC should be independently assessed on a regular basis to ensure that they are comprehensive and reflect the service focus.
Monitor if IC patients pass SEEC	No		Independent audit to compare assessment forms to SEEC.
Monitor referral	No		Monitor numbers of unsuitable referrals made and source
Determine if more resources are needed	Yes	Service managers request without proof	Simulation modelling could be used
Determine if IC processes need improving	No		They need to regularly examine the process of admission and discharge through multidisciplinary meetings.

4.5 Changes which could improve the situation and are regarded as both desirable and (culturally) feasible

The Purposeful Activity model has some activities that were present but could be improved and some that are not present in the real situation but would improve the system and enable me to complete the evaluation. The first part of this discussion is the changes that are regarded by the system owners as desirable and culturally feasible.

The entry to IC services at the time of the research was resource driven rather than needs driven. Many of the referrals for an IC destination were generally dictated by the availability of a bed or place than the suitability of the patient for the particular service. This needed to be changed, as it did not benefit the service or the patient. A solution to this problem is the development and use of explicit and exclusive Service Entry Eligibility Criteria (SEEC) for each service. This could lead to a situation where patients who might benefit from a service could be more readily identified and those who may not benefit would not be admitted to the service. Each type of service specialises for particular disabilities and needs and should be aimed at those patients who really need them. For example, a stroke rehabilitation ward will specialise in the care of stroke patients and provide them with equipment and specialised nursing care that they need. The existence of service entry eligibility (and exclusion) criteria in services will have several other advantages. One advantage is that patients will not be put at risk. For example, a patient staying at home whilst receiving rehabilitation should be able to cope with minimal supervision and a patient that has behaviour problems and wonders may be a danger to him or herself.

Entry Eligibility Criteria did exist for some of the services but they were not clearly stated or transparent nor were they widely known outside the service. The service managers agreed that developing SEEC for each of the services would be of benefit. SEEC would also enable the patients and referrers to understand better the purpose of each of the services in the system. Therefore, a desirable change would be to provide information about IC, the IC services and the SEEC to referrers and users in a systematic way within the geographic region served.

4.6 The accommodations between conflicting interests which will enable action-to-improve to be taken

There were changes that, although desirable by the system owners, created conflict amongst the various service managers. One of these changes was the introduction of a standardised assessment instrument as it would mean a change in working practices and was perceived as potentially leading to more work in a system that was already under pressure as a result limited resources and rapid development. However, in order to satisfy the project needs a standardised assessment form was needed. The conflict regarding the introduction of a standardised assessment form centred on whether one of the existing services assessment forms would be used or whether a new one would be introduced. It was decided that the existing forms contained too many open-ended questions, had not been validated and did not include many of the required items to fully address the relevant patient needs and entry criteria. We agreed that a comprehensive standardised assessment form would be used. The accommodation between all parties was the introduction of a valid standardised assessment initially for a number of months that also incorporated all of the services' existing items, at least in the first instance. The Department of Health has published guidance for the development and introduction of a Single Assessment Process (Department of Health, 2001, 2002a,b,c) that should facilitate the introduction of an appropriate standardised assessment instrument that should be used IC services.

4.7 Activity 4 – taking action in the situation to bring about improvement

The actions to bring about improvements that have evolved from applying Soft Systems Methodology to this IC system can be summarised as follows:

- Develop clear Service Entry Eligibility Criteria for the IC services that do not already have them in place.
- Assess existing Service Entry Eligibility Criteria.
- Introduce information to referrers and patients about IC services in the region.
- Introduce a validated standardised assessment instrument throughout the region.
- Set out clear system performance measures
- Assess resource requirements for services and system capacity.

4.7.1 Developing Service Entry Eligibility Criteria

The idea of services having Service Entry Eligibility Criteria (SEEC) is not new as it pre exists the project and can be found in IC literature (see section 2.1.6). However, the literature does not suggest a method of obtaining these criteria and does not provide a clear description of them. An initial investigation of the services suggested that a few of the services had written criteria but many had not. The services that had a list of their criteria on paper had them in a sentence form that provided very little insight into the service's purpose. The services without a written list of criteria operated in accordance to some unwritten criteria that needed to be extracted. Although these criteria were not written down on a piece of paper, they existed in the subconscious of the employees that understood the service or use them. The process of extracting criteria was through interviews and discussions with service managers. Initially there was a group meeting with all IC managers and some other vital NHS or Social Service employees. This group meeting although useful was not adequate in extracting SEEC and therefore I arranged individual meetings with service providers.

The method of obtaining the SEEC took on the philosophy of soft OR, which is about problem structuring, structured brainstorming, idea capturing, strategy development, mapping, modelling and influence diagramming. However, none of these were used, as they were not appropriate to the task at hand. The aim of the interviews was to get the service employee to provide the factors that influence the admission decision-making for that particular service. These factors were extracted through discussion and in some cases the information was in the form of examples of unpleasant situations that had occurred. Therefore, it was essential that there was a good rapport and trust by the interviewee and the understanding that the project was not concerned in individual situations that had gone wrong. Overall, all NHS staff were willing to discuss and disclose unpleasant facts about the current situation as well as their own feelings and anxieties. The interview lasted about 1-2 hours and in most cases, there were repeat visits and interviews for clarification purposes. This was extremely difficult to achieve as the health employees had very little time to spare and appointments had to be made weeks in advance. The interviews were informal and were conducted in various areas in a service; For example, part of a discussion took place at a table with recuperative care patients eating their lunch.

The interview layout was mostly dependent on whether the service had a list of criteria prior to the project. For the services with a list of SEEC we started with discussing each criterion. This was to understand each one in depth. Overall the existing lists of criteria seemed vague and the employees could not provide precise descriptions of what they would look at in a patient for each criterion. The service employees and managers gave the impression that the existing lists of SEEC were not used in practice and were available as part of policy requirements. On one occasion, a Recuperative Care employee explained that the real admission process involved a face-to-face interview with probing questions and unique to the service assessment form, which provided a guide to a person's suitability, and the treatment that would be needed. Recuperative Care had a written list of SEE criteria, which means that if the list was not good enough to be used by the service then the people referring patients to the service would not have a precise document that would provide them with an idea of a person's suitability. This provided an insight into the unsuitable referrals that had been reported in the discussions with IC service employees.

Another example illustrating the nature of the criteria is one CART criterion that states: individuals that require admission to hospital are excluded from this service. The question asked was how do you know when an individual requires admission to hospital? Is there a list of things that one can assess? The health care professionals could not provide a specific list of things to look for that can be assessed. I was told that this is a difficult question that can only be answered by a health care professional with enough experience, as each situation is different and in each case many factors need to be considered. Some of these questions involve tacit knowledge and one can only ask the question(s), which would probably provide an answer of a yes or no either by the clients or referrers. This is not adequate for a valid assessment, as it requires transparency. In addition, the referral process and the service entry eligibility criteria involve many non-health care professionals that will not have the tacit knowledge required to answer these questions. Some criteria provided an insight into the real requirements of the service's admission process and others did not. Therefore, the SEEC need to reflect the nursing and therapy that is provided in the actual service. Once we had gone through the existing criteria items I enquired about items that had been mentioned in the first group meeting and were not included in the existing SEEC list. The enquiry took the form of some prompting questions (see table 4.4).

Table 4.4 Questions used to explore SEEC for each service

Prompting questions used in Interviews with IC service employees:
Give me examples of patients that would be unsuitable for this service?
Have you ever had patients that were unsuited to this service?
What problems do unsuitable patients cause to the employees and other patients?
Do these unsuitable patients take up more resources?
How do they get admitted into the service?
What sort of patients should enter this service?
What is the difference between your service and other services in Shepway?
Do you have bedblockers?
What makes them bedblockers?

The remaining section provides examples of the type of answers the IC employees gave in response to these questions:

1. *Give me examples of patients that would be unsuitable for this service?* All the services mentioned that there are some older people that would not be suited to the service. For example all the services explained that older people that are medically unstable would not be suitable for IC.

2. *Have you ever had patients that were unsuited to this service?* Many of the services had admitted patients that were unsuitable. One service mentioned that on one occasion they inappropriately admitted an older patient for sentimental reasons.

They knew that this person was terminally ill but they accepted him because of family pressure and the older person's wish to be admitted.

3. *What problems do unsuitable patients cause to the employees and the other patients?* One of the wards provided an example of the problems caused by an unsuitable patient. This patient was a "wanderer", which is a person who wanders off from the ward and hospital grounds, due to cognitive impairment. This wandering condition almost put that patient in a dangerous situation but the person was located in time and returned to the ward. The ward is not set up as a prison as it is for older people that require rehabilitation and convalescence that do not require that level of attention. It is also common knowledge that wards are understaffed, as they cannot find personnel and particularly nurses which means that if one patient needs more attention than others the balance of care is jeopardised.

4. *Do these unsuitable patients take up more resources*? Most services did not hesitate to say yes to this question. The above example of the wanderer is also relevant to this point.

5. *How do they get admitted into the service?* The answer to this question depended very much on the referral process. The involvement of the service manager was influential in terms of the service having less unsuitable admissions. The most unsuitable admissions and the most complaints were heard from the ward sisters, which had less involvement with the admission process. The question revealed that there was not enough transparency in the referral process as far as the service managers were concerned.

6. *What sort of patients should enter this service?* The ward sisters answered this question with difficulty and I had to add the phrase "in an ideal world". The reason for this difficulty is the caring nature of their work that makes them not want to exclude people in need. They also felt that many of their current patients were unsuitable to the service but there was no other service that could care for them. They emphasised the unsuitability of patients with severe cognitive impairment that were on the wards.

7. *What is the difference between your service and other services?* This question was never answered in relation to all available services but in terms of the ones that they had the closest dealings with. The description of the differences of just one or two other services indicated the lack of whole system thinking by the IC employees. For example Recuperative Care discussed CART, CART discussed Day Hospital and Recuperative Care and the wards discussed each other. It was interesting to hear the views of employees of one service about the purpose of another service. In fact it was sometimes easier to understand what a service was about from someone outside the service. All of the services described a difference between them and another service. The services provided differences such as a specialist medical expertise. For example the stroke ward is different to all other wards as it only deals with people that have had a stroke. The other two wards at the Rehabilitation Hospital in Shepway although they had a distinct purpose from each other they also took a mixture of each others patients due to a lack of beds and bed management and very likely a lack of understanding by others of their distinct rehabilitation focus. The "hard core" IC services differences were less about the therapy provided but about issues such as the setting that the therapy takes place e.g. at home if CART was used and in a Rehab centre if Day hospital or Recuperative care were used.

8. *Do you have any bedblockers?* All the services that involved inpatient treatment and therapy replied yes to this question. This was probably because the other two remaining services that do not have inpatient treatment can remove unsuitable patients much more easier than those that are inpatient especially when there is nowhere else suitable to discharge them.

9. *What makes them bedblockers?* The ward managers/sisters provided examples of patients that were taking up recourses whilst having needs that were outside the scope or the capability of their service and had become a burden to the staff as well as taking up a much-needed place/bed.

For some services, this line of questioning was not enough to understand the service's purpose so these services were also observed. For some services, like Recuperative Care and the Day Hospital, I found it helpful to observe a typical working day as it uncovered other aspects that were not mentioned in interviews. For example, I observed that in

Recuperative Care it was extremely important that the older people were motivated because while there were in the service they had to do various activities of daily living like making breakfast and washing up. Observation was not possible in other services like CART as the treatment was in the older person's home.

A conclusion that can be made from this is that all services are different and they experience different problems. I have not provided all the information obtained from these interviews, as the intention is to explain the process of obtaining the SEEC. The process of obtaining the SEEC was an unstructured interview process that had as a main goal to understand as much as possible about access to the service. A list of criteria was obtained for each of the services. The criteria initially took a sentence form, which were abbreviated into one or two descriptive words for simplicity. For example a criterion stating that a person must not be cognitively impaired became "cognition criterion". A table of the CART criteria has been included to illustrate the sort of criteria found (see table 4.5).

Table 4.5 Admission Criteria for CART

CART Admission Criteria
Two therapies - Individuals must require two or more elements of the service
Age – Individuals must be 65 and above
Shepway resident – Reside in Shepway
Rehabilitation Potential – Require rehabilitation
Mobility – Able to transfer with the maximum assistance of one other person
Continence – Continence should be managed
Communicate – Individuals should be able to communicate
Terminal Diagnosis – Individual should have a life expectancy of > 6 months
Behaviour – Individuals should not behave inappropriately
Cognition – Individuals should not be cognitively impaired
Motivation – Individuals should show motivation for rehabilitation

SEEC are a set of rules that can help referrers determine the suitability of a patient to enter a service. The SEEC relate to the purpose of an IC service and initially take the form of sentences that can be translated into assessment items and then into needs. Rehabilitation potential, an important element of IC, is a criterion that must be assessed through the patient's clinical and other characteristics and an appropriate care path must be identified. The care that is provided to the older people is dependent on their requirements therefore an in depth knowledge of their needs and disabilities will help this process. The assessment items are a patient's clinical and social characteristics. The reason for needing to convert the sentences into assessment items is that it enables to compare data and subsequently patients from one setting with those from another. The benefit of collecting a patient's clinical and social characteristics to put into the model logic is that it allows tacit knowledge in terms of Decision-Making to become explicit and be modelled through hard coding the criteria for each setting.

4.8 SSM conclusions

This part of the SSM methodology, taking action to bring about improvement is incomplete without the second part of the multimethodology. The Soft Systems Methodology has provided a framework to structuring the research problem. This methodology has shown that there are activities in the system that should take place but do not and that some can be improved. This IC activity model fits with ideas provided in the IC literature about IC Co-ordination and the current thinking of the Department of Health (see section 2.1). The methodology is a whole system approach as it examines the entire Shepway IC system and Services. It can be used to show the IC function decision-makers what is missing from the current system and what needs to be evaluated.

With this methodology we have made the following findings regarding the four Evaluation Tasks of the operational function of IC:

We have determined that the data collection is not suitable and that a standardised assessment tool is required that will be used across the IC system. The Introduction of a standardised assessment tools is discussed in Chapter 5.

We have determined that all services should have Service Entry Eligibility Criteria that should reflect a discrete focus on specific rehabilitation and convalescence needs. This will be evaluated in Chapter 6.

We have determined that there is a need to monitor IC service resources and capacity. This will be evaluated in Chapter 6.

We have determined that there is a need to monitor the mix of IC services. This will be examined in Chapter 6.

The information and understanding obtained through this process is essential as it points out changes that are required and "*paves the way*" the next part of the multi-methodology, which is simulation modelling.

Applying SSM has meant that I have had to develop and use interpersonal skills such as a good telephone manner, flattering etc that are not taught in academia. Another thing that I have learnt is that SSM involves a great deal of travelling to meetings that have involved car and train journeys to meet very busy NHS and Social Service employees that had little time to spare. In addition, the NHS and Social Service employees use medical terminology that is foreign to the average operational researcher. The process of getting an in depth understanding is not just about following the methodology but it is an internalised process of learning and understanding that is achieved through people contact. The more contact with system Actors, Customers and Owners the better the understanding. In this research, I have met and observed IC patients and employees over a period of several months to achieve a comfortable level of understanding.

5 Simulation Modelling

5.1 Introduction to the Simulation Study

The actual IC system at the beginning of the research project was in its development phase and the operational function was still under formation. This created a fuzzy ill-defined situation that needed structure, which was tackled by SSM – a problem structuring method. Although the problem situation has been explored in detail in the SSM phase of the framework, it has been approached from soft systems thinking rather than hard systems thinking due to the vagueness encountered. The SSM approach has allowed the problem situation to be defined into the following precise questions or areas of investigation:

Are the IC patients admitted to the most appropriate IC service?

Are IC services working to their Capacity?

Are the IC Resources adequate?

Are there any service gaps?

The questions regarding capacity and resources are questions that have been traditionally tackled through a simulation study. The question about SEEC has not been tackled previously but this project will demonstrate that this question can be answered with Discrete-Event simulation models. The question about service gaps has been tackled through a soft approach of mapping described in the literature review (Stevenson, 2001) but does not examine the problem in a dynamic way or allow for a "What if" analysis. This is something that can be achieved though simulation.

This chapter is about applying Discrete-Event Simulation Modelling to the individual services and the overall system function. The system model has a different purpose to the individual models, which is to examine the decision making mechanism of allocating patients to services. The individual models can answer detailed questions about their operational function of the individual services that are not examined by the system model, as it would make it too complicated and slow. The aim of the simulation approach is to "keep it simple".

The models developed for the simulation study are for the CART, Day Hospital, Recuperative Care and the "whole system" model. Each of these has a purpose which will briefly be explained in the following paragraphs:

A discrete-event simulation model was created for the Community Assessment Rehabilitation Team (CART) that examines the team's human resources. The model incorporates the Service Entry Eligibility Criteria for that service in order to examine if the service admits people that pass their criteria. The individual model only examines human resources as the treatment is based at the older person's home environment and the number of places available is dependant on the workload.

The discrete-event simulation model for the Day Hospital similarly to CART examines the human resources as the decision to admit another person depends on the staff workload. The day hospital model like the CART examines the service's SEEC.

The discrete event simulation model for Recuperative Care is an inpatient service and therefore there are two models one that examines the beds/places and the other examines the human resources. The reason that two models are needed is explained in section 5.3.1. The recuperative care model like both the other individual models examines the service's SEEC.

The whole system model incorporates the philosophy of the Single Assessment Process as a decision making process that determines which service patients get admitted to. It also examines the capacity as it includes all the places for each service and beds of each IC ward. For CART and Day Hospital it has an approximate number of places that has been determined by the service managers of those services. The wards do not have individual models as they are modelled adequately in the whole system model.

The layout of the chapter follows the simulation study steps discussed in the methodology chapter. The steps of the individual and whole system models are the same and in this thesis will be examined in parallel.

5.2 Express the real problem

Because the problem situation has been expressed in the SSM phase the first step in this study is to extract conceptual models for each service and the system as a whole.

5.3 The Conceptual Models

The simulation study has conceptual models relating to the individual IC services and the conceptual model relating the whole system. These conceptual models will be described in the following sub-sections.

5.3.1 The conceptual model for the individual services

The individual models must be used to examine SEEC, resource use and capacity with current patient arrival rates whilst the system model is there to examine the IC system interaction.

5.3.1.1 Conceptual model for CART

The CART service is a complicated service to model as it offers variable amounts of treatment and rehabilitation mainly across the five main operational days of the week (Monday to Friday) but that can be increased if more is required. This is because the service offers a patient centred approach with goal setting and the aim is to rehabilitate a person within a maximum of 6 weeks. The main difference between the CART and any other IC service is that all treatment and rehabilitation is offered within the patients /clients own living environment.

The setting is staffed by: Nurses, Occupational Therapists, Physiotherapists and Rehabilitation workers. According to the CART Occupational Therapist the tasks/ work undertaken at this setting can be put into two categories. The first category consists of tasks that are performed by both Rehabilitation workers and the professionals and the second category are tasks that are only performed by the professionals.

The model is concerned with modelling the three basic stages of CART treatment. The conceptual model is described with the following:

Stage 1: Is the initial assessment process, which is undertaken by a Nurse a Physiotherapist and an OT. This is thought to last around 3 hours including travel times etc.

Stage 2: Is the daily visits by a Rehabilitation worker and a Health Professional (either Nurse or Occupational Therapist (OT) or Physiotherapist). These are thought to be on average around 3 hours of combined staff time (including paperwork and all other work and travel) per client per day.

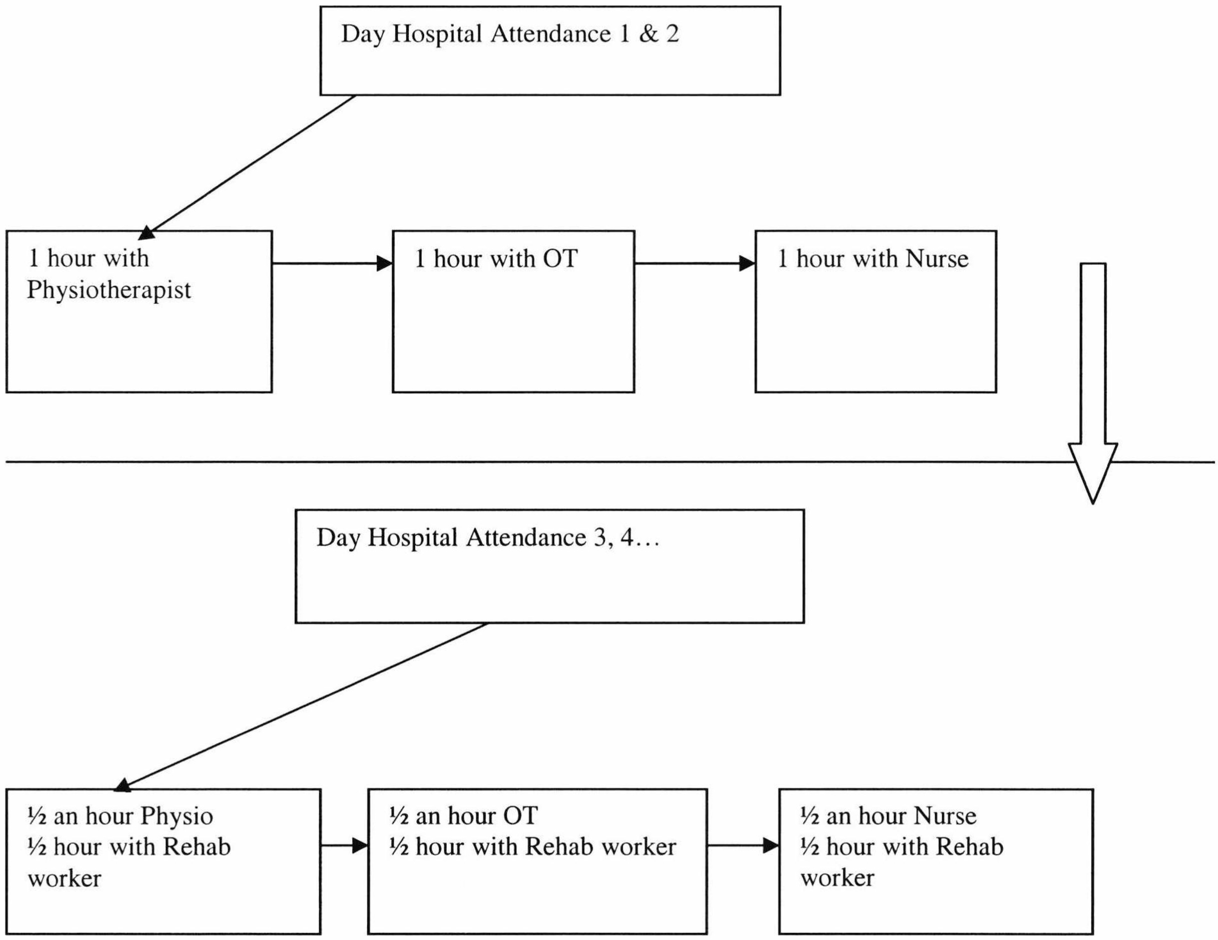
Stage 3: Is the Final Assessment visits by the professional to determine if the goal has been achieved, etc. This is thought to be around 3.5 hours on average.

5.3.1.2 Conceptual model for Day Hospital

The Day Hospital is another complicated service as it operates two days a week and patients may have one or two days of treatment per week. In addition the treatment must consists of two of the three types of treatment/therapy available: Nursing, Occupational Therapy, and Physiotherapy the setting is staffed by: Nurses, Occupational Therapists, Physiotherapists and Rehabilitation workers. The tasks/ work undertaken at this setting can also be put into two categories. The first category consists of tasks that are performed by both Rehabilitation workers and the professionals and the second category are tasks that are only performed by the professionals.

The patient is assessed for 1 hour by a Nurse, an Occupational Therapist and a Physiotherapist on the first two visits and there after he or she is treated/rehabilitated by each of the professionals for half an hour and half an hour by each of the professionals assistants who are the rehabilitation workers. The conceptual model for this service is best explained in a schema (see Figure 5.1).

Figure 5.1 The Conceptual Model for the Day Hospital



5.3.1.3 Conceptual model for Recuperative Care

The care offered at the recuperative care service involves the older person to living for a short period within an environment resembling a residential home but receiving rehabilitation therapy from an occupational therapist and assistant. The therapy sessions are intense and aimed at teaching the person to cope activities of daily living baring in mind any new requirements or disabilities that the older person may have. The recuperative care setting has six beds. The conceptual model for Recuperative Care also takes a lexicographical form.

The recuperative care service is an inpatient service and the resource investigations will involve both the utilisation of the beds and the staff. There are two models for recuperative care one that focuses on staff utilisation and one that examines bed utilisation. Also, although both models are run for five months but they have different time measurements, one is run in days (focusing on bed utilisation) and the other in hours (focusing on staff utilisation).

The manager of the recuperative care setting mentioned in a discussion that the beds are under utilised. Therefore the recuperative care model will be needed to examine the following:

1. The current bed and staff utilisation with the current patient arrival rate.
2. To examine what would happen if patient arrival rates were increased to the point of a maximum of 85% utilisation of beds.
3. To examine how an 85% bed utilisation would affect staff utilisation and how many staff would be required in that scenario.

The choice of the utilisation rate is mainly for two reasons; because 85% of an 8-hour day is 6.8 hours. The individual models do not take breaks into account, which means that 1.2 hours is a reasonable amount of time to dedicate to breaks etc. This was also discussed with the service and ICON team and accepted as suitable.

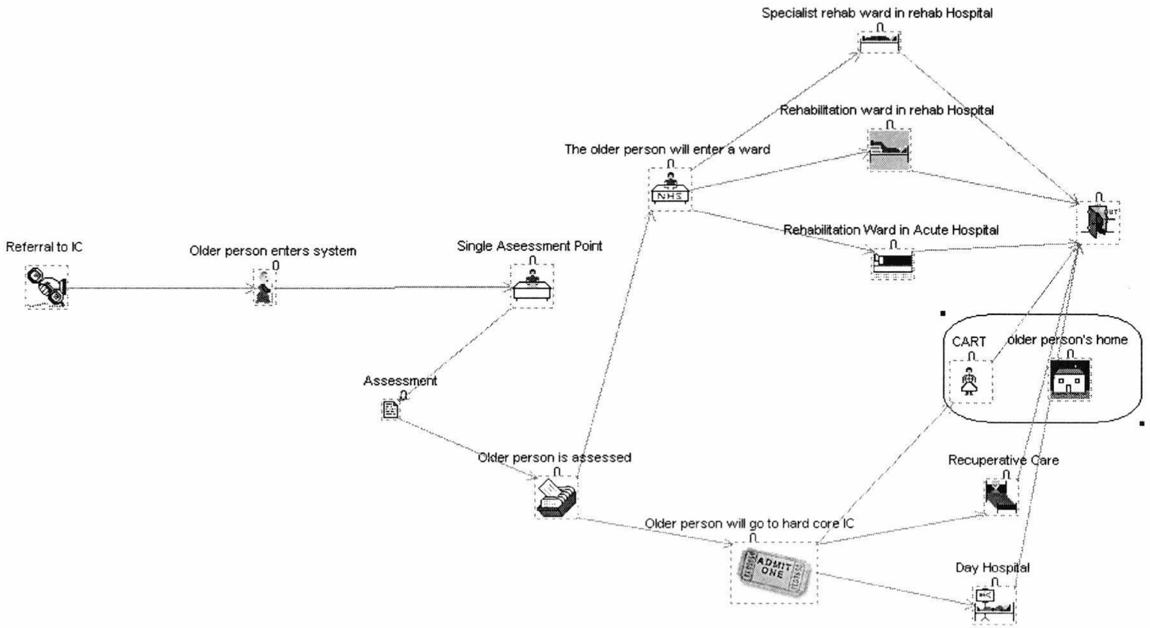
5.3.1.4 The conceptual model for the "whole system"

The whole system model could have taken several forms had I not gone through the SSM phase or consulted the IC Literature. However, it takes a form agreeable to the findings from the SSM methodology which means that it has been formed through interviews with IC employees and consulting literature from the Department of Health and various other organisations such as the Kings Fund.

The SSM findings revealed several activities that should or could be taking place but were not at that time. It is a conceptual model of what should be going on in an IC system or rather what some people would like to be is going on than what is actually happening. Therefore the simulation conceptual view is following the soft paradigm. The worldview used to model this system is that this system will send Older People to the most appropriate setting/service according to their needs and the Service Entry Eligibility Criteria. This view is the most beneficial to the patient, because then he or she will receive the most appropriate treatment that will in turn reduce the possibility of readmission. The data requirements for this conceptual view must enable the simulation models to be patient needs driven rather than resource driven.

The system model for the IC system is about using the most agreeable worldview to service managers and patients and assessing its distance to reality and what changes can be made to achieve this worldview. In the "What if" Analysis the whole systems model will examine questions about the gaps in the service mix. For example, we can use the whole system simulation model to examine the effects of adding a new service or removing an existing service. Finally, the model can be used to see how many of the patients that were assessed though out the course of the data collection were suited to each of the services in Shepway irrespective of whether they actually went there. The diagram illustrates the conceptual model for the whole system. The diagram has been drawn in simul8 but it is not the actual "picture" of the simulation model because that "picture" is too complicated to visually understand because of the several workcenters (see Figure 5.2).

Figure 5.2 The Conceptual Model for the "whole system"



As there is nobody that has an overall knowledge of the system I feel it is necessary to validate the whole system conceptual model in this thesis with more rigour than the individual models. In order to validate my choice of my whole system conceptual model it is necessary to explain why other potential conceptual views are unsuitable.

Many simulation models are modelled using percentages to move work items through the system and there are models such as this one that use attributes to guide the work items. For this model attributes are used to regulate the movement of patients into a service. Using percentages would not suitable for three main reasons:

It is against current IC management thinking as the service managers agreed that older people should enter the most appropriate service depending on their needs. The services have a purpose and therefore it is logical to assume that people engage in purposeful activity.

To use such a model for operational decision making would have been unethical for the patient as decisions would be financially driven rather than ensuring that the most appropriate resources are in place. The current worldview also makes the system viable for the long term as it will prevent readmission.

The service managers when asked in interviews for information on proportions they could not provide an estimate or have any data so the data collection would not be avoided.

Another approach would be to have modelled the system with patients admitted to the service that they are referred to first regardless of the criteria. Obviously to construct a model of this situation, with no SEE criteria and standardised data collection, would not be of any use in future planning other than to demonstrate that the function was flawed. In fact this model would not incorporate the decision making process and would serve the same purpose as the individual models. This approach is also not acceptable because in reality there is a decision making process even if it is subconscious and is problematic due to its lack of transparency.

5.4 The Data Requirements

This chapter describes the data requirements that satisfy the conceptual requirements. In order to satisfy the conceptual model the computer model will require the following data and information:

- Service Entry Eligibility Criteria used for the system model rule base.

- Patients' health and Social characteristics used for observed data distributions.

- Services resource information (Number of each type of staff, number of beds etc) used for both the individual models and "whole system" model.

- Inter-arrival distributions and Length of Stay distributions used for both the whole system model and individual models.

The first two categories are linked to each other and one cannot exist in the model without the other. Specifically the patient health and social characteristics are used to enable the use of Service Entry Eligibility Criteria. The patients' characteristics are obtained using a standardised assessment tool. This involves the data collection process, which was done by another member of the ICON team.

5.4.1 The Assessment Data

The use of a standardised assessment form for all Intermediate Care services enabled structured healthcare data to be collected from patients, describing their medical, physical, functional, psychological and social characteristics on admission to and discharge from each service. The standardised assessment form should have the appropriate fields to determine a criterion. For example, a criterion can be that patients must be able to communicate in order to receive treatment. In this case, the communication criterion required two fields, the first one relates to one's ability to understand and the second one relates to one's ability to be understood (see Appendix H). The benefit of this is that a simulation model can determine whether the patients meet the entry criteria for the setting.

The SSM findings highlighted the need for IC services to provide admission to services based on a standardised comprehensive assessment. The existing assessment forms as discussed, in chapter 4, were neither comprehensive nor standardised. A decision was made to introduce an existing assessment form that would be comprehensive and would be used by all services. The Minimum Data Set (MDS HC) was selected as the instrument to be used for assessments. The MDS has been developed by a team of research and health professionals (InterRAI, 2003) as a basis for assessing the care needs of elderly people. The MDS was chosen because it is comprehensive domains, known validity and reliability, ease of completion and the ability to aggregate data for analytical purposes. It has also been accredited by the Department of Health for use in the Single Assessment Process (Department of Health, 2002a).

As described in the SSM phase of this research, a conflict of interests soon emerged in that, on the one hand, the assessment needed to be comprehensive, and on the other as quick to complete as possible. The climate in which the project was run was one of heavily stretched healthcare resources, hence the staff were understandably cautious when faced with the prospect of additional administrative work. It was therefore necessary to ensure that the scope of the form satisfied the project's needs, whilst being as short as possible. A joint decision between the people that commissioned the project and the ICON project team to use a modified version of the MDS that would include the absolute necessary fields.

In order to decide on the content of the standardised assessment form I participated in a group discussion in order to understand the health and social care items that are relevant to the eligibility and exclusion of patients to the IC services. I asked the following question to focus the discussion:

What health and social care items are important when deciding whether to accept a patient to your service?

The use of problem structuring techniques, such oval mapping, were not suitable as time was limited and it would be very difficult if not impossible to organise a meeting with all the key people for more than a couple of hours. In order to speed up the process we distributed the Minimum Data Set (MDS) assessment form. The discussion examined each of the assessment items of the Minimum Data Set. This approach was to ensure that we would not avoid omitting admission decision-making factors from the discussion. Throughout the process the service managers were told not to think about what would be interesting to know about each patient but to identify items that relate to the decision for the admission process. This was constantly reminded throughout the meeting, which lasted for a couple of hours. There were factors that were important to one service and not to others and some that were important to all. For example many expressed issues like cognitive impairment as important in the decisions process. The group discussed all of the items on the form and some were excluded as irrelevant to the decision of admission. We agreed that the remaining items were essential to the admission process and that these would need to be included in a Standardised Assessment Form. The ICON project group implemented the modified assessment form in the Shepway IC system. Several ICON group meetings took place that centred primarily on the content and format of the forms to be used for data collection. The implementation of assessments forms was a choice given to each service manager to alleviate tensions that are associated with change. Two options were provided: either the data items from the ICON assessment were integrated into existing user forms, or a specially designed separate form comprising the same items was provided. The modified MDS form will be hereon called the ICON assessment form (Appendix H). The admission assessment domains are included in table 5.1.

Table 5.1 The domains of the ICON admission assessment form

Domains in the Assessment form:
Hospital / Social Services numbers (for tracking)
Basic details (e.g. age, ex, marital status)
Cognitive function
Sensory function and Communication
Mood and Behaviour
Social functioning (e.g. interaction, isolation)
Informal support services (caregiver)
Physical function (ADL, IADL)
Continence (bowel and bladder)
Skin condition (ulcers)
Environmental assessment
Service utilisation (not IC services e.g. meals on wheals etc)
Disease diagnosis by category
Health conditions (e.g. falls, preventative health measures, problem conditions)
Medication

5.4.2 The Service Entry Eligibility Criteria & the Assessment forms

In Chapter 4 I demonstrated how the Service Entry Eligibility Criteria were extracted from each service. The criteria were attached to items from the ICON assessment tool in order for them to be coded for use in the simulation models. An example of this is Table 5.2 that shows the CART criteria and the corresponding ICON assessment items.

Table 5.2 Mapping the CART criteria to the ICON assessment items

CART Admission Criteria	Corresponding ICON Assessment Items
Two therapies - Individuals must require two or more elements of the service	None
Age – Individuals must be 65 and above	Date of Birth
Shepway resident – Reside in Shepway	Postcode
Rehabilitation Potential – Require rehabilitation	ADL Performance ADL Decline Experiencing a Flare up Functioning Potential
Mobility – Able to transfer with the maximum assistance of one other person	Eating, Locomotion, Personal Hygiene, Toilet Use
Continence – Continence should be managed	Control of Urinary Function, Bowel Continence
Communicate – Individuals should be able to communicate	Making Self Understood Ability to Understand Others
Terminal Diagnosis – Individual should have a life expectancy of > 6 months	Explicit Terminal Prognosis
Behaviour – Individuals should not behave inappropriately	Behavioural Symptoms
Cognition – Individuals should not be cognitively impaired	Short Term Memory Skills for Decision Making Ability to Understand Others
Motivation – Individuals should show motivation for rehabilitation	Functional Potential

5.4.3 Pilot-Testing of the Assessment form

Pilot testing the data that must be collected is a key element of any research project as it reveals potential problems, thus enabling processes to be refined in terms of both pragmatic issues and data suitability. Pressure from funders to commence data collection at the earliest opportunity prohibited a dedicated pilot-testing phase.

The IC patients were assessed on discharge as well as admission mainly because a patient's discharge profile at one location should match their admission profile at any subsequent location. Hence collecting these data provided a means to examine validity as well as to fill in any gaps from missed assessments. Although, it was necessary to shorten the discharge assessments in order to reduce the workload of staff completing them. Only those domains considered likely to change significantly were included, these are included in table 5.3.

Table 5.3 The domains of the ICON discharge assessment form.

Hospital / Social Services numbers (for tracking)
Cognitive function
Sensory function and Communication
Mood and Behaviour
Physical function (ADL, IADL)
Continence (bowel and bladder)
Skin condition (ulcers)
Health conditions (e.g. falls, preventative health measures, problem conditions)

Patients entered the icon project database by being admitted into one of the systems services. This process would have been much more efficient if a single assessment process and framework was in place. Patients would receive a discharge assessment form, when they were discharged from the service that they entered.

The ethical issue of anonymity of assessment forms in the database was dealt through the use of identification number usually the NHS and or Social Services number. Patients' consent was not required for this element of the project, as health profiles data were only to be used in an aggregated, anonymous form. Service managers kept lists of patients assessed at each location. These were transmitted to the research team at regular intervals, enabling received forms to be checked off against expected ones. This process served as a check to ensure assessments were not lost within the system.

The data collection span for a number of months but the concurrent data collection was from January 2001 onwards until the end of April.

5.4.4 A critical view of the data collection process

The data collection was less successful in some services than others. The success is judged on the numbers of incomplete or lost assessment forms. The ICON team member in charge of the data collection reported, in steering group meetings that forms were not filled in completely because the services were short staffed and simply could not always manage to complete them. This problem was less apparent in Recuperative care because they had comparatively fewer patients due to only having six beds.

The data collection could not be repeated due to time constraints and insufficient funds and a decision was made that we should make the best use of the existing data. The data collected through the assessment forms included the admission date and discharge date as well as their physical and social characteristics. The admission and discharge dates were needed to calculate the patients Length of Stay (LOS) and inter-arrival days. It was important to have LOS and interarrival days for all patients in order to improve the accuracy of the simulation results. Because the whole system model required data for more months than we had collected I used the LOS data and the interarrival data to create suitable probability distributions for each service using Stat::Fit, a statistical software package (Geer Mountain Software, 2001). The package was used in order to ensure efficiency both in terms of time and to reduce manual calculation errors.

The gaps in the data were mainly in terms of the Physical and Social characteristics because the services were required to collect admission and discharge dates. The patients clinical and social characteristics were much more difficult to deal with as the majority of admission and discharge assessment forms arrived at the teams headquarters after the patient had left the system. In these services the employees are faced with many patients and it is difficult for them to recall each case and add the missing data and the aim of the assessment was that the patient was present at the time of the assessment. Also the data assessment forms (questionnaires) needed to be filled in by health and social care professional that were overstretched with their existing amount of work and filling in the patients assessments was a task that could not always be performed and some patients escaped the data collection. Some of the data collection needed to take place in settings that accepted both Shepway and non-Shepway patients, the William Harvey Hospital and the Buckland Hospital. This decision was made because the model was of the Shepway older population and not all of the services are within the geographic confines of the district. The wards outside the Shepway district (Brook & Bethersden and Montgomery & Ramsey), that admit few Shepway residents, only collected data for Shepway patients because there was a general feeling that it would be unfair to ask the staff to collect data for non Shepway patients. There was also the option of obtaining inter-arrival days and LoS for all patients from the hospital information system but unfortunately not the patient's characteristics.

Another issue regarding the gaps in the patient physical and social characteristics was that I could not generate probability distributions for them because various fields were thought to be dependent on each other and it would not be feasible to create input distributions in the same way due to software limitations and my statistical limitations. In addition, the time and effort required would not guarantee success or a more valid data set. A decision was made to use the actual data in Excel, after advice from a geriatrician with knowledge of the assessment form. The gaps in the data still posed a problem and were examined and filled in with the most feasible score for each patient. The score was given on the side of optimism to give the benefit of the doubt. This decision to fill in gaps would of course lessen the validity of the data set to an extent but it would allow the simulation study and experiment to take place and satisfy the authorities that commissioned the project.

5.4.5 The Data Analysis – Generating Interarrival and Length of Stay Distributions

This section is concerned with the process of generating interarrival and length of stay distributions for each of the IC services and wards in our system. Law and Kelton's (1991) three main activities that have influenced the process. The software used for the data analysis, Stat::Fit, lists the distributions in order of best fit based on the Maximum Likelihood Estimators calculations and the goodness of fit tests. Determining the validity of the data and distribution is a vital part data analysis of a simulation study. Stat::Fit has the capability of automating this process and examines the distributions against various tests, which include the chi^2 and the Kolmogorov-Smirnov (for discrete distributions). The results from the data analysis for generating distributions of the patients Interarrival and Length of Stay for: CART, Recuperative Care, Day Hospital, Richard Stevens Ward (stroke), Fitton Ward, Edinburgh Ward, Bethersden Ward, Brook Ward, Montgomery Ward and Ramsey Ward can be found in the Appendix I. Only one example will be provided due to the repetitive nature of this process and that will be for CART.

5.4.6 Generating Interarrival Distributions

The time between two consecutive arrivals is called the interarrival time. This stage is about generating distributions that match the patients' interarrival time for each service and ward.

CART data was collected for approximately a year's because it was part of the pilot study to get the extensive data collection running efficiently. A sample of consecutive interarrival days was chosen to help determine the input distribution. The sample was of 82 patients that entered across 4 months. By importing the 82 CART patients' LOS into Stat::Fit I was able to make an informed choice as to which discrete distributions had the best fit. The Scatter and Autocorrelation graphs of input data generated from Stat::Fit show that the CART interarrival data is comprised of Independent Identically Distributed Random Variables (see Figure 5.3 and 5.4). This is also confirmed by the Autocorrelation of input data graph and the subsequent range that is formed (min=-0.188, max=0.214). The descriptive statistics for this wards data reveal that the distribution is not quite symmetrical as the mean is 1.42 (2d.p.) and median is 1, although the difference is less than 1 day. The skewness is 1.93 (2d.p.), which means that the distribution is skewed to the right and the kurtosis or "tail weight" is 3.83 (2d.p.). The Lexis ratio is 2.16 (2d.p.), which suggests that it may be a Negative Binomial Distribution.

Figure 5.3 The scatter of CART interarrival data

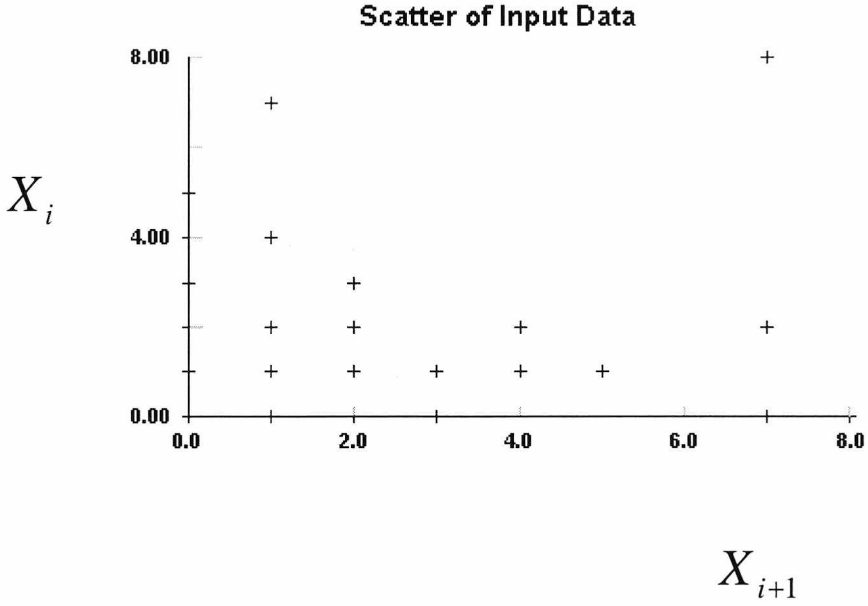
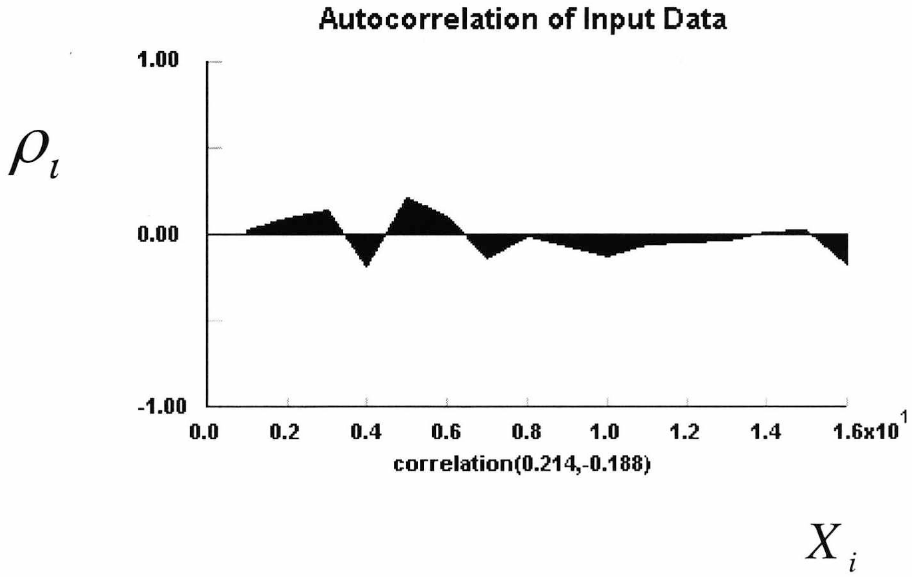


Figure 5.4 The correlation of CART interarrival data



Stat::Fit was used to calculate the Maximum Likelihood Estimation, which provided the main discrete distribution parameters. Stat::Fit ranked the distributions in order of best fit and the Negative Binomial was first, the Geometric was second and the Poisson was third. The distribution of initial choice will be the one ranked best by Stat::Fit. The frequency comparison and the P-P plot showed that the Negative Binomial distribution is a good fit (Appendix I).

The goodness of fit tests showed that the Negative Binomial, the Geometric and the Poisson were suitable distributions as the Chi squared p-values and the Kolmogorov-Smirnov p-values resulted in a Do Not Reject Result. Although any of the above distributions could be used the Negative Binomial is preferred because of the slightly higher p-values compared to the other two distributions. The Negative Binomial distribution is reasonable because it can be used to model the number of trials to get k events, which could be thought of as arrival.

This process was applied to each of the remaining services and the IC wards in order to obtain an interarrival distribution (see Appendix I). The following table lists the generated interarrival distribution for each IC service and ward (see table 5.5).

Table 5.5 The theoretical distributions generated for the IC system

IC Service or ward	Generated distribution
CART	Negative Binomial (2, 0.585)
Day Hospital	Negative Binomial (2,0.416)
Recuperative Care	Geometric (0.0767)
Fitton ward (orthopaedic)	Geometric (0.246)
Richard Stevens ward (stroke)	Geometric (0.26)
Edinburgh ward (general rehabilitation)	Negative Binomial (2, 0.536)
Bethersden ward (general rehabilitation)	Negative Binomial (3, 0.735)
Brook ward (general rehabilitation)	Negative Binomial (3,0.735)
Montgomery and Ramsey (general rehabilitation)	Poisson (0.714)

5.4.7 Generating distributions for the Length of Stay (LOS)

The same process used to determine the interarrival distribution was used to determine the Length of Stay (LOS) distribution. The diagram for the scatter of input data as well as the Autocorrelation range (-0.208, 0.21) confirmed the assumption that the sample comprised of Identically Independent Random Variables. The mean for the sample is 33.4 days and the median is 31 days, which means that the distribution is nearly symmetrical as the difference is less than 3 days. The skewness is 0.53 and the kurtosis is 0.25. The Lexis ratio is 5.75, which suggests that it is a Negative Binomial Distribution. The descriptive statistics are listed in Appendix I for the Community Assessment Rehabilitation Team (CART).

Figure 5.5 The CART scatter of Length of Stay data

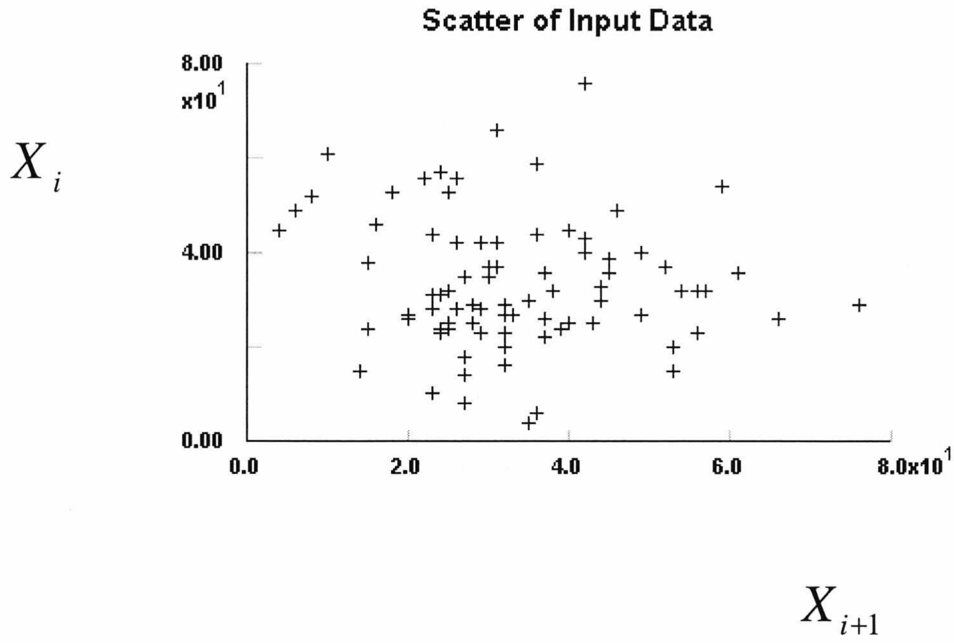
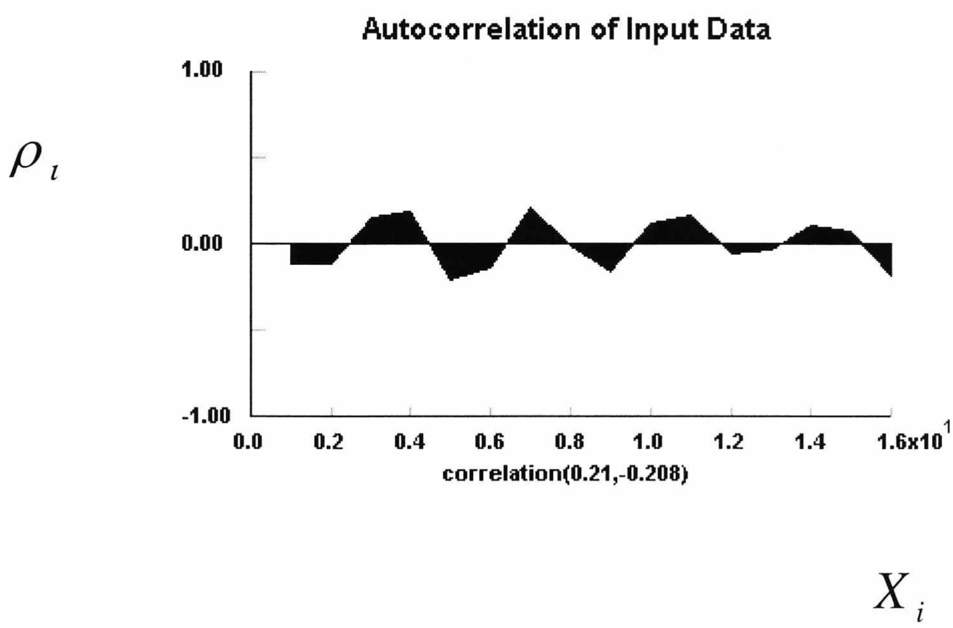


Figure 5.6 The correlation CART Length of Stay data



Stat::Fit calculated the Maximum Likelihood Estimation, which provided the main discrete distribution parameters. Stat::Fit also ranked the distributions in order of best fit and only the Negative Binomial was accepted. The frequency comparison and the P-P plot showed that the distribution is a good fit (Apendix I). The Negative Binomial is suitable as a LOS distribution because it has been used to model "birth and death" (Johnson, 1992) which can be though of as admission and discharge.

The goodness of fit tests showed that the Negative Binomial distribution was suitable as the Chi squared values and the Kolmogorov-Smirnov values as well as their p-values resulted in a Do Not Reject Result. Therefore initially the most appropriate CART LOS distribution was deemed to be the Negative Binomial (7, 0.173).

The process was repeated for each of the IC services and wards (see Appendix I) and the most suitable distribution for each is listed in the following table (see table 5.6).

Table 5.6 Distributions for each service in IC system

IC Service or ward	Generated distribution
CART	Negative Binomial (7, 0.173)
Day Hospital	Negative Binomial (3, 0.0802)
Recuperative Care	Discrete Uniform (7,55)
Fitton ward (orthopaedic)	Negative Binomial (2, 0.0373)
Richard Stevens ward (stroke)	Negative Binomial (2,0.0415)
Edinburgh ward (general rehabilitation)	Negative Binomial (1, 0.0257)
Bethersden ward (general rehabilitation)	Negative Binomial (2, 0.0445)
Brook ward (general rehabilitation)	Negative Binomial (1, 0.034)
Montgomery and Ramsey (general rehabilitation)	Negative Binomial (2,0.0585)

5.5 The computer models

The computer models have been built based on the conceptual models. The individual models are initially modelled exactly as they are in reality with information and data obtained from the actual service managers and employees. The DESM steps for the IC services of older people (Day Hospital, CART and Recuperative Care) was equivalent to undertaking several simulation projects as each service is quite different to the others. In the following sections the computer models will be described for each of the individual services and the "whole system" model.

5.5.1 The CART computer model

The CART service does not have a permanent setting (physical workspace) and this influences the discrete-event simulation model. The model focuses on pattern of the treatment offered unlike simulation models of other services (outside of this research) that model the movement of patients through a physical space. The aim of the model is to examine the staff utilisation and whether there are bottlenecks in the treatment. Therefore, the CART model is mainly comprised of the health care staff (resources) and treatment entities. The model run time is 5 months and the warm up time is 45 days (see Appendix J). The simulation model with the criteria is seen in Figure 5.7 and without the criteria in Figure 5.8. Each older person arrives at the entry point with attributes that are the fields in the admission assessment form. These attributes are in numerical form (as they are scores) and they are held in an Excel file and are fed to the simulation program. The older person also will enter the model with an attribute for each of the criteria that initially are zero until the older person moves through each of the Service's Entry Eligibility Criteria, which take the form of workstation entities. An example of an Eligibility criterion is Cognition. The attribute for each criterion will be scored using Visual Logic code with a number, which either denotes a pass or a failure to pass the criterion. The attribute score for each criterion is calculated at the workstation for each criterion by a Visual Logic code that examines the assessment score attributes that relate to each criterion. Therefore, a patient has moved through all the criteria he or she will have the attributes that he or she had upon entry to the system plus an attribute presenting a pass or fail score for each criterion. The patient will then move to a workstation that will examine the list of attributes and will determine if that patient has passed or failed the SEEC for that service.

The model can show how many patients pass the SEEC. This part of the model is where one can test admission policy. The CART staff were consulted about the hierarchy of the criteria and although this was initially modelled it was dropped as there was disagreement about the hierarchy among the staff. The computer model can examine policies that allow patients to enter if they pass a certain number of criteria, for example six out of the eight criteria.

The second figure showing the CART model has left out the criteria in order to illustrate more clearly the remaining model. The patients after going through the criteria move to the entity called "time accrued" where they are given a new attribute, which is a number that increments each time the older person goes around the loop and reaches time accrued. The number is the days that the older person has been in the system. This number is used at the entity "decision point" to determine if the person has reached his or her LOS, which is done by comparing this number to the older persons LOS (the older persons Length of Stay is an attribute). If these are equal then he or she exits the service. The time accrued attribute has another use, apart from controlling the Length of stay, which is to move the patient to the appropriate treatment path. This is because when the older person is routed to the entity "treatment" that attribute will be used to make a decision about the next route out of the three choices. If the older person is going around the loop for the first time then the routing will be towards the first assessment if it is any other increment (apart from the final week) it will go through the mid assessment route and on the final week will take the third route. The routes are an indication of the type of treatment that the person will receive. The three routes require a different combination of staff and treatment time. The older person will remain in the queue for a few hours after treatment that will allow enough time to go by in order so as to ensure that the person is going around the loop only once a day.

Figure 5.7 The CART model with SEEC

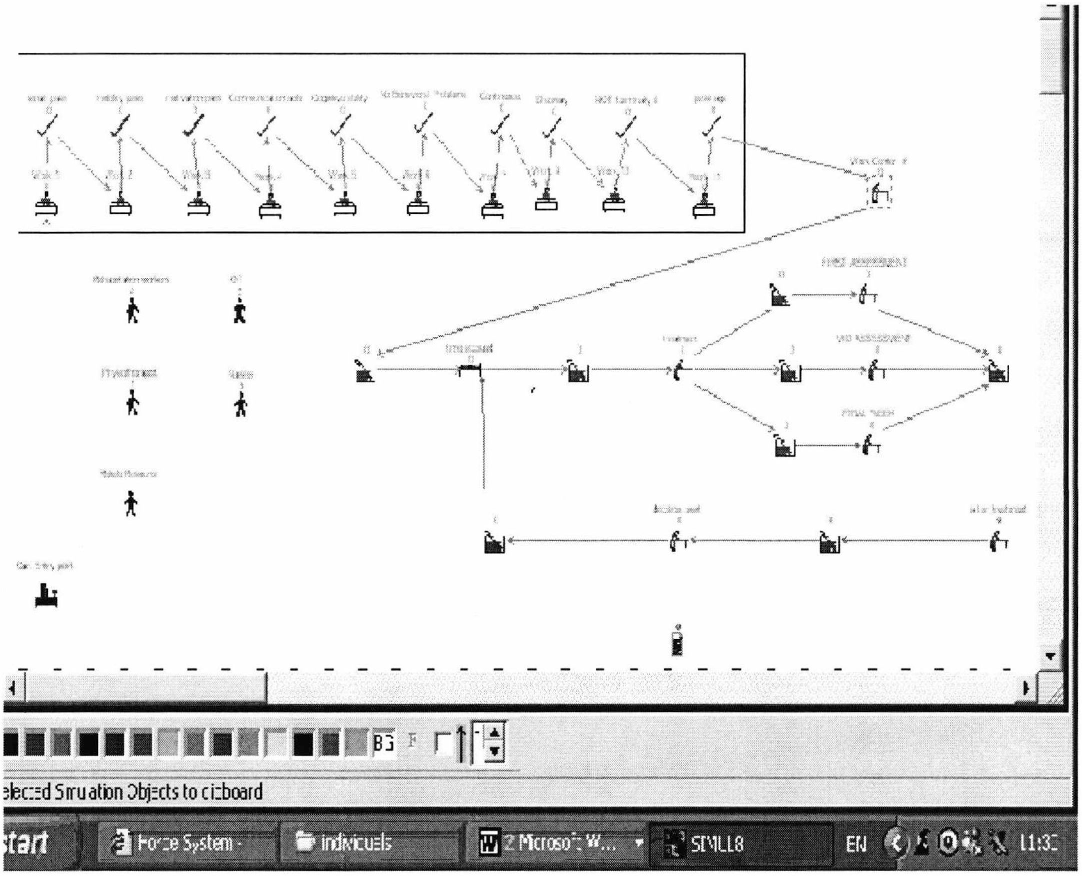
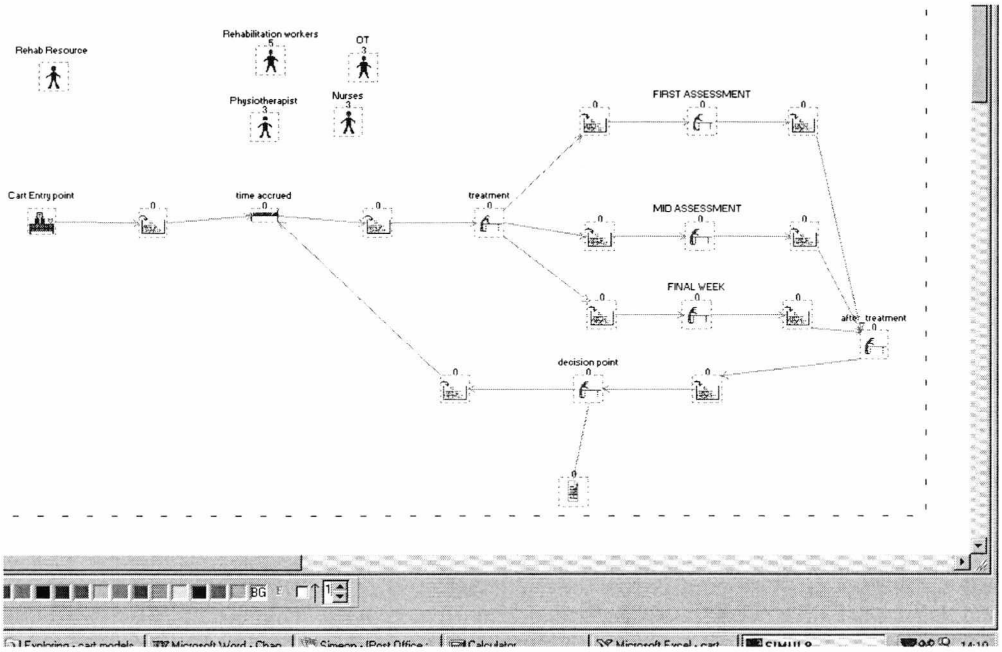


Figure 5.8 The CART model without SEEC



5.5.2 Recuperative Care computer model

The computer model is essentially two models and one of these is further broken down into two submodels (see Figure 5.9). The first Recuperative Care Model is based information provided by the recuperative care manager that divides the service's work into categories (two submodels). Although, there is 24-hour supervision the model focuses on the work done through the day because activities take place between 9 a.m. and 5 p.m. The first category involves the tasks that are involved in the admission process (see left side of table 5.7). These tasks can involve assessment goal planning, paperwork etc. and they do not occur every day but only when a patient is referred and have less priority to the day-to-day care tasks. The second category is providing the day to day therapy and care for the patients (see right side of table 5.7). This type of work will involve the employees helping the patient get up, wash, and get dressed and providing rehabilitation sessions. The model focuses on the utilisation of the service's resources (staff) and the main investigations involve changing the arrival rate to see how that affects the service resources. The two categories of tasks run in parallel and one can consider them as two sub-models of the same model that share the human resources. Both categories of tasks will arrive at the same time into the model. The warm up time for the first model is the same as the warm up time for the second model but in hours. This model warm up time is found from running the second recuperative care model for 5 months (see Appendix J). The second Recuperative Care model simple compared to the first model and examines the capacity of the service in terms of its beds/places (see Figure 5.10). This model is also used to examine the SEEC for recuperative care.

Table 5.7 Recuperative Care Activities

One off input	Time (in hours)	Day to day input	Time (in hours)
Referral	0.5	Washing dressing	0.33
Assessment	2	Rehab sessions	3
Goal planning	1	Note keeping	0.17
Initial assessment	2	Liaison with staff	0.17
Home visit	2		
Paperwork	2		
Discharge work	0.5		
Phone calls	2		

Figure 5.9 The first model for Recuperative Care examining staff utilisation

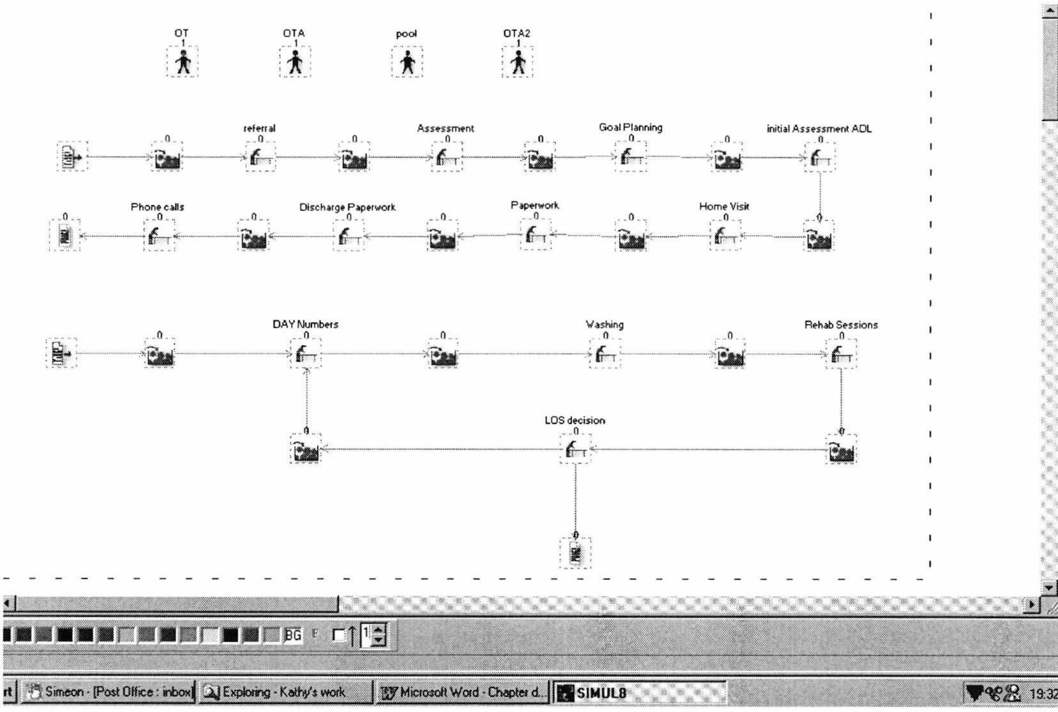
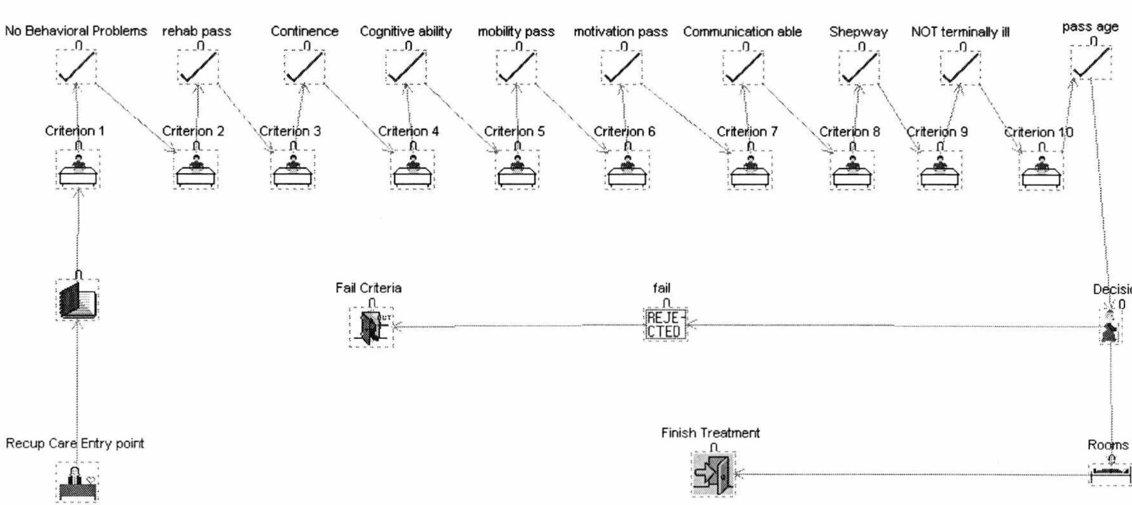


Figure 5.10 The second Recuperative Care model for bed usage



5.5.3 Day Hospital computer model

The day hospital model resembled the CART model as it concentrates on the treatment, and does not have beds. The model is shown with the criteria in Figure 5.11 and without the criteria in Figure 5.12. The patient will enter the model and be initially tested against the criteria as in the CART and recuperative Care model. The main difference of the Day Hospital model with the CART model is the treatment pattern. The entity "treatment" examines the older persons accrued number and if it is under 3 it goes through the first route and if not through the second route. The routes relate to the treatment offered and the staff required. The model is run for 5-months with a warm up time of ten days (Appendix J). Another difference of the Day Hospital model with the CART model is that it only operates for 2 days of the week.

Figure 5.11 The Day Hospital Model with SEEC

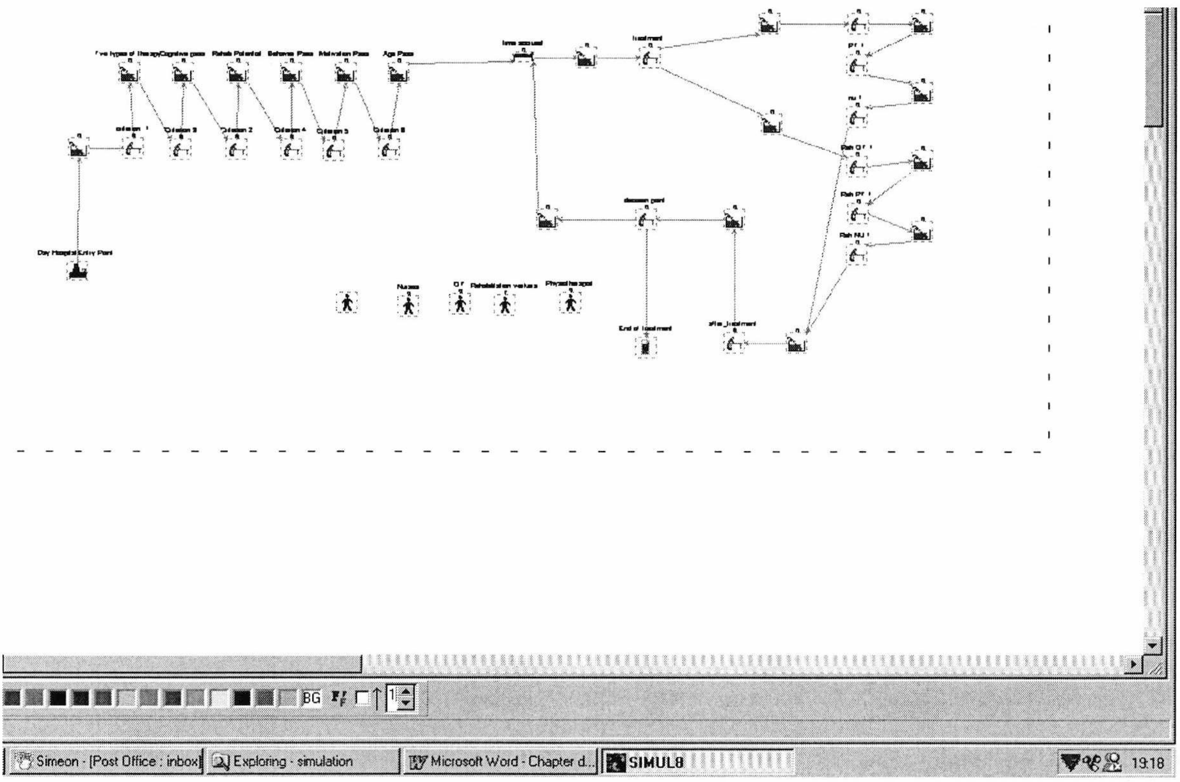
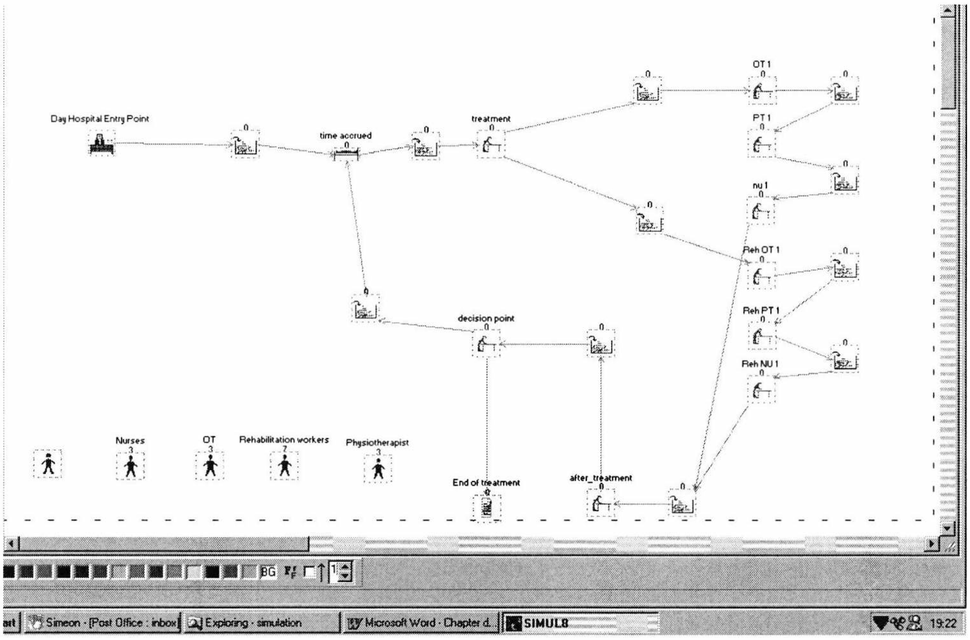


Figure 5.12 The Day Hospital model without SEEC



5.5.4 Description of how the "whole system" model works

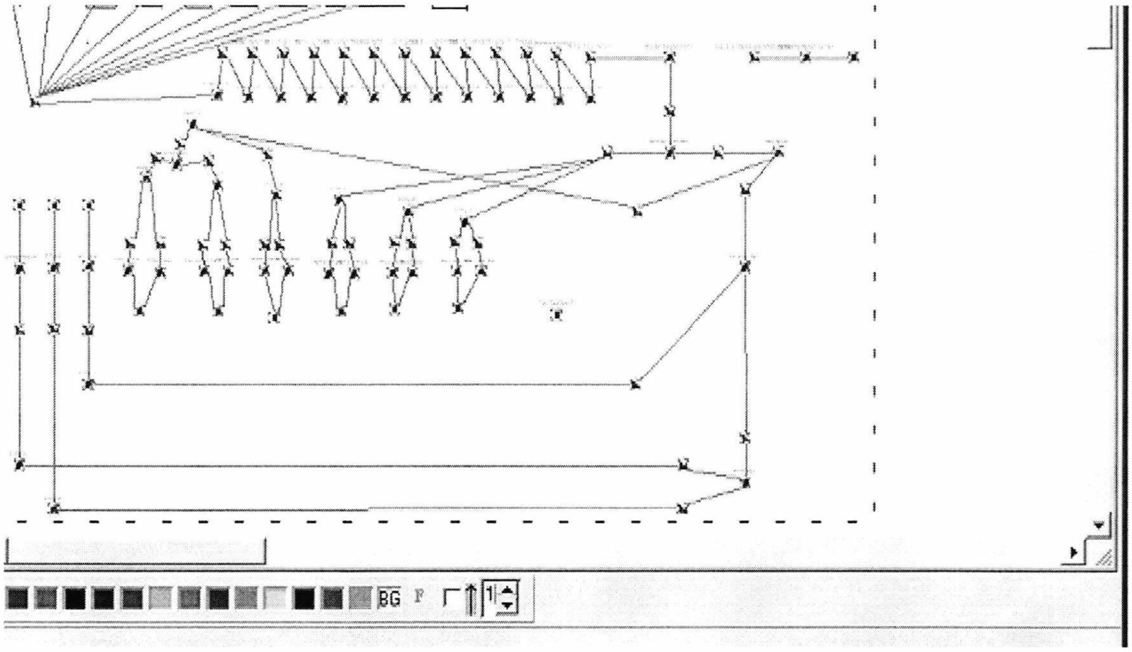
The whole system computer model can be broken up into three main categories of entities; these include the patients, the Service Entry Eligibility Criteria, the services, and the queues for these services.

The model has patients arriving into the system with attributes (approximately sixty) that are mostly the fields from the assessment items as with the individual models. The model is connected to an excel file that contains several excel sheets. There is an Excel sheet of each service with the patients that were assessed at this service over a number of months. The columns hold data from the various fields of the assessment form. The simulation software reads the excel data into the model and each patient entering the model has his or her assessment data as attributes. The model has arrival rates for patients entering the IC system to ensure that the patients are sent in the system at time intervals that resemble the real arrival times. This was achieved through using appropriate inter-arrival rate distributions that were made available through statistical modelling of the time between admission dates explained earlier (see section 5.4.6). These arrival rate distributions are used to show the patients movement into the system over time, which is a fundamental part of the model's dynamic nature. The model runs for approximately 5 minutes and has a RUN time of 5 months. The slow run time is because of the vast amount of attributes that each patient has.

The model has all Service Entry Eligibility Criteria (SEEC) that exist in that system and each patient is tested and scored against all of them. These scores are used to send the patients to the most appropriate setting/service. Each patient will be routed to a service and in some services the patient may need to queue for a bed or place if there is no availability. The places/beds are given in a 'First Come First Served' basis, which is like the real situation. The patients are in the service for the appropriate Length of Stay dictated by the LOS distributions before exiting the system. The model does not have patients moving from one service to another because the rehabilitation and convalescence needs of patients will change after leaving a service. If older people were to move between services, they would need to be scored against the criteria again and this would slows down the model run time even more because of the vast amount of data and information that it already holds. Therefore, this has been dealt with by having the patients re-enter the system as a different entity. There are two reasons for choosing this approach: firstly, in reality many patients will only go to one service and then go home with no further IC services. Secondly, every patient was assessed and was entered in the database as a new entry even if that person was assessed in a previous service. This meant that it was more convenient to treat each new assessment as a new person entering the system.

The services in the whole system model were included with very simple workings (see Figure 5.13). This was to help the model run faster. The services were depicted very simply as beds or places and did not have the richness of their individual models that have resources such as therapists, nurses and rehabilitation workers.

Figure 5.13 The "whole system" model



5.5.5 The "Warm up" time

A warm up time has been calculated for each of the services and wards (see Appendix J) with the approach described in the methodology. The individual services have used the warm up time in their models. However, the warm up time for the whole system model is the largest warm up time from all the services/wards. The reason for this is that all the services/wards will have warmed up before the data is collected and analysed. The warm up time for the system is 90 days as that is the largest warm up time (see Table 5.6).

Table 5.6 The "warm up" time for each service

IC service/ward	Warm up time
CART	45 days
Recuperative Care	10 days
Day Hospital	80 days
Orthopaedic ward (Fitton)	90 days
Stroke ward (Richard Stevens)	90 days
General rehabilitation ward (Edinburgh)	90 days
Rehabilitation ward Bethersden in Acute hospital	55 days
Rehabilitation ward Brook in Acute hospital	70 days
Rehabilitation wards at Buckland hospital (Montgomery and Ramsey)	70 days

5.6 Validation and Verification

This section focuses on techniques used for the model's verification and validation. Three validation elements are required for ensuring that the model at hand is valid. These are conceptual model validity, the data validity and the operational validity. The first part of the validation and verification is examining the data. The simulation models developed have all been validated using various tests and evaluations throughout the development process. The validation and verification process other than myself has been observed by an operational researcher knowledgeable in simulation modelling and other members of the ICON team as well service managers. The "whole system" simulation model has been presented to all localities in East Kent in October 2003 at the request of the East Kent NHS trust. The individual models have been presented to the relevant service manager.

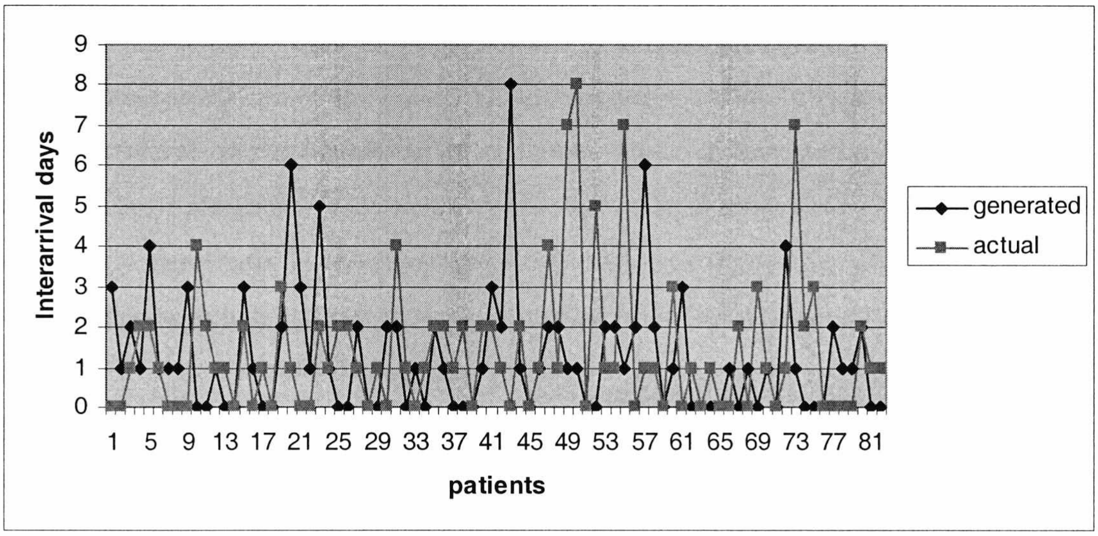
5.6.1 Data Validation and Verification

Part of the validation for the whole system model is the validation of the distributions that have been generated for the inter-arrival and LOS. This has also been part of the bottom-up approach to the "whole system" model development. The guide for the accuracy of the distributions should be high and a general aim is that they are at least 90% accurate. Only the validation and verification of CART's distributions are included in the main body of the thesis because of the repetitive nature of this process. The validation and verification of the remaining distributions is found in Appendix K.

5.6.2 Validation and Verification of CART model

The CART inter-arrival data fitted the Negative Binomial Distribution best. The CART patients are expected to be around 100 over 5 months (82 patients over 4 months). The distribution generated a low 95% range of 80.59, an average of 96.60 and a high 95% range of 112.61. The generated Distribution can be used to generate inter-arrival days that can be compared to the actual data and this is illustrated by a graph of the generated distribution (see Figure 5.14).

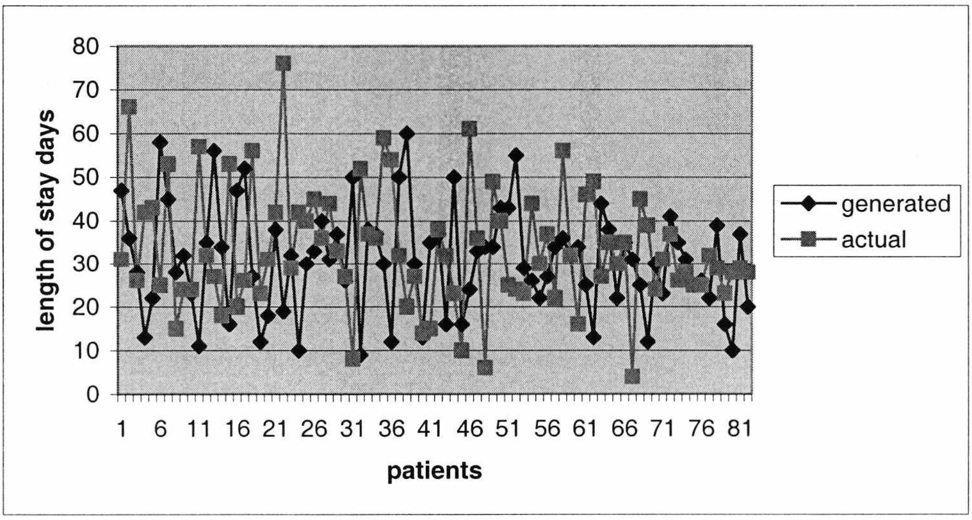
Figure 5.14 Graph comparing the actual CART inter-arrival days with the ones generated by the Negative Binomial distribution.



The Negative Binomial (7, 0.173) was found to fit Length of Stay data for CART. In addition to the Stat::Fit results the distribution was also tested in a simulation model to see if patients stayed in the system for a length of time that resembled the actual data (see Figure 5.15). This distribution gave the most realistic simulation results when compared to the other distributions produced by Stat::Fit. The real LOS data (collected through assessment forms) when analysed with both Stat::Fit and SPSS gave a mean of 33.40, a median of 31 and a mode of 32. The generated distribution when put into simul8 and run (with a warm up time) for a 5-month period the model produced similar results. The simulation results provided an average time in the system in the form of a range. The range had a low 95% of 30.62 an average result of 32.33 and a high 95% range of 33.99. The real data's mean median and mode is within the confidence interval and can therefore be deemed as appropriate. The low 95% range of maximum time in the CART system model was 58.90 the average was 74.40 and the high 95% range was 89.90. The real data used to model the distribution had a maximum value for LOS of 76 days, which is within the range. The distribution is therefore good enough for its purpose and the CART model behaves as it should.

Furthermore, the CART manager said that the care was offered for a max of 6 weeks (approximately 45 days) but the actual data had a max of 76 days of care. The simulation model showed a low 95% range for patients receiving treatment less than 45 days as 77.84% of the patients. An average of 82.63% and a high 95% of the range as in the system less than 45 days is 87.42% of the patients. The real data has 82.93% of LOS within 45 days, which is again within the range of the generated data.

Figure 5.15 Graph comparing the actual CART LOS days with the ones generated by the Negative Binomial distribution.



5.6.3 Validation and verification of the CART model

The CART model was built in several ways before selecting the model closest to reality based on the CART employees' descriptions and information. Each of the entities for the model was tested before joining the whole model together (bottom-up approach). The validation has been about focusing on the conceptual model validity, the data validity and the operational validity. The conceptual model has been the product of informal discussions and interviews with CART employees. The data validity has mostly involved the data analysis involving the CART inter-arrival and Length of Stay as well as selecting a suitable warm up time.

The operational validity has involved the use of various techniques. The first technique used was the "Animation" which is described in Appendix G. The older people were observed flowing through the model and particularly observed the first time they went around the loop to see if the followed the first route. In the same way the operational graphics and the traces technique were applied with a special emphasis on checking the patients' "time accrued" attributes as they moved through the model. The second technique was performing degenerate tests, which was about selecting different length of time for the patient to wait in a queue after his/her treatment before going around the loop again. Determining the most appropriate amount of time for the older person to wait was crucial as it affects the actual time the person stays in the model. If the time is too short then the patient goes around the loop too many times and larger queues are created among the other things. Similarly in the extreme conditions test's various extreme waiting times were considered that were either too short or too long. The third technique was examining the "Event Validity" and this mainly involved the resource utilisation. The employees volunteered crucial information about the Physiotherapist being overworked in real life, which matched the physiotherapy utilisation results of the model. The model has been run several times and in multiple runs and the results do not alter significantly which satisfies the internal validity check. The validation and verification of the CART model suggests that the model adequately satisfies its purpose, which is to enable the system owners to examine its resources.

5.6.4 Validation and Verification of the Recuperative Care model

The validation and verification techniques were applied to various elements of the two models depending on their uncertainty about the operation and difficulty. For example, many techniques were applied to the staff utilisation model as it was quite a complex concept to model and a high degree of confidence was required. Each of the techniques was applied as follows:

The "Animation" technique was applied to both the models in order to see that the patients entered the system and flowed through the model. "Degenerate tests" and the "Extreme Conditions" test were very useful in testing the staff utilisation model especially in terms of the priority scores given to various workstations. Simul8 allow the modeller to score each workstation (between 1=low-100=high) in terms of its importance in attracting resources. This is similar to real life as priority is given to certain work. This model is sensitive to changes in the priority scores as extremely low and high priority scores showed. Therefore once reasonable priority scores were included the operational graphics were observed to see if the queues and staff utilisation were reasonable.

In interviews with recuperative care employees, we were told that some beds are under-utilised and this was evident from the results of the second model. This satisfies the "Event Validity" test and the "Face validity" test.

The traces test was applied as in the CART and Whole system model to examine the criteria which is described more thoroughly in the validation and verification of the whole system model (see section 5.6.6).

5.6.5 Validation and Verification of the Day Hospital

The validation and verification for the day hospital model was similar to the approach used for CART. Therefore, only elements that were unique or extremely important will be mentioned. The technique called "historical data" validation was applied using empirical distributions for the inter-arrival and LOS. Day Hospital employees also mentioned that the nurse was overworked and this was also confirmed in the model (face validity). A vital element of the day hospital validation was from one of the findings, which is explored in the results chapter, that it would be beneficial that the day hospital operates for a third day. The service implemented a third operational day before being presented with the simulation results due to increasing demand, which suggests that the model predicted the future (Historical methods).

5.6.6 Validation of whole system model

The conceptual model validity and the data validity have involved the Soft Systems Methodology and the data analysis that is discussed in previous sections and chapters. The remaining section will focus on the used that ensure operational validity.

The first validation technique is about examining the animation of the whole systems model. The system model's animation has the older people shown as work items that enter the system through the entry points and will move rapidly through the SEEC and then go through the rule base which will send the older people (work items) to their appropriate service. Once they have remained in the service for their LOS they will move into the "exit doors". This process has involved running the simulation model at various speed settings and observing the movement to see if it matches the expected movement.

The second technique applied to the whole system model is Event Validity. The main use of this technique was to observe if the older people went to the same service in the model as in real life. In fact, there were many occurrences of older people being sent to a different service to the one referred to in real life. This does not have a great impact on the validity of the model because the SSM phase showed that the system owners and actors in fact are aiming towards this conceptual model. The system owners and actors have acknowledged in discussions that implementing a single assessment framework and a structured approach to referral would have a great impact on the real situation.

The "Internal validity" technique was applied to the whole system model by running several replications of the simulation and changing the seed of the random number generator to examining the amount of internal variability. An indication that the internal validity is acceptable comes from examining the 95% range of the patient arrivals and Length of Stay. The lower and upper limit for a run time of 5-months is acceptable as seen from the data validation and verification.

The final validation technique applied to the whole system model is face validity. Throughout this phase of the development of the model, the ICON project team with various members from the project steering group were presented with information and assumptions. These mainly took the form of presentations that focused on diagrams (such as the simul8 "front end" diagrams) and there was a general agreement to the conceptual model and its assumptions.

5.6.7 Verification of whole system model

The model verification involves examining the computerised model for errors. Because simulation software is used, there is less possibility of errors from the computer program. However, the visual logic extensions require testing and this is mainly done through mixed testing.

The "Extreme conditions" technique was part of the model development process. The decision making rule base that determined where older people should go according to their eligibility criteria was drastically modified to see the various routings. This technique was very useful in verifying the rule base.

The "Fixed values" technique was applied in combination with the Traces technique was to examine the Service Entry Eligibility Criteria. Older people would enter the system with particular attributes that would allow them to pass a certain number of criteria. Each of the older persons would be observed entering each of the criteria and the score for passing the criterion would be examined. Therefore if you expect the older person to fail a criterion and he or she passes then the visual logic is incorrect.

The final verification technique is about observing the "Operational graphics" which has mainly involved observing the model's queues and other performance measures as the model moves through time. The software has features that enable this to be done. This has meant that blockages (bottlenecks) have been found and corrected as well as any other computer model discrepancies.

The validity of the whole system model has been heavily dependent on the data and the conceptual model. This is because of the model's intended purpose is not primarily to make decisions about resources but to look at the impact of implementing the desirable decision making mechanism, which is also inline with current Department of Health policy on the development of an IC system. As the real system develops and stricter and more precise SEEC are put in place as well as a standardised assessment form it will then be more feasible to validate and verify the whole system model in a more traditional way.

5.7 Chapter conclusions

This chapter has provided an explanation of what the models look like and what they can do. The next chapter provides the "what if" analysis that will explore various desirable and feasible actions that could be taken in the future to improve the services and the decision making mechanism for the whole system.

6 Discrete- Event Simulation Results

The chapter will present the results from the discrete-event simulation models described in chapter 5. Specifically the results will be the following:

Results from "what if" analysis for CART model

Results from "what if" analysis for Recuperative Care model

Results from "what if" analysis for Day Hospital model

Results from "what if" analysis for whole system model

The scenarios for all models are a product of the discussions with the service managers and are thought to be important and worthwhile to explore.

6.1 Results for individual models

The results for individual models are a result of fifteen concurrent runs enabled by a Simul8 multiple run facility.

6.1.1 The CART "what if" scenarios.

The aim of the CART model is to examine the current staff utilisation rates and look at scenarios that have been discussed in meetings with CART employees. Again, like other individual models the aim is to have 85% utilisation of the resources, which are the CART staff. The following table lists the scenarios that are examined (see Table 6.1):

Table 6.1 The CART "what if" scenarios

Scenario 1
Current situation with focus on resource utilisation. 3 Nurses, 1 Physiotherapists, 2 Occupational Therapists(OTs), 4 Rehabilitation workers
Scenario 2
Reducing Staff 2 Nurses, 1 Physiotherapist, 1 OT's, 4 Rehabilitation workers
Scenario 3
Increasing the number of patients entering the service and staff. 3 Nurses, 2 Physiotherapists, 2 OTs, 5 Rehabilitation workers

6.1.1.1 Scenario 1 – CART

This scenario is closest to reality in terms of the parameters used. The average number of people entering CART over a period of 5 months is approximately 100 patients. The initial model produced the following interval of (100,112.26) with an average of 106.13 patients over five months. The operational graphics of the model as well as the summary of the results do not show large queue sizes or large queuing times. This is because the number of patients entering the service is low for the available resources and the CART manager in discussion with the ICON project team has confirmed this. In addition, the utilisation of resources is generally low (see table 6.2).

Table 6.2 The percentage utilisation of CART resources (Scenario 1)

% Utilisation	Low 95%	Average	High 95%
Nurses	44.51	47.11	49.72
Rehabilitation workers	85.92	87.85	89.77
Occupational Therapist	60.01	63.4	66.8
Physiotherapy	76.76	79.06	81.35

6.1.1.2 Scenario 2 – CART

The main aim of the second scenario is to examine the possibility of having fewer resources with the same number of patients entering the service in order to achieve the target of 85% resources utilisation. The most realistic option is to reduce the nurses by one as one of the nurses is also the service manager and most likely has managerial duties to deal with that are not included in the model. The result show that the rehabilitation workers are under utilised and the others are close to aim of 85% utilisation (see table 6.3).

Table 6.3 Percentage utilisation of CART resources (Scenario 2)

% Utilisation	Low 95%	Average	High 95%
Nurses	89.01	91.38	93.75
Rehabilitation workers	61.75	64.27	66.79
OT	69.65	73.35	77.05
Physiotherapy	88.53	90.99	93.45

6.1.1.3 Scenario 3 – CART

In this Scenario, the aim is to increase the number of people entering the service to around 40 people per month whilst increasing the number of staff to cope with the increase. The resources have increased as follows: the rehabilitation workers have increased to five, the physiotherapist has increased by one (total of two), the nurses have reverted to three and the Occupational Therapists are two. The model was initially run with different resource options and this combination of staff was the most suitable for the service requirements. The choice of resources to be increased is because the physiotherapist is overutilised in previous scenarios with fewer patients and more rehabilitation workers are needed to cope with this increase. In addition, rehabilitation workers are cheaper to employ than the other CART staff and cost is always a concern. The average number of patient entering the service has been increased from 106 to 197 over five months, which is almost a 100% increase (refer to scenario 1 and table 6.4).

Table 6.4 Interval of patients arriving to CART

CART	Low 95%	Average	High 95%
Number entered	189.62	197.47	205.31

Table 6.5 Percentage utilisation of CART resources (Scenario 3)

% Utilisation	Low 95%	Average	High 95%
Nurses	94.8	96.12	97.43
Rehabilitation workers	85.36	86.93	88.5
OT	92.93	94.88	96.82
Physiotherapy	79.64	83.31	86.97

The CART results could be improved e.g. the utilisation could get closer to 85% by having some part time therapists but the results have demonstrated the approximate amount of staff required for that increase in patient numbers (see table 6.5).

6.1.2 Results of testing CART SEEC

The CART was found to have 10 main criteria that could be translated through the assessment form fields into rules for the model. For people treated by CART table 6.6 shows the proportions passing each criterion.

Table 6.6 Proportion of CART patients passing each criterion

CART Criteria	% of clients that Passed each Criterion
1. Rehabilitation potential	61%
2. Mobility	73%
3. Motivation	87%
4. Communication	93%
5. Cognition	99%
6. Behaviour	99%
7. Continence	96%
8. Shepway Resident	100%
9. Terminal Diagnosis	100%
10. Age	100%
11. Two types of therapy	100%

Table 6.7 CART Criteria Passed

Criteria Passed:	% passed
10/10	27%
9/10	79%
8/10	96%
7/10	100%
6/10	100%

The most difficult criterion to pass is Rehabilitation Potential and I decided to explore the reasons for this low percentage. The CART manager suggested that this was because many patients were independent in their Activities of Daily Life (ADLs) such as bathing or dressing upper or lower body which trigger the SEE criterion but had needs in their Independent Activities of Daily Life (IADLs) such as meal preparation and ordinary housework, which are not included in the ICON (modified MDS) instrument. This is particularly surprising as 39% of patients are not likely to have Physiotherapy needs, which are linked to ADLs. However, the CART service manager decided along with other service managers to exclude these items in the meeting to shorten the MDS into the ICON version but the IADL fields are in the full MDS. This finding highlight the need for a more comprehensive assessment form to be used in practice such as the full MDS.

We also explored the proportion of clients/patients that passed 10 out of the 10 criteria, at least 9 out of the 10 criteria etc in order to examine if patients generally passed all their criteria (see table 6.7). All clients passed at least 7 of the 10 criteria (see table 6.7). The three criteria with lower proportions of client passes are Rehabilitation Criterion with just 61%, Mobility with 73% and Motivation with 87%. Only 27% passed all 10 criteria and 79% of CART clients passed at least 9 out of 10 criteria. In reality, all the patients examined against the criteria entered the service but if the criteria were used strictly, some patients would be "rejected" and referred to a more suitable service. These findings highlight the fact that criteria are not applied strictly.

6.1.3 Recuperative Care "what if" scenarios

There are two models for recuperative care one that focuses on staff utilisation and one that examines bed utilisation. Both models have a virtual run time of five months but they have different time measurements. The first is run in hours and the other in days. Both models are required in order to fulfil the aims of the Discrete Event Simulation Modelling, which are:

- To see what the current bed and staff utilisation is with the current patient arrival rate.

- To examine what would happen to staff if patient arrival rates were increased to the point of a maximum of 85% utilisation of beds.

- To examine how many staff would be required for an 85% bed utilisation.

The results from each model will be presented separately. The patient arrivals will vary slightly because of the nature of simulation modelling (1-3 extra patients over 5 months) (see table 6.8 & 6.9).

Table 6.8 Recuperative Care scenarios for Bed Utilisation

Scenario 1
Current Scenario: patient arrival interval (11.19,13.47)
Scenario 2
patient arrival interval (15.46, 18.14)
Scenario 3
patient arrival interval (18.98, 22.22)
Scenario 4
patient arrival interval (22.98, 27.15)

Table 6.9 Recuperative Care scenarios for Staff Utilisation

Scenario 1
Current Scenario: 1Occupational Therapist (OT) & 1 Occupational Therapist's Assistant (OTA) patient arrival interval (10.19,11.81)
Scenario 2
1 OT & 1OTA patient arrival interval (18.14, 21.46)
Scenario 3
1 OT & 1OTA patient arrival interval (21.9, 26.24)
Scenario 4
1 OT & 2 OTA patient arrival interval (22.98, 27.15)
Scenario 5
1 OT & 1OTA & 1 part time OTA (3 Days a week) patient arrival interval (22.98, 27.15)
Scenario 6
1 OT & 1OTA & 1 part time OTA (2 Days a week) patient arrival interval (22.98, 27.15)

6.1.4 Results of Recuperative Care "what if" scenarios for bed utilisation

6.1.4.1 Scenario 1 – bed utilisation for Recuperative care

This is the scenario for the current situation with a patient arrival interval of (11.19, 13.47) over a period of 5 months. The average number is 12.33=~13 patients/clients and the average number of patients data collected over a five month period is around 11. The data collected has reportedly got a few missing assessment forms so the patient arrival interval is thought to be more realistic.

The results show that there are no queues and that the average utilisation is 3 beds of the available 6 (see table 6.10). The next scenarios will concentrate on finding out what patient arrival interval will achieve an 85% bed utilisation.

Table 6.10 Recuperative Care Bed Utilisation (Scenario 1)

	Low 95% range	Average	High 95% range
Min use	0	0	0
Average use	1.86	2.1	2.34
Max use	4.28	4.8	5.32

6.1.4.2 Scenario 2 – bed utilisation for Recuperative Care

The patient arrival interval for this scenario is (15.46, 18.14) with an average of 16.80=~17 patients arriving over 5 months. The average bed utilisation is increasing compared to the previous scenario (see table 6.10 & 6.11) but in order to reach 85% utilisation 5 beds must be utilised on average. The average queuing time is 0.16 days, which means that a suitable patient that has undergone all assessments would be able to enter without waiting for a bed to empty.

Table 6.11 Recuperative Care Bed Utilisation (Scenario 2)

	Low 95% range	Average	High 95% range
Min use	0	0	0
Average use	2.64	2.95	3.27
Max use	5.58	5.87	6

6.1.4.3 Scenario 3 – Bed Utilisation for Recuperative Care

The patient arrival interval for this scenario is (18.98, 22.22) with an average of 20.60=~21 patients arriving over 5 months. The average queuing time is 0.97 days, which is still acceptable as in the previous scenario (see table 6.12). The average bed utilisation is 3.83 =~4 beds of the available 6 beds (see table 6.13). This can be improved by further increasing the patient arrival rate.

Table 6.12 Recuperative Care queuing times for Beds (Scenario 3)

	Low 95% range	Average	High 95% range
Min queuing time	0	0	0
Aver queuing time	0.04	0.97	1.91
Max queuing time	1.85	6.27	10.68

Table 6.13 Recuperative Care Bed Utilisation (Scenario 3)

	Low 95% range	Average	High 95% range
Min use	0	0	0
Average use	3.44	3.83	4.21
Max use	5.79	5.93	6

6.1.4.4 Scenario 4 – Bed utilisation for Recuperative Care

The patient arrival interval for this scenario is (25.48, 28.25) with an average number of 26.87=~27 patients arriving over 5 months. The average queuing time is 4.42=~5 days, which is still acceptable according to the recuperative care manager (see table 6.14). The average bed utilisation is 4.79 =~5 beds of the available 6 beds which satisfies the 85% requirement (see table 6.15). This model has determined that when the patient arrival interval is (25.48-28.25) over 5 months the bed utilisation is closer to 85%.

Table 6.14 Recuperative Care queuing times for Beds (Scenario 4)

	Low 95% range	Average	High 95% range
Min queuing time	0	0.13	0.42
Aver queuing time	1.04	4.42	7.79
Max queuing time	7.89	13.93	19.98

Table 6.15 Recuperative Care Bed Utilisation (Scenario 4)

	Low 95% range	Average	High 95% range
Min use	0	0	0
Average use	4.39	4.79	5.19
Max use	6	6	6

6.1.5 Recuperative Care "what if" scenarios for Staff utilisation

6.1.5.1 Scenario 1 – staff utilisation for Recuperative Care

The first scenario will be about examining the current staff utilisation rates, which is based on the current arrival rates. The patient arrival interval for this scenario is (10.19, 11.81) with an average of 11 patients arriving over 5 months. There are practically no queues being built up for any of the staff interventions and the staff are underutilised (see table 6.16). The next scenario is to increase the patient arrivals to see if there are any queues building up and to see how that affects the average staff utilisation.

Table 6.16 Recuperative Care Staff utilisation Rates (Scenario 1)

	Low 95% range	Average	High 95% range
OT	35.68	42.99	50.3
OTA	53.66	58.83	63.99

6.1.5.2 Scenario 2 – staff utilisation rates for Recuperative Care

The patient arrival interval for this scenario is (18.14, 21.46) with an average of 19.8=~20 patients arriving over 5 months. The average queues for the daily interventions are not large enough to cause concern, as they do not exceed 1.23 hours. The staff utilisation is beginning to reach the target rate of 85% (see table 6.17). The next scenario is to increase the patient arrivals slightly in order to increase the patient interval to approximately the same level when the bed utilisation was 85% in the other model.

Table 6.17 Recuperative Care Staff utilisation Rates (Scenario 2)

	Low 95% range	Average	High 95% range
OT	74.71	82.66	90.60
OTA	78.61	84.51	90.41

6.1.5.3 Scenario 3 – staff utilisation rates for Recuperative Care

The patient arrival interval for this scenario is (21.9, 26.24) with an average of 24.07 patients arriving over 5 months. The average queues for the daily interventions are not large enough to cause concern, as they do not exceed 1.97 hours but the "one off" tasks have large queues. Queues times for one off tasks are starting to cause concern and especially Paperwork, as 83 working hours will pass on average before the OT can get to it (see table 6.18). The staff utilisation has exceeded the target rate of 85% and both members of the staff are over utilised (see table 6.19). The following scenario will examine how many more staff are needed for an 85% utilisation of beds.

Table 6.18 Queue times for "one off" interventions (Scenario 3)

queue times in hours	Minimum	Average	Maximum
Goal planning	0.14	22.17	124.33
Initial Assessment	0.52	16.66	63.99
Paperwork	74.95	82.88	143.54

Table 6.19 Recuperative Care Staff utilisation Rates (Scenario 3)

	Low 95% range	Average	High 95% range
OT	87.92	92.94	97.95
OTA	88.73	92.97	97.20

Scenario 4 – staff utilisation rates for Recuperative Care

The patient arrival interval for this scenario is (22.98, 27.15) with an average of 25.07 patients arriving over 5 months. The patient arrival rate has been increased to match the finding of the bed scenario results of attaining 85% bed utilisation. As the patient arrival rates have been slightly increased and because there were queues in the previous scenario an extra staff member has been added in the form of an OT Assistant (now there are 2 in total). The average queues for the daily interventions are not large enough to cause concern, as they do not exceed 2.7 hours. Queues times for one off tasks have been reduced and all are now less than 1.66 hours (see table 6.20). The staff utilisation is beneath the target rate of 85%, which means that the next scenario will examine having a second part time Occupational Therapists Assistant instead of a full time one as in this scenario (see table 6.21).

Table 6.20 Queue Times For One Off Interventions (Scenario 4)

queue times in hours	Minimum	Average	Maximum
Referral	0	1.66	8.08
Paperwork	0	1.61	6.34

Table 6.21 Recuperative Care Staff utilisation Rates (Scenario 4)

	Low 95% range	Average	High 95% range
OT	70.14	74.48	78.81
OTA	61.22	67.12	73.02

6.1.5.4 Scenario 5 – staff utilisation rates for Recuperative Care

The patient arrival interval for this scenario is the same as in the previous one (22.98, 27.15) with an average of 25.07 patients arriving over 5 months. In this scenario, the staff are comprised of 1 Full Time (FT) OT, 1 FT OTA and 1 Part Time (PT) OTA (3 days a week). The average queues for the daily interventions are not large enough to cause concern, as they do not exceed 1.68 hours but the one off tasks have slightly larger queues. Queues times for one off tasks are not a cause for concern as the averages do not exceed 2 working days (see table 6.22). The staff utilisation for the PT OTA is beneath the target rate of 85% therefore the next scenario examines a two day PT OTA instead of a 3-day OTA (see table 6.23).

Table 6.22 Queue Times For One Off Interventions in hours (Scenario 5)

queue times in hours	Minimum	Average	Maximum
Referral	0	9.5	39.37
Paperwork	0	4.15	24.82
Goal planning	0	3.98	27.93
Discharge work	0	2.14	18.08

Table 6.23 Recuperative Care Staff utilisation Rates (Scenario 5)

	Low 95% range	Average	High 95% range
OT FT	76.59	82.52	88.45
OTA FT	68.76	74.61	80.46
OTA PT	64.69	70.38	76.07

6.1.5.5 Scenario 6 – staff utilisation rates for Recuperative Care

The patient arrival interval for this scenario is again (22.98, 27.15) with an average of 25.07 patients arriving over 5 months. In this scenario, the staff are comprised of 1 Full Time (FT) OT, 1 FT OTA and 1 Part Time (PT) OTA (2 days a week). The average queues for the daily interventions are not large enough to cause concern, as they do not exceed 2.74 hours but the one off tasks have larger queues. Queue times for one off tasks are starting to increase although they do not exceed 2 working days (see table 6.24). The staff utilisation for the FT and PT OTA is beneath the target rate of 85% but it is unlikely to have a staff member working for 1 day per week (see table 6.25). In addition, it is important to note that some queues being built up for they "one off interventions" are because they are mainly an OT task and there is only one OT. The third member of staff was chosen to be an OTA because it would be more cost effective because an OTA's salary is less than an OT's.

Table 6.24 Queue Times For One Off Interventions (Scenario 6)

queue times in hours	Minimum	Average	Maximum
Referral	0.27	15.65	55.95
Initial Assessment	0	1.97	19.15
Paperwork	0	4.99	30.36
Goal planning	0	6.2	39.73
Discharge work	0	2.51	27.34

Table 6.25 Recuperative Care Staff utilisation Rates (Scenario 6)

	Low 95% range	Average	High 95% range
OT FT	79.33	85.57	91.82
OTA FT	73.7	79.13	84.56
OTA PT	66.08	72.24	78.41

6.1.6 Results from Recuperative Care SEEC

Recuperative Care Patients passed each of the criteria with a high percentage with the exception of the Mobility criterion (see table 6.26). The service's manager when asked about the results from the mobility criterion explained that the finding was correct and that many of the older people there had mobility needs. The criterion was in place because there was no physiotherapy input and older people needed to be able to transfer with the assistance of one. This service requirement would be changed in time, as the input of a physiotherapist will be included in the service care package. Therefore, this criterion will be more flexible. All the Recuperative Care patients passed at least 8 out of the 10 criteria, which means that they generally satisfy the service initial requirements (see table 6.27). Again, like the other services the SEEC are not applied strictly to each patient but they are used as guide.

Table 6.26 Proportion of Recuperative Care Patients Passing each Criterion

Recuperative Care Criteria	% of clients that Passed each Criterion
1. Rehabilitation potential	95%
2. Mobility	45%
3. Motivation	100%
4. Communication	100%
5. Cognition	95%
6. Behaviour	86%
7. Continence	95%
8. Shepway Resident	100%
9. Terminal Diagnosis	100%
10.Age	100%

Table 6.27 Recuperative Care Criteria Passed

Criteria Passed:	% passed
10/10	32%
9/10	86%
8/10	100%
7/10	100%
6/10	100%

6.1.7 Day Hospital "what if" scenarios

The Day Hospital model simulates a two-day week for five months with a warm up time of eighty days. In discussions with the Day Hospital manager and her team, I found out that they felt that they were generally over-utilised. This is confirmed in Scenario 1 where the Day Hospital has queues that are caused by bottlenecks because of insufficient resources at some workcentres. The remaining scenarios examine various options about reducing queues and resource utilisation (see table 6.28).

Table 6.28 The Day Hospital "what if" Scenarios

Scenario 1 patient interval (41.91,49.15)
1 Nurse, 2 Physiotherapists, 2 OTs, 3 Rehabilitation workers
Scenario 2
2 Nurses, 2 Physiotherapists, 2 OTs, 3 Rehabilitation workers
Scenario 3
2 Nurses, 2 Physiotherapists, 2 OTs, 5 Rehabilitation workers

6.1.7.1 Scenario 1

When running the first scenario it was clear that the nursing treatment offered at this service was severely over-utilised by the patients as described by the manager, who is also the nurse. The queues were due to the over-utilisation of the nurse and in the model, they affect the utilisation percentages of the other resources by making them appear lower than what they ought to be (see table 6.30). In fact, there were large queues building for nursing treatment, offered after the second week of attendance, with an average queue of 30 patients (see table 6.29). This obviously does not mean that patients are actually queuing in the real setting for this treatment but what it actually means is that the patients are not getting the amount of nursing treatment required. The first scenario is usually the one closest to reality and used to validate and verify the model. However, in this case the model illustrates that I have been misled about the nursing treatment time in an attempt to demonstrate that guidelines are followed. This is because this service like many of the other services did not want to undertake a further data collection as the ICON form has taken up a lot of their time. They also do not record the length of time that they spend with each patient. Despite the lack of data I feel that as the Nurse's aim is to provide those treatment times the aim of the next scenarios should be to find out about how many extra staff are needed to comply with their guidelines.

Table 6.29 Queue size for Nursing Treatment (Scenario 1)

Queue size	Low 95% range	Average	High 95% range
Minimum Q size	9.02	12.8	16.58
Average Q size	25.84	30.56	35.27
Maximum Q size	41.48	47.73	53.99

Table 6.30 Percentage utilisation of Day Hospital Resources (Scenario 1)

% Utilisation	Low 95%	Average	High 95%
Nurses	99.06 %	99.28 %	99.46 %
Rehabilitation workers	70.77 %	72.32 %	73.88 %
OT	54.9 %	56.06 %	57.23 %
Physiotherapy	54.65 %	55.89 %	57.13 %

6.1.7.2 Scenario 2

The main aim of the second scenario is to reduce the queue for nursing treatment and the nurse resource utilisation. In this scenario, we have added an extra nurse and this reduces the queues to an average of two patients, and the average nurse utilisation is reduced to 67% (see table 6.31 & 6.32). This percentage utilisation would have been higher if a new bottleneck was not created by the overutilisation of the rehabilitation workers that subsequently create a queue of patients (the bottleneck has moved forward). This Scenario does not eradicate all queues as a new one is created and has an average queue size of 12.57 patients because there are not enough rehabilitation workers.

Table 6.31 Queue size for Nursing Treatment (Scenario 2)

Queue size	Low 95% range	Average	High 95% range
Minimum Q size	0 patients	0 patients	0 patients
Average Q size	1.35 patients	1.8 patients	2.26 patients
Maximum Q size	4.22 patients	4.93 patients	5.64 patients

Table 6.32 Percentage utilisation of Day Hospital Resources (Scenario 2)

% Utilisation	Low 95%	Average	High 95%
Nurses	65.65 %	67.05 %	68.46 %
Rehabilitation workers	99.90 %	99.94 %	99.98 %
OT	66.88 %	65.88 %	66.88 %
Physiotherapy	65.98 %	67.34 %	68.71 %

6.1.7.3 Scenario 3

In this scenario, the aim is to reduce the over-utilisation of rehabilitation workers and the subsequent queues that were mentioned in the previous scenario. In order to achieve that we have increased the rehabilitation workers by two. There are now practically no queues but staff are slightly over-utilised (see table 6.33). However, unless the patient interval increases adding a new Nurse, Occupation Therapist and Physiotherapist would make the service underutilised. While these scenarios were being explored the Day Hospital started operating for an extra day a week (from 2 to 3 days) because of the problems of finding staff to hire for the then current operational days. This means that fewer patients would have attended each of those days and therefore a better service would have been provided. The Day Hospital manager reported that these scenarios confirmed her decision to operate an extra day a week.

Table 6.33 Utilisation of Day Hospital Resources (Scenario 3)

% Utilisation	Low 95%	Average	High 95%
Nurses	84.53%	88.73%	92.93%
Rehabilitation workers	81.24%	85.88 %	90.53%
OT	85.51%	89.76%	94.02%
Physiotherapy	85.10%	89.44%	93.78%

6.1.8 Results of Day Hospital SEEC

The Day Hospital was found to have 6 main criteria. Significant numbers of patients did not pass two of these, namely Rehabilitation Potential with 44% and Cognition with 46% (Table 6.34). Finding out that 54% of Day Hospital patients are cognitively impaired did not surprise the Day Hospital staff but it did surprise the IC system owners. This demonstrates that simulation has been used to communicate and prove issues had not been achieved with other means such as discussions in meetings. The day hospital staff had not been happy about rehabilitating cognitively impaired older people and felt that the Day Hospital was not the appropriate environment for them. However, they said that they had very little choice but to accept these patients. The older people that failed the cognition criterion also failed the rehabilitation potential criterion not because these items share assessment fields but because the patients were inappropriately referred there. This is confirmed in Table 6.35, which shows that 93% of the Day Hospital patients pass at least 4 out of 6 criteria.

Table 6.34 Proportion of Day Hospital Passing Each Criterion

Day Hospital Criteria	% passed
1. Two types of Therapy	100%
2. Rehabilitation Potential	44%
3. Cognition	46%
4. Behaviour	90%
5. Motivation	97%
6. Age	90%

Table 6.35 Percentage that passed the Day Hospital Criteria

Criteria Passed:	% passed
6/6	12%
5/6	63%
4/6	93%
3/6	100%
2/6	100%

6.2 The whole system model's "what if" scenarios

There are two points that need to be made before examining the results from the Scenarios. Firstly, all of the scenario results will be of a single run, unlike the individual models that are a result of 15 runs, because of the size of the model. The second point is that the CART and Day Hospital have been modelled as being dependent on places rather than resources. The CART places are taken to be between 40 and 45 because the CART manager mentioned in interviews that they are capable of concurrently treating that amount of patients. The Day Hospital is modelled with 24 places again as a result of a conversation its service manager. This is in order to reduce the unnecessary complexity and it does not interfere with the scope and the purpose of the system model.

The scenarios for the system model are as follows:

- Scenario 1 is the closest to reality as the services that exist are in place and the only major deviation from reality is having a Single Assessment Process.

- Scenario 2 looks at reducing the large queues that have formed for recuperative care by routing some of the patients to CART.

- Scenario 3 is about improving on scenario 2 by increasing the Day Hospital places.

- Scenario 4 is about improving on the results from scenario 3 by increasing the Recuperative Care places

- Scenario 5 is about creating a service for the cognitively impaired

- Scenario 6 is about creating a service for patients with behavioural problems

6.2.1 Results for Scenario 1

In the first scenarios results, the wards do not appear to have large queues like some of the hard core IC services that have surprisingly large queues. This could be considered as an indication that implementing a Single Assessment Process through the use of a single assessment tool would increase the amount of patients that qualify to go to the "hard core" IC services. This finding is extremely desirable by all in the system. The results of this first scenario will focus on the utilisation information of the IC services.

Table 6.36 Results of Scenario 1 for "whole system" model

Service Type	CART	Recuperative Care	Day Hospital
Number in Queue	0	69	5
Min time in queue	0	54	0
Ave time in queue	0	96.41	7.54
Max time in queue	0	138	20
Min Number in Q	0	25	0
Ave Number in Q	0	49.23	5.21
Max Number in Q	1	69	14
Number in Service at the end of simulation run.	14	6	24
Min resource Use	0	0	0
Ave resource Use	15.49	6	23.47
Max resource Use	23	6	24
Number completed treatment	74	32	108
Min time in system	5.12	61.12	6.12
Ave time in system	32.74	109.24	43.41
Max time in system	61.12	157.12	120.122
% in system less than time limit of 6 weeks	82.43	0	59.26

The model finished the 5-month run with the recuperative Care service having an extremely large queue of 69 people (see table 6.36). The average number in the queue throughout this run has been 49 people with an average queuing time of 96 days. This has affected the length of time the older people are in the IC system as none have left the recuperative care service in less than 45 days (6 weeks). The Day hospital is also experiencing over-utilisation with an average resource use of 23.5 (1 d.p.) out of the 24 available places. Although, in reality there is no set number of places, the resources are limited and in order to provide appropriate amounts treatment for each patient the number of patients registered must be controlled. The increase of Day Hospital places is explored in Scenario 3. The CART results show that the service is slightly under-utilised. This is a result of the older people being more eligible to the Recuperative Care SEEC rather than the CART SEEC. This is because their SEEC are similar and this is an indication of the limitations of their current criteria. This finding is the motivation behind the next Scenario that will aim to reduce the queuing time for Recuperative Care patients.

6.2.2 Results for Scenario 2

In this scenario, the simulation model will send some recuperative care patients to CART when the recuperative care queue exceeds 7 people. This may seem unrealistic as a solution but it does reflect current practices by the referrers to these services. However, it would be more desirable by the system owners to improve the criteria and have more patients qualifying for CART. The patients that are suitable for either of these services are similar and in some cases patients choose Recuperative Care over CART because of the setting that it is provided e.g. inpatient service similar to residential home (and vice versa).

Table 6.37 Results of Scenario 2 for "whole system" model

Service Type	CART	Recuperative Care	Day Hospital
Number in Queue	0	7	14
Min time in queue	0	4	0
Ave time in queue	0	24.91	9.52
Max time in queue	0	39	25
Min Number in Q	0	2	0
Ave Number in Q	0	5.93	7.68
Max Number in Q	1	7	19
Number in Service at the end of the simulation run	45	6	24
Min resource Use	0	0	0
Ave resource Use	24.29	6	23.82
Max resource Use	36	6	24
Number completed treatment	113	35	107
Min time in system	11.95	16.12	7.12
Ave time in system	35.28	54.86	41.50
Max time in system	88.12	81.12	81.12
% in system less than time limit	76.99	28.57	59.81

The results from this second scenario are an improvement to the results of the first Scenario as the Recuperative Care queuing time has been dramatically reduced (see table 6.37). This shows that a simple change in the IC decision-making mechanism can have dramatic results. In the following Scenario, the results are further improved by increasing the Day Hospital places.

6.2.3 Results for Scenario 3

Scenario 3 is about keeping the changes from Scenario 2 whilst increasing the Day Hospital places by 6 (24 existing places + 6 new = 30 places) to 30 places, This means that the Day Hospital would have the appropriate number of staff to have 30 patients a month on their "books". This increase is because of a conversation with Day Hospital staff that mentioned that the Day Hospital could manage approximately 12 patients per day and treatment was at that time twice a week. Patients do not necessarily need to attend both sessions per week therefore it was thought that the Day Hospital could have a maximum of 24 places for patients at any time. The Day Hospital manager suggested that they were considering operating for 3 days a week and this scenario is relevant.

Table 6.38 Results of Scenario 3 for "whole system" model

Service Type	CART	Recuperative Care	Day Hospital
Number in Queue	0	7	0
Min time in queue	0	24	0
Ave time in queue	0	32	0.52
Max time in queue	0	47	5
Min Number in Q	0	3	0
Ave Number in Q	0	6.68	0.40
Max Number in Q	1	7	4
Number in Service at the end of simulation run	43	6	25
Min resource Use	0	0	0
Ave resource Use	28.23	6	27.19
Max resource Use	45	6	30
Number completed treatment	121	29	115
Min time in system	11.12	38.12	4.12
Ave time in system	37.34	62.29	36.87
Max time in system	78.95	113.12	101.12
% in system less than time limit of 6 weeks	76.86	20.69	73.04

The Day Hospital results are further improved with an average resource use of 28 places out of the available 30 (see table 6.38). The average time in the system has also improved from 41.5 days to 36.9 days, which is more desirable by the system owners.

Table 6.39 Number of Patients in wards at the end of the simulation run (Scenario 3)

Service type	Number in Queue	Number in service	Number treated
RVH wards	9	51	166
WH wards	0	35	157
Buckland wards	0	38	170

The people that qualified for the wards at the end of the simulation run have very few queues. Table 6.39 provides the distribution and number of people in the wards at the end of the run. The result from each ward has been grouped into one category relating to the hospital that it belongs. As mentioned in the first Scenario the queue sizes for the wards are not a cause for concern. This could mean that if SEEC were used then fewer people would actually require ward treatment than the ones going there currently (in reality).

6.2.4 Results for Scenario 4

This scenario is about increasing the Recuperative Care beds by 6 beds to 12 beds in total.

Table 6.40 Results of Scenario 4 for "whole system" model

Service Type	CART	Recuperative Care	Day Hospital
Number in Queue	0	7	0
Min time in queue	0	5	0
Ave time in queue	0	15.02	0
Max time in queue	0	27	0
Min Number in Q	0	1	0
Ave Number in Q	0	5.38	0
Max Number in Q	1	7	1
Number in Service at the end of simulation run	13	12	24
Min resource Use	0	0	0
Ave resource Use	18.08	12	20.45
Max resource Use	26	12	30
Number completed treatment	89	52	94
Min time in system	4.12	20.12	3.12
Ave time in system	32.87	47.42	31.04
Max time in system	70.12	90.12	82.12
% in system less than time limit of 6 weeks	82.02	57.69	78.72

This Scenario shows that even increasing the number of Recuperative beds from 6 to 12 does not make a difference in the queuing time or number as there are many older people that qualify for recuperative care (see table 6.4). This finding, that more people could go to recuperative care, can be considered as a "prediction" or the model may have influenced reality because it was completed by Spring 2002 but in October 2003 a system manager reported that the Recuperative Care service was now at full capacity.

6.2.5 Results for Scenario 5

This Scenario is about keeping the changes up to Scenario 3 but creating new IC services for the purpose of rehabilitation and convalescence for the Cognitively Impaired. This service is not defined in detail; it could be a ward or a service similar to recuperative care. For example, it could be a service similar to Recuperative Care but with more staff and 24 hour supervision. The model examines a change in policy where patients with cognitive impairment would be rehabilitated separately. Therefore, this scenario explores a potential IC avenue and not a specific service or set of services. This is an idea that was discussed with several IC and other health and social care workers because they reported problems with mixing impaired with non impaired patients. However, the National Service Framework for Older people (Department of Health, 2002c) recommends that people with mental health problems should be included in IC. This can be considered as a potential service "gap" in the system and the results are equally supportive (see table 6.41). The results show a substantial effect on the wards and a less significant effect on the 'hard core' IC services. It is equally surprising to see that if SEEC were strict the vast amount of people with cognitive impairment requiring rehabilitation would end up in the wards (see 6.42). This scenario can also indirectly provide a solution to creating a service for the cognitively impaired as the "system owners" can changing some wards into IC for the cognitively impaired without having a drastic affect on the rest of the system.

Table 6.41 Results of Scenario 5 for "whole system" model

Service Type	CART	Recuperative Care	Day Hospital
Number in Queue	0	4	0
Min time in queue	0	4	0
Ave time in queue	0	31.26	0.09
Max time in queue	0	48	4
Min Number in Q	0	0	0
Ave Number in Q	0	5.92	0.06
Max Number in Q	1	7	1
Number in Service at the end of simulation run	20	6	20
Min resource Use	0	0	0
Ave resource Use	21.92	6	22.54
Max resource Use	30	6	30
Number completed treatment	96	31	103
Min time in system	9.12	23.12	3.12
Ave time in system	35.87	59.83	33.13
Max time in system	79.12	87.12	104.12
% in system less than time limit of 6 weeks	79.12	12.90	77.67

Table 6.42 Number of patients in wards at end of run (Scenario 5)

Service type	Number in Queue	Number in service	Number treated
Cognitive impairment	327	50	151
RVH wards	0	4	25
WH wards	0	20	77
Buckland wards	0	9	70

The improvement of having such a service or set of hard core IC services for the cognitively impaired is found in the ward results rather than the hard core IC services. The effect of this change does not have a great impact on hard core IC services, which is positive as it means that the model does as it is suppose to do which means that the rule base is correct. This is another indication that the model is operationally valid.

6.2.6 Results for Scenario 6

This scenario is about removing patients with Behaviour problems, which is again something that was deduced from conversations with nurses and various other IC staff. This is similar to the previous scenario but removing the patients with Behaviour problems. IC employees have mentioned that although some people with behavioural problems are also cognitively impaired many are not. Therefore, it is worthwhile exploring this scenario as well.

Table 6.43 Results of Scenario 6 for "whole system" model

Service Type	CART	Recuperative Care	Day Hospital
Number in Queue	0	7	0
Min time in queue	0	20	0
Ave time in queue	0	28	0.92
Max time in queue	0	42	9
Min Number in Q	0	4	0
Ave Number in Q	0	6.63	0.67
Max Number in Q	1	7	5
Number in Service at the end of the simulation run	22	6	30
Min resource Use	0	0	0
Ave resource Use	23.37	6	27.43
Max resource Use	30	6	30
Number completed treatment	100	34	104
Min time in system	9.12	33.12	3.12
Ave time in system	35.76	54.03	41.08
Max time in system	72.12	99.12	141.12
% in system less than time limit of 6 weeks	73.00	23.53	61.54

The effect of this decision is again greater on the wards than the 'hard core' IC services (see table 6.43 & 6.44). The number of those with behaviour problems is less than those with cognitive impairment although as discussed previously some may fall under both categories (see table 6.44). The importance of both of these Scenarios is that it provides proof that there are many in the system that have needs and requirements associated with Cognitive Impairment and Behaviour and there is currently no provision for them. Furthermore they are treated amongst those that do not have these requirements, which is problematic to both the patients and staff.

Table 6.44. Other distribution of patients at end of simulation run.

Service type	Number in Queue	Number in service	Number treated
Behaviour Problems	6	50	142
RVH wards	3	35	110
WH wards	3	26	130
Buckland wards	0	40	144

6.2.7 Discussion of the whole system model

On inspection of the movement of the people in the model going to the wards or the 'hard core' IC services, it was found that many of them in reality went to different services or wards to the ones allocated. This can be attributed to one of four reasons:

- These patients should have gone to the service or ward as shown in the model but were sent inappropriately to another setting. This can be because the patients were not referred to the appropriate setting in the first instance and were accepted by a different service. This is because there is no whole system approach to the referral mechanism.

- The criteria do not have a strict enough interpretation through the assessment items or that the assessment items are not filled in correctly. Therefore, the patients in the model are not being sent to the most appropriate service for their needs.

- The criteria, the assessment data and the model logic are correct but the services do not have a clear enough focus and therefore a patient's needs could be treated in more than one service. The question posed in this case is whether services should have a clear and distinct patient focus. If all IC patients have the same needs then only service would be needed, and this would be the most cost effective option. However service managers have reported that patients have different needs and requirements.

- The model logic is incorrect and that is the reason that many of the people went to different services to the ones in reality.

The likelihood of one of the above being solely responsible is unlikely and it is thought that some of the above reasons may have influenced the outcome of the patient movement through the model. It is thought that the later option is the least likely, as the model has been examined very carefully to determine if it obeys its logic or not. In addition, the model's logic has been determined from observation and interviews with the IC services. The project team discussed this finding with a senior IC manager and she provided the answer. The manager (also system owner) had visited some of the wards to examine the discharge process and discovered that several of the patients were inappropriately placed there at that moment in time. It is also possible that many of those patients were inappropriately placed there in the first place. This means that the most likely option is the first one that the SEEC, the referral, admission and discharge process require further improvements to fit with the worldview of the system owners. The model provides an insight and understanding of the issues and problems that relate the IC system. The results are useful because we can inform the system providers about the following:

- The Single Assessment Process can work with a comprehensive standardised assessment tool. This has been examined in a virtual world and if it is implemented in the real world then clear and precise criteria are needed that can be mapped to a standardised assessment form.

- There are service gaps in the system for the cognitively impaired and those with behaviour problems.

- Many older people are not referred to the most appropriate service according to their needs.

- Finally this IC simulation experiment has equally been about exploring whether a model of a complex health and social care system could be built, as well as creating a tool for future decision making.

6.3 Summary of individual models' "what if" analysis

This section will provide a brief overview of the scenarios examined for each of the models with a particular focus on the most useful results.

The CART first scenario was the closest to reality and it showed that resources are under-utilised apart from the rehabilitation workers. Therefore, the current numbers of patients entering the service do not require the amount of resources available to them. The following scenario examined reducing resources to reach as close as possible to an 85% staff utilisation with the existing rates of patients entering the service. The final scenario examines an idea mentioned by CART that potentially it aims to have around 40 patients a month entering the service whilst increasing the staff but maintaining utilisation rates as close as possible to 85%. This is achieved if the physiotherapist and rehabilitation workers are increased.

The Recuperative Care models found that Recuperative care is underutilised in terms of both staff and beds. The following scenarios concentrated on finding out how many patients needed to be admitted to the service to have an 85% utilisation of their beds and the second model examined how many staff would be needed for that number of patients.

The Day Hospital was found to be over utilised and the subsequent scenarios examined increasing the current number of staff to get the staff utilisation rate as close as possible to 85%. Another main finding for the Day Hospital was the numbers of cognitively impaired patients that are inappropriately placed there that are also thought to lack rehabilitation potential.

The whole system model has illustrated that the Recuperative Care service could be in high demand if the Single Assessment Process is put in place with SEEC. The service providers are also changing the policy of providing the service free to patients based on being means tested. The scenarios provide the IC system owners with information that will prepare them for an increase in the demand for Recuperative Care. The "whole model" also examines a number of scenarios including creating a service for the cognitively impaired and the model shows that many patients, especially those in the wards would be eligible. The system owners are considering changing one of the rehabilitation wards into a rehabilitation service for the cognitively impaired.

6.4 Conclusion

The results of the models have been presented to all the interested parties and all have been accepted as a valid representation of reality. The simulation model has provided the system's actors and owners with understanding of how the IC system can be improved and what is actually currently "missing". In some cases, the results have provided them with "ammunition" as they have confirmed problems and issues that they are facing but cannot prove by any other means especially when it comes to funding staff.

The simulation modelling has completed the evaluation of the operational function of IC as it has addressed issues surrounding capacity, resources and Service Entry Eligibility Criteria. The models of the services are expected to change with time as the services are further developed but approach was an experiment to see if simulation modelling could be used to model such a complicated system and services.

7 Conclusions and lessons learnt

7.1 Introduction

In the introductory chapter of this thesis, I explained the background of the project and briefly defined the scope of the project and the areas that the PhD would contribute towards. In the literature Review, I explained IC and I wrote about the work of others that is of relevance to this project. In the methodology chapter, I provided some information about Shepway and I explained what elements of the methods I would use to tackle the problem and how I would apply them. In the SSM chapter, I showed how I used SSM and what I found from the SSM phase. In the simulation chapter I showed how I created the models and the simulation results chapter I included the main simulation results and findings from the "What If" analysis. In this chapter I will explain how and what this work contributes to the body of scientific knowledge and I will start by repeating the initial PhD contribution framework.

The primary aim of the investigation was to better understand and to answer the action research questions about the IC function. The second aim of the investigation was to contribute to the available scientific knowledge. The investigation will further the knowledge through learning across three dimensions which is illustrated in Figure 7.1.

The first dimension (1) is learning about the methods, SSM and DESM, by applying their theory to the problematic situation. The SSM contribution includes my experience of using "primary task" root definitions and whether current SSM and other relevant theories and frameworks are useful. The DESM contribution includes modelling a community system instead of the traditional inpatient facilities, modelling a complex integrated system, using DESM under a soft paradigm, and examining a series of questions by Robinson et al. (1998). Part of the learning is about using the two methods in the specific situation, which is Intermediate Care.

The second dimension (2) is learning about applying a multimethodology and the combination of methods. The contribution is demonstrating that these two methods that come from two different paradigms can be combined if the soft paradigm is used as the overall guiding approach. I discuss my experience and feelings of applying a multimethodology and I contribute my beliefs about using Mingers's grid to map methodologies. I also contribute specific learning about applying the multimethodology to the intervention system and IC in general.

The third dimension (3) is learning about the specific situation. I have contributed my experience of applying OR to community Health and Social care for older people and reported findings from the project that are generalisable to other IC systems and services.

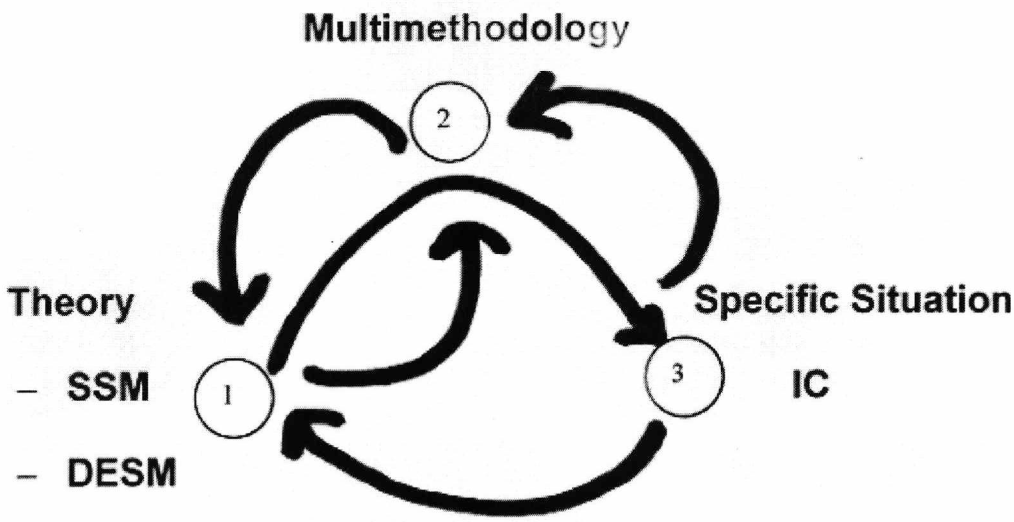


Figure 7.1 the contribution of the PhD learning

7.2 Discussion of action research approach

In the introduction, I used Checkland's words to explain how I could make this action research project part of the body of scientific knowledge.

"*action research should be conducted in such a way that the whole process is subsequently recoverable by anyone interested in critically scrutinising this research. This means declaring explicitly, at the start of the research, the intellectual frameworks and the process of using them which will be used to define what counts as knowledge in this piece of research. By declaring the epistemology of the research process in this way, the researchers make it possible for outsiders to follow the research and see whether they agree or disagree with the findings. If they disagree, well informed discussion and debate can follow. Also the learning gained in a piece of organisation-*

based action research may concern any or all of: the area focused on in the research; the methodology used; or the framework of ideas embodied in the methodology."

(Checkland, 1999, p.A40)

However, by undertaking this project I have been able to create an action research framework that can be used by others to evaluate their IC functions. The framework consists of the following set of steps that match the generic set of action research steps (see Figure 1.1 from the introduction chapter):

Enquiry
Map the IC system and services to be evaluated and explore IC literature.
Create awareness (project team and owners) of project and objectives and enable participation and cooperation of project team or analyst with IC system and services.
Talk either through interview or group meetings to system owners, actors and people in the wider system. Discuss primary tasks and collect information about system and services.
Diagnosis
Determine what primary tasks the system should have with owners and actors.
Compare real world and systems world with owners and actors and determine desirable and culturally feasible actions.
Action planning
Get agreement/consensus from owners and actors for action.
Agree data collection tool with owners and actors and timescale to model patient decision making mechanism of system through simulation model.
Action
System owners and actors make feasible and desirable changes to primary tasks.
Build simulation models for services and system and collect data.
Evaluation and Learning
Conduct "What if" analysis using simulation model and learnt about system
Present findings to system owners and employees.

In the introductory chapter, I mentioned the look-think-act action research framework that Stringer (1996) proposes as the starting point. However, one criticism of Stringer's (1996) framework is that it does not fit with my framework as it ignores learning. The IC framework has been part of the learning for Shepway and happens to also contribute to the understanding and development of IC in general. This is something that is not generally accepted as action research projects are usually only about learning about the actual system e.g. Shepway. In fact, Stringer writes that

"Community-based action research starts, as does all research, with a problem to be solved. Unlike positivist science, however, its goal is not the production of an objective body of knowledge that can be generalised to large populations. Instead its purpose is to build collaboratively constructive descriptions and interpretations of events that enable groups of people to formulate mutually acceptable solutions to their problems."

(Stringer, 1996, p.188)

The reason that Stringer makes this statement is because social and behavioural worlds do not have the stability required by a scientific method to produce the same results. However, in this case part of the results of this action research project is to test the framework. The system owners have other localities apart from Shepway that are also of interest to them. They commissioned a research project to enable them to evaluate the operational function of their IC systems and Shepway was subsequently chosen as the starting point and the testing ground for a framework. The funding would not stretch to their other systems but part of the Shepway experience and the findings are generalisable. The approach has generated a body of knowledge that can be used to inform other IC systems owners about a framework that can be used to improve and evaluate their IC function. This process is developed for specific geographic regions (and population) that individually can be considered as whole system. I have also been able to produce a definition of evaluation in IC which is something that has not been defined. Of course this is just the starting point and in time as more research is conducted the operational function will become more precise and what should be part of the evaluation of IC will possibly change.

Another contribution is the acknowledgement that this action research project has some key characteristics, described by Stringer (1996), that are considered beneficial as they are part of our modern and democratic society's social values. This acknowledgement can help understand and explain the reason that the findings from this project have been accepted by the stakeholders in the intervention system. (This project can also be referred to as action research in the community otherwise known as community based action research.)

Stringer (1996) writes that a *"fundamental premise of community-based action research is that it commences with an interest in the problems of a group, a community, or an* *organisation. Its purpose is to assist people in extending their understanding of the situation and thus in resolving problems that confront them*". The research started with an interest in the problems of a group and specifically the group of people In East Kent. The research was about understanding the Intermediate Care function resolving the current problems of this function as well as helping them confront and prepare for the Single Assessment Process (Department of Health, 2002b). Therefore this premise is shared.

Community based action research is democratic and it enables the participation of all people. In addition to this point Mahachek (1992) explains that the success of a simulation project is more dependent on the participation and motivation of the health employees than the analyst's talents. In this research I tried to talk and interview as many different types of IC employees as I could but due to practicalities it was not possible to talk to all the employees in the Shepway IC system. Therefore I could not enable the participation of all IC staff although no one was "turned away" that wanted to participate. In addition I spoke several times to various individuals and groups that were involved about the potential benefits of this action research project to their working lives. These motivational discussions were repeated throughout the project to encourage data collection and before sorting out problems that occurred e.g. patient data getting misplaced or lost etc.

Community based action research is equitable acknowledging people's equality of worth. By using SSM as part of the process of conducting action research a multitude of views were taken into account that all had the same weight and to some extent they were different pieces of the puzzle. Therefore the project complies with this characteristic.

Community based action research is liberating, providing freedom from the oppressive, deliberating conditions. The project did not need to liberate anyone from anything so you may think that this characteristic is redundant in this project. However, it has empowered the IC employees to have 'a say' on how their system could work. It is generally known that health care employees especially of lower "rank" do not get the opportunity to give their views on operational matters. This IC Community action research can also be thought of as liberating from the patient's point of view (older person) because IC is about the older person being as independent as possible.

Therefore, by improving the IC function we are allowing more people to be liberated from dependency and to maximise the level of independency.

The final characteristic of community based action research is that it is life enhancing, enabling the expression of people's full human potential. The term life enhancing is one of the key characteristics of the IC function. In this research, we found that there was a gap in the service provision for cognitively impaired and therefore reporting this finding will probably result in an action that will be life enhancing for the cognitively impaired older people that require rehabilitation.

7.2.1 Discussion of the project's notional relationships – the Intervention system, the Intellectual resources and the problem content system

The importance of discussing the notional relationships within a project is highlighted by Mingers (2001) who has produced a diagram (see figure 1.2, section 1.3) that represents the relationship between the three notional systems. The notional systems are the problem content system (real world situation of concern), the intellectual resources system (available theories and methodologies) and the intervention system (the agent undertaking the intervention). In this project the problem content system is the IC system, the intellectual resources system were OR methods and techniques that are relevant to this problem and I was the main agent of the intervention system. Mingers (2001) provides some critical questions that concern the context of an intervention. These questions have been used to examine the relationship between the three notional systems. Some questions have been answered in the initial problem exploration phase. Therefore, only the questions that have not already been considered will be explored.

Initially I will consider the relationship between my existing knowledge and experience, and the intellectual resources system. At the start of the project, I had some experience in simulation modelling from an undergraduate project that received a first for, which could mean that I applied the simulation theory correctly to the problem situation. In contrast, my experience of SSM was purely from reading books and studying for an undergraduate module and I had no real proof that I was able to apply it to a real problem. In fact, I have had to learn again about SSM in order to apply it and I did not feel able to teach it to IC employees for them to undertake. SSM practitioners have been known to teach the process to their clients and get them to do it and take the consultancy role (Checkland, 1990). However, it is unlikely that the system owners could have found suitable candidates that had the time available even if there was someone who was suitably experienced to teach it. I also do not believe that it has been a disadvantage in this project because my role has been more of a facilitator and I have worked with the employees in a manner that has not aimed to disrupt their work (desirable by them). However, I acknowledge that my knowledge and skills have affected the notional intervention system and if someone else were to carry out the project, they would probably tackle it differently either using different methods or applying the same ones more effectively.

The second relationship is between the practitioner and the problem situation. The relationship has no previous history and initially I had very little understanding of health care in general. I have had to spend a considerable amount of time building a relationship with various key employees and generally trying to understand health care. Therefore, if someone else were to carry out this project with a good understanding of IC and older people he or she could complete the work in less time and possibly obtain/extract more information.

The third relationship is between the problem situation and the intellectual resources. The problem owners and the employees of the IC system had no knowledge of the OR methods or techniques at the start of the project. In fact, they had only experienced typical health care research methods such as randomised control trials. Therefore data collection was acceptable to them as they had collected data for other projects but OR methods such as SSM which considers various viewpoints were felt to be more intrusive. This could only be offset by instilling confidence about the process and the presentation and use of the results. Some employees have admitted that after the presentation of the findings they feel more comfortable about the results than they expected and that they are not opposed to further work.

7.3 The learning about the IC function

The evaluation of the operational function of IC was determined to be about:

1. Evaluating the effectiveness/suitability of data collection & information gathering.

2. Evaluating suitability of patients entering IC services

3. Evaluating individual services, for example utilisation of resources

4. Evaluating the system as a whole, for example gaps in the system

In the SSM phase, we used the comparison of the real world with the systems world to evaluate the effectiveness of the data collection and information gathering. The evaluation highlighted the fact that the services were not using a standardised and comprehensive patient assessment tool, which meant that they were not gathering enough or the "same" information. In addition, the information collected by each service was not comparable to other services within that either system or even outside as it was created by employees from each service. For the purpose of this research, we adopted a modified version of the MDS by InterRAI which although an improvement was also found to be not comprehensive enough for the assessment of patients for entry to the service. This was mainly because it was a shortened version of the MDS and many fields had been removed. However, it was shortened after a consultation with the service managers of the system because they felt it would take too long. The result of appraising the data collection and information gathering is that the current method is not effective or sufficient. Therefore, a comprehensive and standardised assessment tool should be used across all IC services in that system. This finding can be generalised to all IC systems and more recent documents from the Department of Health suggest that all IC systems will be required to use a single assessment tool by April 2004 (Department of Health, 2001b).

The second evaluation task involved examining the suitability of patients entering IC services. The IC literature (see section 2.1) suggested that Eligibility criteria needed to be in place in IC services. The comparison of the real world with the system world revealed that Service Entry Eligibility Criteria do not formally exist for all services e.g. the wards. In addition, those services that have them need to add and improve them, as they are not sufficient or easy to assess. I defined the SEEC for each service through discussions with each service's manager and employees. The improved SEEC were initially evaluated by translating them into assessment items and incorporating them into the simulation models for each service. I found that although patients that entered each service in Shepway past the majority of the SEEC, they did not pass all of them. This could mean that there are some inappropriate admissions to each service. The service managers when presented with these findings said that the criteria were not strictly applied in some situations in order to the make allowances because of sentimental reasons. In fact, none of the patients (that were described) that failed the criteria went on to live independently and in many of the cases, the patient soon died. The service managers and system owners have since agreed that criteria must become exclusive. Therefore, this approach has enabled the evaluation of the suitability of patients entering a service and the system owners are committed to continue to improve the service SEE criteria. The use of the principles of a soft paradigm through simulation has enabled consensus and agreement that would not have been possible if SSM was used on its own. This task does not examine if the patients might have been better suited to another service but the whole system simulation model does examine this.

The third task involves appraising the resource utilisation of the individual services and this is achieved through building discrete-event simulation models for each service. This task involves examining Checkland's (1999) Efficiency, which in this case is to ensure that IC resource utilisation is sufficient and appropriate for the patients. The models examined the current resource utilisation, whether that was staff or beds or places, and a selection of scenarios. The scenarios presented herein were obtained through a discussion with each of the service managers about future possibilities and concerns. The service managers said that the results from the models proved situations that could not be conveyed to the system owners in any other form. The simulation models apart from appraise the current resource utilisation have enabled the service managers to plan for the future.

The fourth task involves evaluating the system as a whole. This task examines Checkland's (1999) performance criteria for Efficacy and Effectiveness. The criterion for Efficacy in this research is to ensure that patients are rehabilitated in the most appropriate setting for their needs. This criterion examines the system's decision-making mechanism in terms of the referral process of patients to the IC services of that system. By using the SEEC as a rule base for the decision making process of referral we are able to determine if patients are rehabilitated in the most appropriate service for their needs. This conceptual model is also in line with the Department of Health initiative of a Single Assessment Process (SAP) to Health and Social Care for the Elderly

(Department of Health, 2001b) and demonstrates how it can work in practice. The findings from the whole system model are that many of the older people were not referred to the most appropriate service for their needs. The Department of Health has instructed IC owners to ensure that there is Fair access to their services, which means that two older people that are alike should be eligible for the same services (NSF).

The criterion for effectiveness in this research is to ensure that IC is available and provided at the appropriate time for all the older people that require it in that health and social care system. This means that we must determine if the mix IC services available can cater for all the needs of that system. The whole system model can be used to examine if there are any service gaps. A service gap will exist if there is an exclusion criterion for all existing services. For example, patients with mild Cognitive Impairment should not be excluded from receiving IC. However, the existing services available in that IC system are not suitable for the cognitively impaired which means that there is a service gap. The second element in the criterion for effectiveness is whether IC is provided at the appropriate time and this can be examined through looking at the queuing time in the whole system simulation model. For example, the system owners may decide that it is unacceptable for a patient to queue for more than two weeks to enter an IC service. Therefore, by modelling the system as a whole we are able to examine if the system satisfies the IC criteria for Efficacy and Efficiency. The three measures of performance used in SSM have been used to evaluate the function of the IC system through simulation modelling.

The existing services need a more precise focus, which will mean that they each tackle a discrete set of older people's needs. This will also mean that the criteria can become more precise and that fewer inappropriate people enter services but also that there is a better chance of referring a person to the most appropriate service. This is part of having a whole systems approach to IC. In addition, the referral process requires more communication and exchange of information by the relevant parties. There is a lack of communication regarding strategic matters between IC staff and there are no identifiable IC headquarters.

Other things have also come out of this evaluation framework like the need for the IC system at local level to provide literature for both potential IC patients and people that refer to IC services i.e. bed managers. In addition, the current referral procedure requires further research as it is problematic and it needs to be aligned to the Single Assessment Process instead of the "ad hoc" approach that is currently adopted.

IC services should be available for cognitively impaired and these could take many forms. For example they could resemble the Recuperative Care setting but with 24 hour supervision as well as offering treatments such as Physiotherapy, Occupational Therapy, and Nursing.

7.3.1 What are the problems from modelling the IC system?

The Problems that have occurred whilst modelling the IC system are the following:

- Throughout the duration of the project the Shepway IC system was in its development phase and therefore still forming, which has meant that many changes have taken place. Therefore, it may be beneficial in the future to evaluate a more mature system (see Appendix L).

- Another problem was that IC employees identified with their service but did not seem to identify themselves as part of the system. If people do not feel that they are part of a system it is difficult for them to think about how it could work.

- Another difficulty was to identify someone that had detailed operational knowledge of the entire Shepway IC system. In fact we did not manage to find such a person and SSM was used to enable understanding.

- The software had certain limitations – although the software has been used to model other health care systems like A& E departments or outpatient services it was difficult to deal with the vast number and complexity of the patient attributes. A vast amount of information and data was required in capturing the fundamental phenomena behaviour of the system, which meant that the model required several minutes to run. This is because this software, like other software available, is for single facility services modelling that needs a smaller amount of data to be used. The simulation software used, simul8, is a standard simulation package with the same capability as other simulation packages, which means that it is likely that this problem would have occurred even if other simulation software were used. In fact, Davies and Davies (1994) discuss the limitations of discrete event simulation software and go on to suggest, that where the source code is available, to use it to make improvements but in this case it was not an option. If the software could be improved then a conceptual model such as the one described by Cohen et al. (1980) could have been applied. Simulation languages reduce model development time but flexibility is also reduced!

7.4 Learning about the methods

7.4.1 Learning about SSM

In the methodology chapter, I explained that I was mainly interested in obtaining the primary task root definition of the operational function of IC. Checkland (1990) writes about the use of a primary task root definition that: "It can tend to point only in the direction of improving the efficiency of existing operations" (Checkland, 1990, p.66). This research has not just been about improving the efficiency of existing operations because it is also introduced new elements to the relevant system. Therefore, the focus on primary tasks has not necessarily inhibited the process or just improved the efficiency of existing operations. This could be because the literature available for older people has enabled a more detailed exploration. The literature available has been produced by various organisations that are not owners or customers or actors but they can be considered as the wider system, such as charitable organisations e.g. Kings Fund etc. This variety of worldviews is an advantage.

Another SSM finding is that the system could be identified as having potentially multiple system owners, which include IC system managers (project commissioners) and the Department of Health. However we only had direct contact with the IC managers and we decided that they were in fact the main system owners for the purposes of this project and they are also able to make changes to the system provided. In addition, the majority of those that I spoke to identified the IC system managers as system owners. The Department of Health can be considered as the wider system but SSM does not guide you to examine in depth the wider system like is needed in this case. Therefore, there are two possibilities here, the first one would be to include it as an environmental constraint, and the second would be to define CATWOE for organisations such as the Department of Health, which can be considered as "guardians". If it was included as an environmental constraint then it would have been acknowledged but the people that were interviewed do not tend to read Intermediate Care Literature so I would not have known much about it from them. In fact, one of the reasons that the literature has been examined is because this is part of doing a scientific piece of work, which may not be examined to this extent by practitioners. Therefore, one possible solution for practitioners that are enquiring about organisations such as this one that has several layers of hierarchy and a significant level of influence by different organisations is to apply Checklands CATWOE to the body of literature. Understanding and acknowledging these guardians or stakeholders is important because they contribute to the improvement of these systems through commissioning research and generally "look after" the older people's interests.

The SSM approach can be categorised as Checkland's (1999) Mode 2 because it is problem oriented and not methodology driven. In health and social care, projects such as this one where the problem is extremely complex and another methodology is also used, it is difficult and in this case pointless to apply the full methodology when in fact only part of it is needed. The system examined has several employees who do not all know each other or even work in the same building, which makes the use of primary tasks route definitions time saving and inevitably means that the approach is problem oriented.

In this project by creating a purposeful activity model of the primary tasks we have been able to examine the current activities with the ones that could be introduced (real world versus systems world). We have found that there are activities that should be taking place according to the current Department of Health literature and we have also found activities that are desirable by the employees but are not currently in place and thus contradicting Checkland's (1990) words about using primary task root definitions.

Another finding is that it has not been useful to disclose the name of the method (SSM) in this particular project, but it was adequate to say that: I need you to help me understand your system so we can model it. This approach was because everyone was initially told that simulation modelling would be used and although the term was impressive it was also daunting to them. Soft Systems Methodology has an equally daunting name and I did not want to intimidate them with academic terms and loose sight of the aims of the method. This approach to the exploration was to focus on understanding and improving and was appropriate in this case because IC is relatively new and there is a substantial amount of fear that it may be found not to work etc.

Since completing the project I have come across some approaches, that are thought to complement SSM, and I will retrospectively discuss the usefulness of each of these in terms of this project.

The first issue is whether Critical Systems Heuristics and specifically the "12 categories could have been useful. After completing the project I was introduced to Critical Systems Heuristics which is about helping planners to think of what ought to be done and not to produce knowledge of what is. Critical Systems Heuristics philosophy has been developed by Ulrich (Flood, 1991) and is considered to be about the design and assessment of purposeful systems which are underpinned by four main principles. The first principle involves purposefulness, which is said to be necessary to map social reality. Part of the CSH methodology is about making transparent the beliefs that inevitably enter into social system designs through the 12 "critically heuristic categories". The 12 critically heuristic categories can be used to question system designs and potential designs. The 12 categories are translated into two sets of 12 questions (Flood, 1991) with the first set being about the "what is" (e.g. question 4: who is actually the decision taker?) mode and the second being about the "what ought" mode (e.g. question 4: who ought to be the decision taker?). After examining the questions I feel that this part of the methodology would have been particularly useful for the interviews conducted to find our about the problem including culturally and politically because it would have provided guidance to the process and made it transparent.

These CHS insights may have also been useful in this project in finding purposeful activity. In CSH a purposeful system is one were the ability to determine the purpose must be spread throughout the system. This was not the case in IC and a purposeful model was subsequently designed. The new design of the purposeful activity was evaluated against Checkland's three Es (1999) but there is a question as to whether it would have been useful to formally consider the remaining three CSH principles, which are called "quasi-transcendental". These are the system idea, the moral idea, and the guarantor idea and are designed to be used as critical standards, which the limitations of the social systems designs can be compared. The system idea is about forcing us to consider and to reflect upon our limitations in comprehensiveness in our attempts to map social reality and to produce social systems designs. The moral idea is about forcing us to consider and reflect upon the design of the system in terms of the values that are built in and the moral limitations of those designs especially to those in the wider system. The guarantor idea is about not being able to guarantee improvement and therefore seeking opinions from as many experts and from different stakeholder groups in order to incorporate as many sources of imperfect guarantee as possible. These "quasi-transcendental" principles have not been formally considered through a process such as CSH but they were considered in an internalised manner as doing so is part of human nature and "common sense" which have been triggered by a sense of worry and discomfort due to the importance of the IC system to society. However, this may be part of my personal characteristics as the agent in the intervention and if other were to copy this process it may be useful to consider these principles in a formal manner.

The second issue is whether Connell's (2001) matrices of stakeholder participation and SSM success would have been useful. Connell writes that the SSM literature does not adequately address how to differentiate the different classes of SSM users and that there should be a distinction between: a. "those who *use* the approach and those upon whom *it is used*", and b. "those *on whom* the approach is used compared with those *with whom* the approach is used". Connell (2001) identifies a group of stakeholders within the problem situation rather than modellers of it which are referred to as "tangential users" and writes that these may be ignored and that they may be very influential in determining the success of the project. The author proposes using a participation matrix (Table 7.1) to help clarify the identity of users. By using the matrix, it is possible to map at least four classes of users. Although the matrix in table 7.1 was used retrospectively, it does not seem to offer any new understanding to this project and it is unlikely that it would have been of any use at the time.

Table 7.1 Stakeholder participation Matrix (taken from Connell, 2001)

	Involvement of stakeholders in the modelling process		
		High	Low
Apparent commitment of users	Willing	1 Enthusiastic participants	3 Endorsers
	Reluctant	2 Active participants	4 Distanced participants

Connell (2001), also writes that there is sparse mention of the implementation difficulties in the SSM literature but suggests that the existing literature suggests a framework around two aspects of successful and unsuccessful SSM interventions:

1. "the structuring issues, for instance the contribution of the methodology in helping to identify or clarify the problem situation, together perhaps with the utility or comfort afforded to the users by adopting the approach; (p.154)" and

2. "the implementation issues, for instance, once we had a clearer picture of what needed to be done, did the prior processes of soft OR modelling help to achieve a successful outcome? (p.154)"

Both of these points have been considered and addressed in this thesis but it would have been useful to have had this insight at the start of the project. In fact, the author produces a second matrix in that paper called the SSM success matrix, (Table 7.2) that takes into account the evaluation of the contribution of the approach, the evaluation of the outcome as well as gaining insight and managing change. The author explains that it is used to evaluate a single application within each of the four quadrants with a high positive value if:

Quadrant 1 "the approach was viewed as successful, in that it helped to gain insight;"

Quadrant 2 "the approach was viewed as successful, in that it helped to manage change;"

Quadrant 3 "the problem situation was successfully resolved, through a clearer understanding of it from SSM use;"

Quadrant 4 "the problem situation was successfully resolved; the change being managed through SSM use."

Table 7.2 The SSM success matrix (taken from (Connell, 2001))

	SSM use	
SSM success	Gaining insight	Managing change
"structuring" success (evaluation of approach)	1	2
"implementation" success (evaluation of outcome)	3	4

The author explains that a particular application may fall into more than one quadrant. The project fits into quadrant 1 and 3 but as the project actions are slow and ongoing it is difficult to place it in the remaining two quadrants. This matrix has been useful and could be used as part of an SSM application.

Another issue is whether power relationships have affected the outcome of SSM. Rosenhead (1999) has reported on the effects of unequal power relationships on participative approaches. Power relationships were not evident in this project although this was probably because the system is not dominated by Consultant Physicians (like other health care system SSM studies).

Pala et al. (2003) write about validating SSM models, contrary to Checkland's (1999) belief that SSM models are different to hard OR models as they do not purport to be representations of anything in the real situation. They explain that part of the validation can be to examine whether the actions from the "action to improve the situation" did improve the actual situation and discuss two relevant sub questions. Firstly, "to what extent does SSM enable users to learn about a real world situation and whether the situation has improved or not?" Secondly, "to what extent is SSM helpful in distinguishing potentially effective actions from potentially ineffective ones?" Both these questions are considered in turn. SSM has enabled a great deal of learning about IC for that specific system and for IC in general. However, this question ignores the fact that the implementation of the action may be taken over a long period of time especially when it comes to the organisation such as the NHS, that have a complicated power structure and implementation is usually slow. Therefore, the SSM has satisfied the learning element but it may take years to be able to make a judgement on all of the action. The second question is about the assessment of action prior to taking action. This question may be extremely useful if several alternatives are available or even know to exist for each action. In this research, this point is demonstrated by the action to develop SEEC and assessing the criteria using DESM prior to the system owners deciding whether to put them in place in the services or modify them. However this has resulted from the combination of the SSM methodology with simulation modelling and if the simulation modelling was not used then there would not be an assessment of the action prior to taking action that did not involve debate among the actors and owners.

Another issue that several SSM authors including Checkland discuss is whether SSM has been successfully applied. Many of these authors quote of the following words by Checkland (1999):

"thus if a reader tells the author 'I have used SSM and it works', the author will have to reply 'How do you know that better results might not have been obtained by an ad hoc approach'? If the assertion is: 'The methodology does not work' the author may reply: 'How do you know the poor results were not simply due to your incompetence in using the methodology?

(Checkland, 1999, p.A12)

"*Any methodology which will be used by human beings cannot, as methodology, be proved to be useful*".

(Checkland, 1999, p.A12)

I have used SSM and it helped me satisfy the project needs. If SSM was not used I would not have been able to structure the problem or consider using DESM with a soft paradigm. Another contribution of SSM in this project is that it assisted in deriving a better Conceptual model because the system or organisation modelled was complex with a lot of interacting parts and there was no identifiable person that had an overall understanding of the system or problem. If I had only taken into account other health care simulation projects and the people that commissioned the project I would have ended up with a conceptual model that would have only answered questions about resources. Therefore I have demonstrated the usefulness of the SSM method.

7.4.2 Learning about DESM

This project has contributed towards the learning of simulation modelling in general and about applying simulation modelling in the community. In 1988, about fifteen years ago Smith-Daniels et al (1988), described a gap in the literature of capacity management modelling outside inpatient facilities and very little has been done since then. The majority of modelling is still for inpatient facilities. This project demonstrates capacity modelling in the community, which is a contribution to the literature. In the following paragraphs, I will describe the contribution of this project to DESM:

Unlike the other simulation models developed for health and social care, the models developed for this project are capable of examining whether patients are suitable to enter services. Exploring the decision-making mechanism in organisations is a new dimension to the usual simulation questions and could have an impact in other areas outside health care. In the literature review I mentioned a paper by Robinson et al (1998) that suggests two approaches to "knowledge acquisition" for the decision making mechanism; extracting the decision rules from an expert and learning from the simulation model by examples. The approach used in this thesis was a mixture of the two and resulted from the SSM phase. A set of questions have been provided in the SSM chapter to determine the SEEC that are used as rule base for the "whole system" simulation model. The contribution of this is that the questions can be used by IC managers that need to develop SEEC for the services as well as for those who may wish to replicate this approach in order to evaluate their health system. In fact, Robinson et al (1998) criticise authors that do not provide a discussion on the process of obtaining the examples.

In Robinson et al (1998) conclusions, there is list of questions that arise from their preliminary research. Each of their questions will be stated and answered in turn based on the project:

Question 1: For more a complex environment, how many examples would be required to train an expert system to a satisfactory level? The expert system used for the IC model was created from the Visual Logic in Simul8. Increasing the number of SEEC and making them more precise can help the model behave closer to reality (in this case how the employees would like the system to behave). However, a major drawback of the IC services is that they do not have a precise patient focus and their SEEC are not applied in a strict enough manner. Therefore, the issue is not the number of examples but making the services behave as the "actors" and "owners" would like them to behave.

Question 2: To what extent should outlier decisions be identified and included in the simulation expert system? If an older person in the individual service models "fails" the eligibility criteria of the service, it illustrates an outlier decision to refer and subsequently admit that person to the service. Because information of the actual service's patients was used in this project it means that the people showed to fail the SEEC in the individual service models were actually admitted to each of these services. In this project identifying outlier decisions about patient admissions has been extremely beneficial as it has allowed the service managers to think about the admission process (procedures and policy) and the referral process (procedures and policy). Therefore, it has contributed to their understanding of the impact of their decisions to admit unsuitable patients into their service.

Question 3: To what extent should the induced rules be edited before attempting to use them in the simulation? The induced rules in IC initially took the form of sentences that were transformed into assessment items/fields with a range of scores in order to code them in the simulation. The process was observed by a geriatrician with extensive knowledge of assessments of older people to make sure that the transformation was appropriate. This transformation process was essential for using the rules in the simulation.

Question 4: Having trained an expert system, how can it be prevented from giving spurious decisions if situations occur in a simulation run, or indeed the real world, that have not been previously encountered? It is very likely that in most real life systems there will be a number of spurious decisions being made. The main question is whether the decision makers are aware that they are making spurious decisions or are they correctly following a decision making mechanism with flaws. In this project, various service employees reported of unsuitable referrals and provided examples of them. This was investigated in the simulation model's virtual environment. The simulation model was "built" to behave like the employees and owners wanted it to behave by including their decision-making "rules". The model did not behave as the real system because their rules (SEEC) generally were not applied. Therefore, the "whole system" simulation model contributes to the understanding of the current decision making mechanism and has helped educate the staff in improving their SEEC and making them more widely available. For example, the CART service has put their SEEC on their referral form because of the model.

The fifth question is about comparing this rule-based approach with case based reasoning and neural networks and this is not considered because of a lack of knowledge in both areas. This is not applicable to this research.

Another contribution of this project is demonstrating how Complex integrated systems can be modelled as one system by using real data. This is important because Jun et al, describe a gap in the literature of models representing complex integrated systems. In this simulation project, the access to services and ability to collect real data has enabled the whole system model to examine the service provision gaps. This could also be applied to other healthcare systems and possibly to other fields with similar characteristics.

I have also learnt that conceptual models can be partially influenced by other conceptual models, for example this conceptual model was initially based on a conceptual model from manufacturing. This means that my initial experience in simulation modelling guided me to look for resemblances between the two systems. Although the main similarity was the need for real data.

Another contribution of this project is highlighting the need for a warm up time for a model of a system with complex interacting parts and each has a warm up time. The warm up time for the whole system can be the largest warm up time of the individual services.

One of the issues that emerged from the project was the need for determining suitable bed occupancy rates. This is something that Bagust in 1999 has also described in the Literature Review. This concept was foreign to the service managers I spoke to and this project brought this topic to their attention. After consultation we decided that eighty five percent was appropriate. The use of simulation modelling contributed to determining suitable bed occupancy levels for planning in IC.

Another contribution was to determine suitable distributions for the interarrival days and Length of Stay. Ridge et al 1998, described using the negative exponential curve or a Weibull curve fitting routine for bed capacity planning in Intensive care. When someone is in Intensive care then minutes and hours matter and people move out of beds very quickly. This is not the case with IC as whole days matter but minutes and hours do not matter. Therefore, in community care discrete distributions fit better than continuous distributions.

Another contribution is that simulation modelling can be applied with a different paradigm. I modelled the most agreeable IC system and not the actual IC system, which means that the model does not actually behave like the real system. This is a move from the traditional positivist approach and demonstrating that simulation can be used in other paradigms. However, this has had a negative effect on the validation of the whole system simulation model because traditional methods of validation are positivist. Determining methods for partial validating and verifying models of systems that do not match reality but are desirable should be considered for future work.

7.5 Multimethodology learning

In the literature review, I mentioned some of the operational researchers' positions on pluralism and the approach to mixing methods. I feel that the reader should know that I have read most of this literature retrospectively (after the research) and therefore very little if any of it has directly shaped my approach "to choosing the methods" or "thinking about the problem" or "mixing the methods" in this research. The reader may feel that my ignorance of the theoretical issues around pluralism could have hindered my research so I will reflect on some philosophical positions retrospectively. It may also be to see which philosophical position and approach I fit closest to, considering that I have only been guided by knowledge of the individual methods, instinct and common sense. I will therefore begin by declaring what I agree with or not based on my experience.

Jackson's (1999) coherent pluralism does not represent my experience although, if the project only needed a system simulation model, then I could have adopted his approach and it would be described as a soft simulation. Although it may seem that I have adopted a "anything goes" position this is not the case as I was ignorant of all positions including that one and I feel that I have learnt from this retrospective multimethodological reflection. I believe that my approach is best described as multiparadigm multimethodology (Mingers and Blocklesby, 1997) for one intervention by one agent. In addition, I feel that the relationship between my soft and hard methods can be described by both Pidd's (2004) second and third relationship, as they feed off each other in an eclectic and pragmatic way and to some extent the soft OR/MS methods are seen as containing the hard OR/MS methods.

In terms of the approach to mixing the methods I have found some "common ground" with Midgley's (2000) creative design of methods and particularly when he describes the starting point of systemically interrelated questions, which feature in two chapters (the introduction and the methodology) of this thesis. I find it comforting that common sense or the situation has guided me in a direction advocated by Midgley.

Another issue that I feel that I should reflect on are my feelings about mixing or switching between paradigms in one intervention. Ormerod (1997) believes that switching between paradigms was not an issue for him and that the limitations lie in the competence of the consultant and the participants rather than the methods themselves and Brocklesby (1995) believes that shifts in paradigms can be a "painful experience" for the individual concerned. These are not opposing views as they both refer to the analyst's experience. I also believe the more experience the analysts have in working with multiparadigm multimethodologies the easier it is, although, I do not think it is an issue of personal competence as suggested but experience and practical knowledge of OR/MS. I disagree with Ormerod that the fault lies with the competence of the analyst or participants and not the methods because these human created tools and methods, like humans, will be prone to imperfection and need adapting to fit situations. I also believe that my painful experience is mostly related to my then positivist mind frame instilled during my degree, which I have unlearnt to some extent like Brocklesby (1997) suggests must happen. Therefore, Brocklesby's view is more helpful and encouraging to a "newcomer" in multiparadigm multimethodology.

I also found that reading about multimethodology practice, even examples of pragmatic pluralism (White and Taket, 1997) or coherent pluralism (Jackson, 1999), like Robinson (2001) (on using simulation in a soft intervention), was a great relief and an encouragement to carry on. These examples are useful in demonstrating the process of philosophically positioning a project. Robinson places his approach closest to pragmatic pluralism because the mixing of paradigms was not intended but the project could also be described as coherent pluralism as simulation modelling was applied under the soft paradigm. In addition, he provides information on his paradigm perspective by using Rosenhead's characteristics (1999) (see section 2.4.1 of the literature review) and Jackson's (1999) guidelines to show the positioning of his study on the hard to soft continuum by placing "ticks" next to fields that represent his approach. Most of his "ticks" (X) are for the soft approach and he places one tick for each dimension (row). This approach has effectively shown where he believes his is positioned and he encourages the reader to form his or her opinion on "the relative 'hardness' and 'softness' of the attributes in relation to the simulation study. Although, the table is useful for Robinson's project it is not useful for this research as a table for this project would requires ticks in many dimensions in both the soft and hard continuum. This is because I have applied SSM under the soft paradigm and DESM under both the soft and hard paradigm. This has been very useful in seeing the difference between my approach and Robinson's and others may benefits from undertaking this brief exercise. In addition, if the agent has any doubt about using a multiparadigm multimethodology this exercise may help him or her clarify this.

Lehaney et al.'s (1999) paper about an intervention in an outpatient dermatology clinic that utilised simulation within a soft systems framework, mentioned in the literature review, is the most similar work to this project and therefore it is necessary to reflect and compare their approach and views on multimethodology with mine. They discuss paradigm incommensurability and explain that they did not view SSM and Simulation modelling as completely different approaches as they both facilitate debate and decisions, the notion of different paradigms is inappropriate. Although I agree that both facilitate debate and decisions, I do not agree that one paradigm can always be adopted when using a multimethdology of SSM and simulation modelling. In fact, their approach is closest to the ideology of coherent pluralism than multiparadigm multimethdology. However, some of our other differences in our projects may have affected our approach to multimethodlogy:

The first difference is the scale of each study and the size of the systems investigated. The IC project spanned across several services and each would have been equivalent in size as their dermatology clinic, which means that in IC there is more complexity, stakeholders and questions. There were both problems/questions perceived as being solved by hard OR and others by soft OR just like Midgley's (2000) creative design of methods describes. Another difference is that although both projects are in health care, Lehaney et al.'s is based in a hospitals environment but Intermediate Care is both community based and hospital based. Therefore, there was a greater geographical and cultural difference within IC. Having to manage such a plethora of views and information meant that the SSM phase was mostly dedicated to understanding what was going on and what the various stakeholders thought was going on and what needed evaluating.

A final difference is that although we both approached SSM using primary tasks, we were using them for a different purpose. Lehaney et al.'s primary tasks were activities that existed (part of their current system) and formed the conceptual model for the Discrete-event simulation model, which aided agreement for the acceptance of the simulation model. Obtaining the primary tasks in the IC project was to understand the operational function of IC the system and find out what could improve it. Although some of the primary tasks influenced the whole system simulation model, they do not reflect the conceptual model.

At the start of the project, I had very little evidence of the suitability of SSM with Simulation. I thought that the methods chosen would be mutually exclusive but could possibly be linked. As the project progressed I found Lehaney (1996) and Robinson's articles (2001) that discusses using Hard OR in soft interventions to demonstrate that DESM can be used to support soft OR interventions. In addition I found that there was an interest in combining soft and hard OR from Mingers (1997) who has reported that further examples are required of the use of multimethodologies and that there are fewer examples of soft and hard OR available. During the course of the project I found that the two methods, SSM and simulation could be combined.

The individual simulation models for the services have decision-making that is purposeful and the conceptual model would therefore be that of the actual services, which means that they would follow the hard paradigm assumptions. However, the "whole system" model follows the soft paradigm assumptions. Therefore, simulation has been applied with two different paradigm assumptions in order to satisfy the project needs. The actual IC system is not unique in its problems, which means that this would probably be the approach if it were applied to other IC systems.

The process of deciding on the use of these two methods has been dependent on the needs of the project and no formal mapping methods have been used. The problem was broken down into areas of exploration and each of the methods has been attached to an area. However, Mingers (2000, 2001) provides a framework for mapping methodologies using a grid to link the characteristics of different methodologies that has been applied retrospectively to see if it had been useful or not. Mingers's (2000, 2001) grid is represented by table 7.3.

Table 7.3 Mingers grid for mapping methodologies (Mingers, 2001)

	Appreciation of	Analysis of	Assessment of	Action to
Social	social practices, power relations	Distortions conflicts interests	Ways of altering existing structures	Generate empowerment and enlightenment
Personal	Individual beliefs, meanings, emotions	Differing perceptions and personal rationality	Alternative conceptualisations and constructions	Generate accommodation and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

The application can fit into the grid as follows:

Table 7.4 an application of Mingers (2001) grid for mapping methodologies

	Appreciation of	Analysis of	Assessment of	Action to
Social	SSM (1)		SSM simulation (2)	SSM (3)
Personal	SSM (4)			SSM (5)
Material	Simulation (6)	SSM Simulation Statistics (7)	Simulation (8)	

I will briefly explain how each of the method slots in the grid (see table 7.4) by examining each of the mappings:

(1) SSM was used to appreciate the cultural and political effects on the IC operational function.

(2) SSM was used to compare the systems world with the real world, Simulation was used to assess the decision making mechanism of patient referral into services.

(3) The SSM comparison was used to find out how to improve the IC function.

(4) The primary task root definitions (SSM) were used to appreciate the IC employees' experiences and feelings of the IC function.

(5) The SSM comparison findings were used to find which action was desirable and feasible.

(6) The simulation models for the IC services were used to appreciate the services resource utilisation and capacity.

(7) The action from SSM was used to explore and make improvements to the SEEC. The SEEC for each service were subsequently assessed in the simulation models of each service. Statistical analysis was required to determine suitable distributions for the interarrival days and length of stay for the whole system simulation model.

(8) Simulation was used for "what if analysis" of alternative physical and structural arrangements.

A criticism of this framework is that it does not show the sequence, but that could be demonstrated by adding a number in each slot similarly to the numbers I have used to explain the reasoning for each method being placed in each slot. However, it is comprehensive and it clearly demonstrates the bits where more than one method was used and how and why the methods are linked. This is very useful in illustrating that I have used a multimethodology.

The use of this multimethodology to IC has enriched the understanding of IC and examines IC from a different perspective by describing the problems from a non health care and non-clinician perspective. The Multimethodology can be considered a whole system approach, something that has been advocated as an approach by those responsible for IC. Therefore, it has added to the IC literature an innovative approach to evaluating the operational function of IC.

I have also learnt that my hard OR background has made me feel an enormous discomfort in applying simulation under a soft paradigm. However, this does not necessarily mean that I am a hard OR person but it does mean that I have only been taught to use hard OR with a hard paradigm. It may be more encouraging to new management science students to use multimethodologies if OR methods were taught under different paradigms.

7.6 Conclusions and further research

The framework can be further refined through further research and improvements, some of these being:

It is clear that further improvements can be made to the system simulation model by improving the data collection tool. It was not possible to redo the data collection with a different tool in this research because of two constraints, time and money. Collecting data for a real life experiment such as this one has put a great burden on their staff that have collected the data. This problem is one that could have been avoided if the services had put in place a comprehensive standardised assessment prior to the project.

The model can be further improved over time as computers get faster and more reliable and as software improves.

There was one essential criterion that could not be translated into assessment items as it involves tacit knowledge. Medical stability has been reached in order for the patients to be there as there isn't a doctor on site. This is a vital element of entry to IC that we have acknowledged even though we could not measure it.

7.7 Future work that can be done in IC as a result of this research

In the introduction I set out a framework of what I could contribute towards but during the project I found an issue that is important but requires extensive research that could involve both rehabilitation medicine and OR. There is very little written in the literature over the IC treatment timetable and maximum LOS. This research would be of equal importance to the DoH as the person(s) that determined the A&E departments should aim to have an average four-hour waiting time. The services in the system examined have a maximum of six weeks treatment, which has been determined by the Department of Health. The use of the maximum six-week treatment in Intermediate Care is contradicted by an IC definition by A. Steiner that describes it as function rather than a discrete set of services. Therefore is it correct to use a maximum of 6 weeks in a service? For example, Patient A may enter Recuperative Care for 6 weeks and then go home and patient B enter CART for 4 weeks and then goes to Day Hospital for 4 weeks (total IC of 8 weeks) and Patient C who is with CART for 8 weeks. Is the total time in each service supposed to be 6 weeks or the function of all IC services? We have examined the LOS of Patients that have entered IC services and we have found some patients in all IC services with a LOS that exceeds 6 weeks but should we really penalise these services and make them believe that they need to confirm to the 6-week rule? Would it be better if the rule was for 75% of patients to be out of a service within 6 weeks? Conducting such research would be very helpful to continuing the development and improvement of these services.

Another issue that could be explored is creating generic models for IC services and the system similarly to Taylor and Kuljis (2000) CLINSIM model which could reduce the time required to model other IC services.

Applying this evaluation framework to other IC systems or generally to other systems would be useful in determining its usefulness. The framework in theory could be applied to systems with the following characteristics:

- The system has a discrete set of services.
- The system has a specific population/clientele.

The framework would especially benefit systems that:

- Have an Operational function that is not understood.
- Have questions about Resources and the decision making process.
- Are new and still forming.
- Are large and there is no all round understanding of the system.
- Are spread out geographically & communication is limited.

Appendices

Appendix A – Description of Services involved in Action Research

This section will focus on providing some general information regarding the services that are included in the project. This information was initially collected from the managers and other employees of these services either in written form or through interviews.

Community Assessment Rehabilitation Teams (CART)

The Community Assessment Rehabilitation Teams (C.A.R.T.) provide a type of care that involves living at home with minimal or no supervision and a multidisciplinary team rehabilitate the older person within his/her own home. The multidisciplinary team comprises of rehabilitation workers, physiotherapist, occupational therapists and nursing staff are available depending on the person's needs. The CART visits are regular and the sessions intense and catered to suit the individual's needs. Shepway CART caters for around 40-45 patients at any one time with treatment periods of up to 6 weeks. Shepway CART is available exclusively to Shepway residents.

Recuperative Care

Recuperative Care involves the older person living for a short period of time in an environment resembling a residential home but receiving rehabilitation therapy from health care professionals. The therapy sessions are intense and aimed at teaching the person to cope activities of daily living baring in mind any new requirements or disabilities that the older person may have. Lawrence House has six recuperative care beds, approximately half of which are used by Shepway residents, and allocated on a first come first served basis. Length of stay is up to six weeks, with therapy programmes tailored to the needs of each individual.

Day Hospital

Day hospital is suitable for older people that can live with minimal or no supervision at home and that are also well enough to be taken to the day hospital once or twice a week for specialised medical investigations and input from therapists. The Shepway Elderly

Care Day Hospital is open two days per week. Again a multidisciplinary team are available to patients based on need, and exclusively for Shepway residents. The Day Hospital is also used for medical assessment for admission to CART.

Royal Victoria Rehabilitation Ward-Fitton

This service involves rehabilitation care for patients that require orthopaedic rehabilitation in a rehabilitation hospital ward setting (Royal Victoria Rehabilitation Hospital). The ward will have therapists and specialised nurses but it does not have an on site doctor which means that patients must be medically stable. This service is aimed at elderly patients that are not well enough to cope with rehabilitation at home but do not require the intense medical care that is provided in the some of the wards of the acute hospital.

Royal Victoria Rehabilitation Ward-Edinburgh

Edinburgh ward provides rehabilitation, convalescence and in a few cases palliative care in a rehabilitation hospital ward setting (Royal Victoria Rehabilitation Hospital). The palliative care should not ordinarily be offered as it is not part of the ward's purpose but does so because of the general lack of availability of palliative beds. The ward shares therapists and specialised nurses but it does not have an on site doctor which means that patients must be medically stable. Once again this setting is aimed at older patients that are not well enough to cope with rehabilitation at home but do not require the intense medical care that is provided in the acute hospital setting.

Royal Victoria Rehabilitation Ward-Richard Stevens: Stroke

This ward is aimed at patients that require rehabilitation and convalescence after a stroke in a rehabilitation hospital ward setting (Royal Victoria Rehabilitation Hospital). The ward has therapists and specialised nurses but it does not have an on site doctor which means that patients must be medically stable. Like the other Royal Victoria rehabilitation wards this service is aimed at older patients that are not well enough to cope with rehabilitation at home but do not require the intense medical care that is provided in the acute hospital setting.

Buckland rehabilitation wards

The two Buckland Hospital wards Montgomery and Ramsey work closely together and provide rehabilitation and convalescence to elderly in Dover and the surrounding area. This means that there are a few Shepway residents that are treated there because they live closer to Dover than Folkestone. The wards do not have a 24 hour doctor on site and the treatment is very similar to that offered at the (Fitton and Edinburgh) Royal Victoria Rehabilitation wards.

William Harvey rehabilitation wards

The two rehabilitation wards (Bethersden and Brook) at the acute Hospital William Harvey receive a few Shepway patients that have mainly been filtered through other acute specialist wards e.g. orthopaedics wards. The main difference between these patients and the patients at the other hospitals is that they have a 24-hour on site doctor. Therefore the majority of patients in these wards are medically unstable.

Appendix B – Literature Review extension

7.7.1.1 Papers on Patient Scheduling and Admissions

Jun et al. (1999), describe the papers in this subcategory of "patient flow" as "procedures that determine how patient appointments (with medical staff) are scheduled both in terms of when and how they are set in a given day, and their length of time. More specifically this involves rules that determine when appointments can be made and the length of time between appointments. More advanced simulation articles will include the designating specific kind of medical staff who will be responsible for treating patients and the clinic space that will be required to deliver the necessary treatments... These issues can have a significant impact on how resources (staff etc) can be optimally utilised so as to maximise patient flow (hence increase profitability) without incurring additional costs of excessive patient waiting" (Jun et al, 1999, p.110) The paper's literature review has been condensed into the paper authors and year of publication along with the area of application and included in a table (Table B.1). The area of application that has substantial papers is Outpatient Clinics.

Table B.1 Papers on patient scheduling and admissions from the Jun et al. (1999) survey

Authors and Year	Area of application
Feter and Thomson 1965	Outpatient Clinics.
Smith and Warner 1971	Outpatient Clinics
Rising, Baron and Averill 1973	Outpatient Clinics
Kho and Johnson 1976	Radiology Department
Kachhal, Klutke and Daniels 1981	Ear, nose and throat Clinic
Baily 1952	Outpatient Clinic
Smith, Schroer and Shannon 1979	Outpatient Clinic
Williams, Covert and Steele 1979	Outpatient Clinic
Murphy and Sigal 1985	Operating Rooms
Fitzpatrick, Baker and Dave 1993	Operating Rooms
Magerlein and Martin 1976	Operating Rooms
Klassen and Rohleder 1996	Outpatient Clinic
Swisher, Jun, Jacobson and Balci 1997	Outpatient Clinic
Stewart and Standridge 1996	Veterinary Practise
Hancock and Walter 1979	Hospital Inpatient Facility
Hancock and Walter 1984	Hospital Inpatient Facilities
Lim, Uyeno and Vertinsky 1975	Orthopaedics Ward
Walter 1973	Radiology Department
Goitein 1990	Outpatient Clinic

Kho and Johnson (1976) describe a simulation project undertaken to improve a hospital health care delivery system. The study encompasses a set of standardised data collection and analysis techniques, modelling strategies, validation and evaluation tools. The computer model simulates patient flow through a radiology department. The modelling recommendations include making modifications such as scheduling schemes, increase in resources and a possible increase in patient load.

Papers of Patient Routing and Flow Schemes

According to Jun et al (1999) there is a significant advantage when using discrete event simulation over other mathematical modelling tools especially when one is dealing with complex patient routing and flow schemes. These models usually involve emergency rooms. The patient's health problems can range from a minor injury to a life threatening one. Though the arrival of patients is highly unpredictable, medical staff can control the sequence by which they are treated. By altering patient routing and flows, it may be possible to minimise patient waiting time and increase staff utilisation rates. The majority of the papers included in table (Table B.2) are applied to Emergency Departments (A&E).

Table B.2 Papers of Patient Routing and Flow Schemes from the Jun et al. (1999) survey.

Authors and Year	Area of application
Garcia, Centeno, Rivera, DeCario 1995	Emergency Department
Kraitsik and Bossmeyer 1993	Emergency Department
Kirtland et al 1995	Emergency Department
McGuire 1994	Emergency Department
Blake and Carter 1996	Emergency Department
Ritondo and Freedman 1993	Emergency Department
Edwards et al 1994	Medical Outpatient Clinics

A paper that has not been included is by Pollack-Johnson (1987) that describes a simulation project that aims to improve the patient transportation system (on gurneys and in wheelchairs) at a medium sized Midwestern Hospital. The motivation was that the hospital administrators suspected that the use of nurses and technicians for transportation of patients when nursing assistants were too busy was not cost effective. The aim of the model was to study several alternatives, which included sharing of nursing assistants across departments. The system was modelled as a queuing network.

Papers of Scheduling and Availability of Resources

Jun et al. (1999) also looked at articles that where directed at patient scheduling in order to accommodate the existing physician and staff. The majority of scheduling simulations for health care clinics are directed at patient scheduling although "*a number of studies have addressed the problem from the reverse side that is staff can be scheduled to meet patient demand, while the patients' arrivals can be left unchanged*"(Jun et al.,1999,p112). In some case the latter is unavoidable as for example for walk in clinics where the patient arrival rate cannot be changed and clinic managers must schedule their staff accordingly. Studies of this sort are beneficial when patient throughput is variable but there are still pressures to maintain high quality of health care while minimising costs.

Table B.3 Papers of Scheduling and Availability of Resources from the Jun et al. (1999) survey

Authors and Year	Area of application
Alessandra, Crazman, Parameswaran, Yavas 1978	Hospital clinics
Mukherjee 1991	Hospital Pharmacy
Draeger 1992	Emergency Department
Evans, Gor and Unger 1996	Emergency Department
Kumar and Kapur 1989	Emergency Department
Lambo 1983	Health Care Centre in Nigeria

Weng and Houshmand (1999) examine a health care simulation of a local clinic with the key performance measure being to maximise patient throughput and to reduce patient time in the system. The clinic being modelled is considered an outpatient clinic at a local hospital with different patient classifications which include urgent care and acute care patients. The "benchmarking engineers" over a period of two months collected the data needed for the simulation model that mainly consisted of patient process times and patient arrival times. The data also included expenses and revenues, which formed the basis for the performance measures.

Papers on Bed Sizing and Planning

Table B.4 Papers on Bed Sizing and Planning from the Jun et al. (1999) survey

Authors and Year	Area of application
Butler, Reeves, Karwan, Sweigart 1992	Hospital Beds
Butler, Karwan, Sweigart 1992	Hospital Beds
Lowery 1992	Operating Rooms and Critical Care Beds
Lowery1993	Critical Care Beds
Lowery and Martin 1992	Critical Care Beds
Dumas 1984	Hospital Beds (wards)
Dumas 1985	Hospital Bed
Cohen, Hershey, Weiss 1980	Hospital Beds
Zilm, Arch and Hollis 1983	Critical Care Beds
Romanin-Jacur and Facchin 1987	Paediatric Semi-Intensive Care unit Beds
Hancock, Magerlein, Storer, Martin, 1978	Hospital Beds
Wright 1987	Surgical Beds
Harris 1985	Surgical Beds
Gabaeff and Lennon 1991	Emergency Department Beds
Vassilacopoulos 1985	Emergency Department Beds
Altinel and Ulas 1996	Emergency Department Beds
Freedman 1994	Emergency Department Beds
Lennon 1992	Emergency Department Beds
Williams 1983	Intensive Care Beds

Papers on Room Sizing and Planning

Jun et al. (1999) write that "the use of computer simulation for planning of future expansion, integration, and/or construction of new facilities and departments has greatly enhanced the hospital administration decision maker's ability to find the most cost effective and efficient solutions to remain competitive"(Jun et al.,1999, p.114).

Table B.5. Papers on Room Sizing and Planning from the Jun et al. (1999) survey.

Authors and Year	Area of application
Currie, Iskander, Michael, Coberly 1984	Operating Room, Transportation needs, Radiology Staffing
Kwak, Kuzdrall and Schmitz 1981	Surgical Suite
Kuzdrall, Kwak and Schmitz 1981	Surgical Suite
Olson and Dux 1994	Hospital Surgicenter
Amladi 1984	Outpatient Clinic
Meier, Sigal and Vitale 1985	Ambulatory Surgery
Iskander and Carter 1991	Day Care Facility
Kletke and Dooley 1984	Maternity ward
Levy, Watford and Owen 1989	Outpatient Clinic
Mahachek Knabe 1984	Obstetrical Gynaecology Clinics

Lowery and Davis (1999) use simulation to determine operating room requirements. The study was initiated by a Boston Hospital construction project to renovate its existing surgical suite to include 32 operating rooms – two fewer than the current number. This was due to a decision that the new suite would be used for performing primarily inpatient cases and 95% of all outpatient cases would be moved to another facility. The hospital administrators, planners and clinicians were also keen to know that the 32 rooms would be sufficient for accommodating a projected increase in the inpatient surgical volume. The model results showed that the projected changes in the surgical workload could be accommodated in 30 operating rooms or even fewer if scheduled block time was extended during the weekdays and Saturday blocks were added.

Papers of Staff Sizing and Planning

Jun et al. (1999) discuss issues surrounding staff sizing and planning. Staff sizing and planning is an important factor when designing health care delivery systems in hospitals in order not to have staff under-utilised or in insufficient numbers (overutilised). Several simulation studies have been conducted to determine the staff size or the number of physicians for Emergency Departments.

Table B.6 Papers of Staff Sizing and Planning from Jun et al. (1999) survey

Authors and Year	Area of application
Carter, O'Brien-Pallas, Blake, McGillis, Zhu 1993	Emergency Department
Badri and Hollingsworth 1993	Emergency Department
Klafehn and Owens 1987	Emergency Department
Klafehn et al 1989	Emergency Medical services
Liyanage and Gale 1995	Emergency Service
Gonzalez, Lopez-Valcarcel, Perez 1994	Emergency Department
Bodtker, Wilson and Godolphin 1992	Clinical Chemistry Laboratory
Godolphin, Bodtker, Wilson 1992	Clinical Laboratories
O'Kane 1981	Radiology Department
Klafehn 1987	Radiology Department
Coffin, Lassiter, Killingsworth, Kleckley 1993	X-ray Facility
Klafehn and Connolly 1993	Outpatient Haematology Laboratory
Vemuris 1984	Outpatient Pharmacy
Ishimoto, Ishimitsu, Koshiro, Hirose 1990	Hospital Pharmacy
Hashimoto and Bell 1996	Outpatient Clinic
Wilt and Goddin	Outpatient Diagnostic Centre
McHugh 1989	Nurses in Hospitals
Stafford 1976	Multifacility Outpatient Clinics
Aggarwal and Stafford 1976	Outpatient Health System

Rossetti et al. (1999) simulated an emergency department and focused on identifying inefficiencies and problem areas within the existing emergency department system. More specifically the project challenged the current attending physician staffing schedules and evaluated alternative staffing strategies as well as analysing the corresponding impacts on patient throughput and resource utilisation.

Isken et al. (1999)simulated an outpatient Obstetrical Clinic for the purpose of exploring questions related to demand, appointment scheduling, exam room allocation patient flow patterns and staffing. The authors report that clinical resource allocation problems can be decomposed into four related components: demand forecasting, practise patterns analysis, facility sizing and staffing. The resources that are modelled include physicians, nurse practitioners, residents, support staff (nurses, medical technicians and front office personnel) exam rooms, special purpose areas like specimen collections and waiting areas. Patients arriving into the model were divided into urgent and scheduled. Interestingly, patient punctuality was also modelled through altering the actual arrival time to the clinic by a random positive or negative quantity. Each patient could fall under the category of one of eight types and each type was provided with a detailed visit flow diagram, which specified the sequence of locations. The paper provides many ideas that can be applied to other outpatient clinics in general.

Swisher et al (2001), examine the design and development of a DESM of a physician clinic environment within a physician network. The simulation model can be used to design customised clinics to meet specific needs of the resident physicians. The model contains several user defined input parameters like the composition of the medical staff, the number of registration windows, the number of examination rooms, number of check in rooms and the number of specialty rooms. The model is typically run for a 15-month period using the first month as a warm up period and the remaining months are the steady state period.

Computer Simulation Literature In Healthcare That Include A Cost Or Economic Analysis.

Some papers have an economic analysis that is based on the simulation scenarios of the model. An article that falls into this category is that of Weng and Houshmand (1999) is about simulating at an outpatient clinic within a hospital. There where three main scenarios (models) apart from the baseline (model of current situation) that where using as key performance measures patient maximising patient throughput and minimising patient flow time in conjunction with variable expenses and revenues. Although this research does not consider costs or any other financial implications in may be possible to incorporate these in future research.

Literature of Modelling using real patient data

Adams et al. (1999) describe the design and implementation of simulation tools for the purpose of modelling infectious disease transmission. The model accounts for "realistic infection transmission systems" by explicitly modelling a. heterogeneous populations of individuals with varying social and geographic characteristics, b. complex interaction between individuals to characterise opportunity for transmission, c. infection characteristics such as transmission probabilities and infection duration and d. contact and infection histories. This modelling approach is about evaluating the effectiveness of interventions with real patient data relating to an individual's attributes.

Davies et al. (2000), develop a DES model for evaluating screening services for diabetic retinopathy. The model is created using Patient Oriented Simulation Technique (POST) have been developed to assist policy makers in the choice of screening strategy in terms of operator, equipment, frequency of screening and target population. The models describe a population of diabetic patients that "regenerate" through new arrivals over a period of 25 years. The data used in the models included both the population breakdown and the occurrence of diabetes by age, sex and ethnic origin and the occurrence of eye disease by age and sex. Other data sources were the incidence of diabetes, mortality, patient compliance as well as the characteristics of the screening and treatment programmes. The models can be used to help monitor the success of retinopathy screening programmes in reducing vision loss and to evaluate the effects of different modes of detection and improved treatment techniques.

Marshall et al. (2001), develop a Bayesian Belief Network for the management of geriatric hospital care. The Bayesian Belief Networks (BBN) are "*statistical graphical models which provide a framework for describing and evaluating probabilities where there is a network of inter-related variables*". In the paper BBN is used to predict the duration of stay and the patients' destination on departure from hospital. The BBN model's the behaviour of geriatric (elderly) patients using predictive variables, which include personal details, admission reasons, and dependency levels. This approach uses data from a large hospital patient database that contains 4722 patient records.

Christodoulou et al (2001), models the bed occupancy of people aged over 65 years using a continuous time hidden Markov model with discrete states. The paper uses the continuous time hidden models and includes the effect of covariates, age and sex in the model. The models outcomes involve evidence that gender has an effect on the Length of Stay but age doesn't.

De Vries and Beekman (1998) write about applying simple dynamic modelling for decision support in planning for regional health care. The model is applied to psycho-geriatric patients, who are waiting to be admitted to a nursing home. The author reports that the model uses high quality data from the collective nursing homes of the health care region of The Hague. The model provides projections on the average waiting time and the length of the waiting list, from yearly data that are routinely collected.

Millard et al (2001), model hospital and social care bed occupancy by elderly people in an English health district. The model is of "a total health and social care system" and uses the analysis of a one-night bed occupancy census of 6068 elderly peoples (over 65) admission dates in seven different provider groups. The provider groups included NHS acute hospitals, NHS geriatric hospitals, NHS psychiatric hospitals, private and local authority residential homes, nursing homes, etc. The modelling is performed with exponential equations and the data analysed concerned the sex, age, the type of residence and dates of admission of the individual person. Access and Excel were used for data handling and the flow models were created using a MS-DOS based Bed Occupancy Management and Planning System (BOMPS) modelling package. The software calculates and sort the individual time of occupancy and then fits and visually displays the best fit exponential curve and finally generates resource utilisation measures dependent on the parameters of the best fit equation. The paper concludes by explaining that it will be very difficult to plan *for beds in large hospitals unless methods of activity analysis are introduced that demonstrate to decision makers the contribution being made to the whole by the different components of care.* Seymour (2001) describes the work of Millard regarding bed modelling and provides some insights on health care modelling. Garcia-Navarro and Thompson (2001) analyse bed usage and occupancy of the newly introduced geriatric rehabilitative care in a hospital in Spain. The decision support system BOMPS (Bed Occupancy Management and Planning Software) is used to document the effects on bed usage and occupancy of policy changes.

Appendix C Theoretical Distributions

Negative Binomial

$$p(x) = \binom{k+x-1}{x} p^k (1-p)^x$$

x = number of trials to get k events

p = probability of event $\in$ [0,1]

k = number of desired events = positive integer

The Negative Binomial distribution is a discrete distribution bounded on the low side at 0 and unbounded on the high side. The Negative Binomial distribution reduces to the Geometric Distribution for k = 1. The Negative Binomial distribution gives the total number of trials, x, to get k events (failures), each with the constant probability, p, of occurring. The Negative Binomial distribution has many uses; some occur because it provides a good approximation for the sum or mixing of other discrete distributions. By itself, it is used to model accident statistics, birth-and-death processes, market research and consumer expenditure, lending library data, biometrical data, and many others (Johnson, 1992).

Geometric(p)

$$p(x) = p(1-p)^x$$

p = probability of occurrence

The Geometric distribution is a discrete distribution bounded at 0 and unbounded on the high side. It is a special case of the Negative Binomial distribution. In particular, it is the direct discrete analogue for the continuous Exponential distribution. the Geometric distribution has no history dependence, its probability at any value being independent of a shift along the axis. The Geometric distribution has been used for inventory demand, marketing survey returns, a ticket control problem, and meteorological models. (Johnson, 1992) (Law, 1991).

Poisson

$$p(x) = \frac{e^{-\lambda} x^{x}}{x!}$$

λ = rate of occurrence

The Poisson distribution is a discrete distribution bounded at 0 on the low side and unbounded on the high side. The Poisson distribution is a limiting form of the Hypergeometric distribution. The Poisson distribution finds frequent use because it represents the infrequent occurrence of events whose rate is constant. This includes many types of events in time or space such as arrivals of telephone calls, defects in semiconductors manufacturing, defects in all aspects of quality control, molecular distributions, stellar distributions, geographical distributions of plants, shot noise, etc It is an important starting point in queuing theory and reliability theory. Note that the time between arrivals [defects] is exponentially distributed, which makes this distribution a particularly convenient starting point even when the process is more complex. The Poisson distribution peaks near lambda and falls off rapidly on either side.

Discrete Uniform(min, max)

$$f(x) = \frac{1}{\max - \min}$$

min = minimum x

max = maximum x

The Discrete Uniform distribution is a discrete distribution bounded on [min, max] with constant probability at every value on or between the bounds. Sometimes called the discrete rectangular distribution, it arises when an event can have a finite and equally probable number of outcomes.(Johnson, 1992)

Appendix D Statistical Tests

CHI^2 Chi Squared test

The Chi Squared test is a test of the goodness of fit, of the histogram or line graph with the fitted density or mass function. The test starts with the observed data put in classes (intervals). Stat::Fit has an automatic calculation, which chooses the least number of intervals that do not over smooth the data. The test then calculates the expected value for each interval from the fitted distribution, where the expected values of the end intervals include the sum or integral to infinity (+-) or the nearest bound. In order to make the test valid, intervals (classes) with less than 5 data points are joined to neighbours until remaining intervals have at least 5 data points. Then the Chi Squared statistic for this data is calculated according to the equation:

$$\chi^2 = \sum_{i=1}^{k} \frac{(n_i - np_i)^2}{np_i}$$

where χ^2 is the chi squared statistic, n is the total number of data points, n_i is the number of data points in the ith continuous interval or ith discrete class, k is the number of intervals or classes used, and p_i is the expected probability of occurrence in the interval or class for the fitted distribution.

The resulting test statistic is then compared to a standard value of Chi Squared with the appropriate number of degrees of freedom and level of significance, usually labeled alpha. In Stat::Fit, the number of degrees of freedom is always taken to be the net number of data bins [intervals, classes] used in the calculation minus 1, because this is the most conservative test, that is, least likely to reject the fit in error. The actual number of degrees of freedom is somewhere between this number and a similar number reduced by the number of parameters fitted by the estimating procedure. While Chi Squared test is an asymptotic test, which is valid only as the number of data points gets large, it may still be used in the comparative sense(Brunk H. D., 1960, Law Averill M., 1991, Stuart Alan, 1991).

The goodness of fit view also reports a REJECT or DO NOT REJECT decision for each Chi Squared test based on the comparison between the calculated test statistic and the standard statistic for the given level of significance.

While the test statistic can be useful, the p-value is more useful in determining the goodness of fit. The p-value is defined as the probability that another sample will be as unusual as the current sample given that the fit is appropriate. A small p-value indicates that the sample is highly unlikely, and, therefore, the fit should be rejected. Conversely, a high p-value indicates that the sample is likely and would be repeated and, therefore, the fit should not be rejected. Thus, the higher the p-value, the more likely the fit is appropriate. When comparing two different fitted distributions, the distribution with the higher p-value is likely to be the better fit.

Kolmogorov-Smirnov Test

The Kolmogorov Smirnov test is a non-parametric statistical test of the goodness of fit of the fitted cumulative distribution to the input data in the Data Table, point by point. The Kolmogorov Smirnov test (KS) calculates the largest absolute difference between the cumulative distributions for the input data and for the fitted distribution according to the equations:

$$D = \max(D^+, D^-)$$

$$D^+ = \max(\frac{i}{n} - F(x))$$

$$D^- = \max(F(x) - \frac{i}{n})$$

$$i = 1, \ldots, n$$

Where D is the KS statistic, x is the value of the ith point out of n total data points, and F(x) is the fitted cumulative distribution. Note that the difference is determined separately for positive and negative discrepancies on a point by point basis.

The resulting test statistic is then compared to a standard value of KS statistic with the appropriate number of data points and level of significance, usually labelled alpha. The

KS test is not a limiting distribution; it is appropriate for any sample size. While the KS test is only valid if none of the parameters in the test have been estimated from the data, it can be used for fitted distributions because with the understanding that it is then a conservative test, that is, less likely to reject the fit in error. The validity of the KS test can be improved for some specific distributions. These more stringent tests take the form of an multiplicative adjustment to the general KS statistic (Brunk H. D., 1960, Gleser Leon Jay, 1985, Law Averill M., 1991, Stuart Alan, 1991).

The goodness of fit view also reports a REJECT or DO NOT REJECT decision for each KS test based on the comparison between the calculated test statistic and the standard statistic for the given level of significance. Note that the KS test can be applied to discrete data. While the test statistic can be useful, the p-value is more useful in determining the goodness of fit. The p-value is defined as the probability that another sample will be as unusual as the current sample given that the fit is appropriate. A small p-value indicates that the sample is highly unlikely, and, therefore, the fit should be rejected. Conversely, a high p-value indicates that the sample is likely and would be repeated and, therefore, the fit should not be rejected. Thus, the HIGHER the p-value, the more likely the fit is appropriate. When comparing two different fitted distributions, the distribution with the higher p-value is likely to be the better fit.

Appendix E – Fitting the variables to theoretical distributions

Independent Identically Distributed Random Variables

$\hat{\rho}$

Law and Kelton (1991) propose using two graphical techniques are used to informally assess whether the data are independent. The first graphical technique is the correlation plot which is a graph of the sample correlation $\hat{\rho}$ for j = 1,2,3,...l (l is a positive integer). The sample correlation $\hat{\rho}_j$ is an estimate of the true correlation ρ_j between two observations that are j observation apart in time. However the sample correlation will not be exactly zero even if the sample values are independent, since the sample correlation $\hat{\rho}_j$ is an observation of a random variable whose mean is not equal to zero. Although if the sample correlation differs from zero by a significant amount then there is strong evidence that the variables observations are not independent.

The statistical software Stat::Fit was used to obtain the Autocorrelation calculation. The auto correlation, rho, is calculated from the equation:

$$\sum_{i=1}^{n} \frac{(x_i - \bar{x})(x_{i+j} - \bar{x})}{\sigma(n-j)}$$

where j is the lag between data points, sigma is the standard deviation of the population, approximated by the standard deviation of the sample, and x bar is the sample mean. The calculation is carried out to 1/5 of the length of the data set where diminishing pairs start to make the calculation unreliable. The auto correlation varies between 1 and -1, between positive and negative correlation and data near either extreme are auto correlated. Stat::Fit warns that the auto correlation can assume finite values due to the randomness of the data even if no significant auto correlation exists.

The second graphical technique is plotting a scatter diagram of the observations $X_1, X_2, ...X_n$ by plotting the pairs (X_i, X_{i+1}) for i= 1,2,..,n-1. If the observations are independent then the points on the diagram will be scattered within a quadrant.

Once the observations from the data are determined to be an independent or random sample then we can move on to determine their underlying distribution. Law and Kelton (1991) have categorised the stages of obtaining a probability distribution into three activities, which are defined and explained in the following sections.

7.7.1.2 Activity 1: Hypothesising families of distributions

The first activity is about deciding what families of distributions appear appropriate on the basis of their shapes without being concerned about the actual parameters. The requirements of the computer model were that the distributions produced days that were a whole positive number. It is also useful to examine the summary statistics from the input data that can be used to an extent to suggest a suitable distribution (Law Averill M., 1991). The main elements that are examined for the discrete distributions are the mean and median and the Lexis ratio, the skewness and the kurtosis. In the case of discrete distributions if the mean and median are approximately equal then the distribution may be symmetric. In addition, the skewness is a measure of the symmetry of a distribution and if it is more than zero it is skewed to the right and if it is less than zero it is skewed to the left. The kurtosis describes the "tail weight" of a distribution. Finally, the Lexis ration can be used to discriminate between Poisson (Lexis ratio=1), Binomial (Lexis ratio < 1), and Negative Binomial (Lexis ratio>1) Distributions.

Activity II – estimation of parameters from the data

The IID data in Activity I assist in suggesting relevant families of distributions and Activity II is concerned with determining the parameters of the distributions. Activity II also uses an estimator, which is a numerical function of the data. In this research, the Estimator Considered is the Maximum Likelihood Estimator because it is also described as suitable by Law and Kelton (1991). This process was automated through using Stat::Fit because it does it fast and accurately.

Activity III – Determining how representative the fitted distributions are

Once at least one probability distribution has been determined as suitable it is useful to examine how well the distribution fits the data. In the case that more than one distribution has been determined as suitable then the best fit is found. The are two ways of examining the best fit one is through Heuristic Procedures and the Second is through Goodness of Fit tests.

Two heuristic or graphical procedures will be discussed the Frequency comparison and the Probability Plot.

Frequency Comparison

In the case of discrete data a Frequency comparison is a graphical comparison of a line graph of the data with the mass function of a fitted distribution. If the fitted distribution is a true representation of the true underlying distribution of the data then expected proportion of the observations and the observed proportion of the data closely agree.

P-P plot

The P-P plot is a heuristic or graphical procedure for comparing the fitted distribution with the true underlying distribution. A probability-probability (P-P) plot is a graph of

$\hat{F}(X_i)$
the model probability

versus the graph of the sample probability

$\tilde{F}_n(X_i) = q_i$ for i = 1,2,...,n

if the graph of the model probability is close to the graph of the sample probability then the P-P plot will also be approximately linear with an intercept of 0 and a slope of 1.

7.7.1.3 What Goodness of Fit tests are considered to verify the distributions?

A goodness of fit test is a statistical hypothesis test that is used to assess formally whether the observations

$X_1, X_2, ..., X_n$

are an independent sample from a particular distribution function $\hat{F}$. The Hypothesis tested is:

Ho: the Xis are IID random variables with distribution function $\hat{F}$.

There are two points that need to be made about the goodness of fit tests. Firstly that failure to reject the null hypothesis should not be interpreted as it being true. The second point is that these tests are very powerful for small to moderate sample sizes and a very large sample size will mean that the null hypothesis will almost always be rejected. It is therefore sufficient to have a distribution that is almost correct or good enough for the intended purpose. For the purposes of this research, the Chi squared test and the Kolmogorov-Smirnov tests have been used as they are incorporated in Stat::Fit.

Appendix F – The Simulation Model Structure

Brooks et al. (2001) explains that "simulation consists of building a virtual world out of small components". In this section, we will examine the components of the computer model. Pidd (1998) acknowledges Fishman (1973) as the person that first pointed out that a basic discrete event simulation program can be divided into a three part structure consisting of the simulation executive, the model logic and a set of general tools. However, Brooks et al. (2001) divides the simulation program into nine elements, which include the following:

Simulation executive – the equivalent of an operating system. The simulation executive controls the running of the entire simulation. This may be performed by simulation software or by a simulation program written by the modeller for the particular application. For simulation software the executive will be the same for a range of simulation models and in a simulation program is custom designed for the particular problem. In this research simulation software is used because of the large cost and the development time that is required to create bespoke software.

Simulation clock – controls the run time of the simulation.

Random Number generator – a built in algorithm to generate random numbers, for example, for distributions relating to the interarrivals. It is a numerical algorithm that generates a sequence of numbers. They are usually pseudo random number generators because the same sequence of numbers will be generated. However this can be altered if the seed is changed.

Entities – are objects in the model and these can be Storage bins (queues), workstations, resources, work objects etc.

Events and states – models are made by a number of entities whose changes in behaviour is determined by events. For example an event can be an arrival of an object to a workstation. Between the events the entities are in a constant state in which their behaviour does not change. A modeller must decide which events to model from a system.

Event rules – these can be determined through object routing or through enhancing the model logic e.g. Simul8's "visual logic" The model logic, which is the expression of the activities that the entities engage in, is written by the modeller of the system.

Record of the current state of the entities – is about recording the current state of an entity that is used to inform the simulation executive.

Event list – record's the scheduled events and the time that they will occur.

Collection and recording of output statistics. This forms part of the set of general tools described by Pidd (1998). This is a very important part of the simulation as it allows the modeller to understand what happened in the run.

Appendix G – Validation and Verification approaches and techniques

Approaches to the Validation process

According to Sargent (1998) there are three basic approaches to use in deciding whether a simulation model is valid or not and each of these requires the development team to conduct verification and validation as part of the model development process. The first approach is also the most common approach, it is a subjective decision and involves the development team to make the decision as to whether the model is valid based on results from various tests. The second approach is often called "independent verification and validation" and uses a third independent party to decide whether the model is valid. The third approach involves using a scoring system for various aspects of the model. The scores are determined subjectively. The approach adopted for this research is the first one involving mainly the development team. The bulk of the validation and verification phase will focus on: Conceptual Model Validity, Computerised Model Verification and Operational Validity.

Conceptual model validity – is defined by Sargent (1998) as determining that the theories and assumption underlying the conceptual model are correct and that the model representation of the problem entity are "reasonable" for the intended purpose of the model". The theories and assumptions such as linearity, independence, stationary and Poisson arrivals are tested using mathematical analysis and statistical methods on problem entity data. Examples of applicable statistical methods are fitting distributions to data, estimating parameter values from the data and plotting the data to see if they are stationary.

Computerised model verification – is defined by Sargent (1998) as ensuring that the computer programming and implementation of the conceptual model is correct. The use of a special purpose simulation language eliminates many of the errors involved in developing a computer program using a general-purpose higher order language. Computer model verification requires that the program must be tested for correctness and accuracy. There are two basic approaches to testing and these are static and dynamic testing (analysis).

In static testing techniques such as a "structured walk through" can examine the correctness of the structure properties of the program. This technique involves each program developer explaining the computer code statement by statement to other members of the modelling team to convince them of the correctness. Although this research uses simulation software the models require certain visual logic extensions that are verified with this technique. In our case there is no programming language written by the modeller but visual logic extensions have been used to enhance the capabilities of the software. Therefore, this technique can be applied to the code used for the visual logic extensions.

In dynamic testing the computerised model is executed under different conditions and the resulting values are used to determine if the computer program and its implementation are correct (Sargent Robert G., 1998). There are three different strategies used in dynamic testing: (1) bottom-up testing, which means testing the submodels (model components) first and then the overall model, (2) top-down testing, which means testing the overall model first and then the submodels, and (3) mixed testing, which uses a mix of bottom-up and top-down testing. The individual models were built first and then the system model, which could be considered as a bottom up testing. This is because the individual simulation models depicted the services in a more complex way than the system model as the system model included all the services. In addition, understanding gained from the individual models helped build the whole system model. However, elements of top-down testing were included in the overall approach so it is fairer to say that mixed testing was applied to the models.

Operational validity – is defined by Sargent (1998) as determining that the model's output behaviour has sufficient accuracy for the model's indented purpose over the domain of the model's intended applicability. This is where the majority of the validation takes place. This process is affected by whether or not the system is observable or not through obtaining system data. This research has obtained system data, which means that the system has been observed. This part requires a comparison of the system output with the model output and it is achieved using graphical displays to explore the model behaviour and using statistical tests and procedures. Sargent (1998) suggests that in order to obtain a high degree of confidence in a model and its results, comparison of a model's and the system's input output behaviours for at least two different sets of experimental conditions is usually needed. In this research the input output measures would be interarrival days between patients and the length of stay of patients. The experimental conditions can be though as the run time of the model e.g. five months. There are three basic comparison approaches used:

Graphs of the model and system behaviour data – these are usually histograms, box (and whisker plots) and behaviour graphs using scatter plots. For example, in this research I have compared interarrival days with those generated by the theoretical distributions used in the simulation models. The approach has been influenced by Kleijnen (1995). Kleijnen (1995) suggests that before comparing simulated and real world data that the analysts should feed the real world input data into the model in historical order which should provide (after running the model) a time series of simulation output and compare that time series with the historical time series for the output of the existing system. This comparison can be done by three techniques. The first technique involves the output data of the real system and the simulated system to be plotted such that the horizontal axis denotes time and the vertical axis denotes the real and simulated values respectively. The analyst can "eyeball" the graph to see if the model adequately reflects the system. The second technique is the Schruben—Turing test, which involves showing system expert a mixture of simulated and real time series and challenge them to identify the data that were generated by the computer. The third technique involves using mathematical statistics to obtain quantitative data regarding the quality of the simulation model. The first and second techniques have been used for practical reasons.

Confidence intervals – these are obtained for the differences between the means, variances and distributions of different model and system output variables for each set of experimental conditions. Simul8 produces a confidence interval of simulation output for multiple runs. In terms of this research the simulation output of interest was the number of people entering a service over five months and their Length of Stay. For example, I compared the actual numbers of people entering each service with the confidence interval produced by simul8 of the arrival numbers.

Hypothesis tests – these can be used in the comparison of means, variances, distributions and time series of the output variables of the model and system for each set of experimental conditions to determine if the model's output behaviour has an acceptable range of accuracy. Kleijnen (1995) suggests that instead of only testing the mean or variance the analyst may test the whole distribution of the random variable. Then the analyst can apply a goodness of fit test such as the chi-squared and Kolmogorov-Smirnov Tests. This is also described earlier in the data analysis.

Data validity – is defined as "ensuring that the necessary data for model building, model evaluation and testing and conducting the models experiments to solve the problem are adequate and correct"(Sargent, 1998, p.123). However, data validity is usually not considered part of the model validation as in many cases there are no actual data used because it is usually difficult, time consuming and costly to obtain sufficient, accurate and appropriate data and is frequently the reason that attempts to validate the model fail. In this project the actual data is available through data collection and data validity is part of the development process. Therefore the main concern of the process is that the data is appropriate, accurate and sufficient. These points are further discussed in Chapter 6.

Validation Techniques

The validation techniques used in this research throughout the development stage of the simulation models are the following(Sargent Robert G., 1987, 1998):

The first validation technique is examining the models "Animation" to verify the computerised model and the operational validity. The Animation allows one to examine the operational behaviour of the model, which is displayed graphically as the model moves through time.

The second validation technique used is performing "Degenerate Tests". This test is about testing the degeneracy of the behaviour of the model by selecting different values of the input and internal parameters.

The third tests is examining "Event Validity" which is about examining occurrences of the simulation model are compared to those in the real system to determine if they are similar.

The fourth test is the "Extreme Conditions Tests" which is about looking at the behaviour of the model under extreme and unlikely conditions, e.g. if there are no patients entering a service simulation model there should be none exiting the model.

The fifth tests is "Face Validity" which is about asking people that are knowledgeable about the system if the model and/or its behaviour are reasonable. This technique is suitable for evaluating the conceptual model validity, the computerised model verification and the operational validity. This usually will involve system experts examining a flow chart or a graphical model or the set of model equations.

The sixth test is the "Fixed Values" which is about using fixed values to test the various model input and internal variables and parameters e.g. the values for the entities attributes.

The seventh test is the "Historical Data Validation" which is about using data collected from the system to see if the model behaves in a similar way to the system. This process would involve collecting data and using part of it to build the model and the other part to see if the model behaves in a similar way. This test would be useful in examining the number of people entering a model over a period of time compared to the actual number.

The eighth test is the "Historical methods". The three historical methods of validation are rationalism, empiricism and positive economics. Sargent (1998) explains that "Rationalism assumes that everyone knows whether the underlying assumptions of a model are true. Logic deductions are used from these assumptions to build the valid model. Empiricism requires every assumption and outcome to be empirically validated. Positive economics requires only that the model be able to predict the future and is not concerned with a model's assumptions or structure (causal relationships or mechanism)." This test is fitting to the system model of this research as it links with the SSM phase. If the SSM process validates the underlying system structure and if the system stakeholders agree with this structure then surely his is an indication of the validity of the model.

The ninth test is internal validity, which is about running several replications of the stochastic model to determine the amount of (internal) stochastic variability in the model. If there is a high amount of variability then the models results may be questionable.

The tenth test is "Operational Graphics" which is about examining the values of various performance measures graphically as the model moves through time. The simul8 software shows various performance measures graphically such as queues as the simulation model moves through time.

The eleventh test is Traces, which is about tracing (following) the behaviour of different entities through the model. This test is used to determine if the model's logic is correct and if the necessary accuracy is obtained. This technique is most commonly used for model verification. Kleijnen (1995) suggests that an analyst may calculate some intermediate results manually and to compare these results with the outputs of the simulation program and "getting all intermediate results from a computer program automatically is called tracing" (Kleinjen, 1995, p.147). However, if the analysts do not wish to calculate intermediate results by hand it is possible to "eyeball" the programs trace for errors.

Appendix H The ICON Assessment Instrument

Int er mediat e Car e
ICON
Or ganisat ion & Nor mal isat ion

Care Pathways Core Assessment (Version 8.1- 161000)

(Composed of assessment items from MDS-HC © InterRAI-UK)

1. CASE DETAILS

1.1. Completed on (Date) ______

1.2. Completed by (Assessor) ______

1.3. Completed at (Location) ______

1.4. Social Services (Genisys) Number ______

1.5. NHS Hospital Number ______

1.6. Name of Subject

1.6.a. Surname ______ 1.6.b. First Name(s) ______

1.7. Date of Birth ______

1.8. Gender ...... M F

1.9. Marital Status 4 3 2 1 0

0=Never married. **1**=Married. **2**=Widowed. **3**=Separated. **4**=Divorced.

1.10. Accommodation (at time of referral / admission)

1.10.a. Type of accommodation 6 5 4 3 2 1 0

1=Private/own home with no home care services. **2**= Private/own home with home care services. **3**=Warden accommodation. **4**=Nursing home. **5**=Residential home. **6**=Other.

1.10.b. Postcode of the above ______

1.10.c. Subject lived/lives with 6 5 4 3 2 1 0

1=Alone. **2**=Spouse only. **3**=Spouse and other. **4**=Child. **5**=Other(s) (not spouse or children). **6**=Group setting with non-relative(s).

1.10.d. Living Arrangement 1 0

0=Subject has moved in with another person. **1**=Another person has moved in with subject.

1.11. Subject Referred/admitted from ______

1.12. Subject Discharged/referred to ______

2. COGNITIVE FUNCTION

2.1. Short-term memory recall ability 1 0

0=OK. **1**=Not OK.

2.2. Cognitive Skills for Daily Decision Making 4 3 2 1 0

0=Independent. **1**=Some difficulty in new situations only. **2**=Decisions become poor in specific situations. **3**=Decisions consistently poor. **4**=Rarely made decisions.

2.3. Cognitive Function – Miscellaneous:

3. SENSORY FUNCTION and COMMUNICATION

3.1. Vision (Ability to see in adequate light and with glasses if used) 4 3 2 1 0

0=Sees fine detail, incl. regular print. **1**=Sees large print, not regular print. **2**=Limited vision, unable to see newspaper headlines, but can identify objects. **3**=Object identification in question, but eyes appear to follow objects. **4**=No vision or sees only light, colours or shapes.

3.2. Hearing [Appliance: ______] 3 2 1 0

0=Hears adequately. **1**=Minimal difficulty when not in quiet setting. **2**=Hears in special situations only. **3**=Absence of useful hearing.

3.3. Making Self Understood 3 2 1 0

0=Expresses ideas without difficulty. **1**=Difficulty finding words or finishing thoughts, but in time, little prompting required. **2**=Difficulty finding words or finishing thoughts, prompting usually required. **3**=Ability is limited to making concrete requests. **4**=Rarely understood.

3.4. Ability to Understand Others 4 3 2 1 0

0=Clear comprehension. **1**=Misses some part of message, but comprehends most conversation with little or no prompting. **2**-=Misses some part of message, with prompting can often comprehend conversation. **3**=Responds adequately to simple, directions. **4**=Rarely understands.

3.5. Swallowing 4 3 2 1 0

0=Normal. Safe and efficient swallowing of all diet consistencies. **1**=Requires diet modification to swallow solid foods. **2**=Requires modification to swallow solid foods and liquids. **3**=Combined oral and tube feeding. **4**=No oral intake.

3.6. Sensory Function – Miscellaneous:

4. MOOD AND BEHAVIOUR PATTERNS

4.1. Indicators of Mood *(To be finalised)*

0=Indicator not exhibited in last 3 day. **1**=Exhibited 1-2 of last 3 days. **2**=Exhibited on each of last 3 days.

4.1.a. A feeling of sadness or being depressed 2 1 0

4.1.b. Repetitive anxious complaints, concerns 2 1 0

4.2. Behavioural Symptoms

If exhibited, ease of altering symptoms. **0**=Did not occur in last 3 days. **1**=Occurred, easily altered.**2**=Occurred, not easily altered.

4.2.a. Wandering 2 1 0

4.2.b. Verbally abusive behavioural symptoms 2 1 0

4.2.c. Physically abusive behavioural symptoms 2 1 0

4.2.d. Socially inappropriate/disruptive behaviour 2 1 0

4.2.e. Resists care 2 1 0

4.3. Mood and Behaviour – Miscellaneous:

5. SOCIAL FUNCTIONING

5.1. Involvement

5.1.a. At ease interacting with others (eg: likes to spend time with others) .... Y N

5.1.b. Openly expresses conflict or anger with family/friend .... Y N

5.2. Change in Social Activities 3 2 1 0

As compared last assessment or 90 days ago, decline in level of social, religious or occupational activities. **0**=No decline. **1**=Decline, subject not distressed. **2**=Decline, subject distressed in morning. **3**=Decline, subject distressed all of the time.

5.3. Isolation 3 2 1 0

Time subject is alone during day. **0**= hardly ever. **1**=About one hour morning. **2**=Long periods of time, e.g. all morning. **3**=All of the time.

5.4. Subject says or indicates that he/she feels lonely .... Y N

5.5. Social Functioning – Miscellaneous:

6. INFORMAL SUPPORT SERVICES

6.1. Primary Informal Caregiver

Note: ADL includes personal care functions; IADL (Instrumental ADL) includes shopping, laundry, housework.

6.1.a. Gender .... M F

6.1.d. Lives with subject .... n/a Y N

6.1.e. Relationship to subject 2 1 0

0=Child or child-in-law. **1**=Spouse. **2**=Other relative.

6.1.i. Provides advice or emotional support .... Y N

6.1.j. Provides Instrumental ADL care .... Y N

6.1.k. Provides ADL care .... Y N

Questions (l) to (n): **0**=No. **1**=1 to 2 hours per day. **2**=More than 2 hours.

6.1.l. Willing to provide more advice or emotional support 2 1 0

6.1.m. Willing to provide more IADL care 2 1 0

6.1.n. Willing to provide more ADL care 2 1 0

6. INFORMAL SUPPORT SERVICES (Continued)

6.2. Caregiver Status

6.2.a. A caregiver is unable to continue in caring activities .... Y N

6.2.b. Primary caregiver is not satisfied with support received .... Y N

6.2.c. Primary caregiver expresses feelings of distress, anger or depression .... Y N

6.3. Extent of Informal Help

Hours of Care Rounded, for instrumental and personal activities of daily living received over the LAST 7 DAYS, record extent of help in hours from ALL OF: primary informal caregiver, family, friends and neighbours.

6.3.a. Sum of time across five weekdays .... ________

6.3.b Sum of time across two weekend days .... ________

7. PHYSICAL FUNCTIONING

7.1. Meal preparation during the last 7 days

7.1.a. Performance 4 3 2 1 0

0=Independent: did on own. **1**=Some help: help some of the time. **2**=Full help: performed with help all of the time. **3**=Performed by others. **4**=Activity did not occur.

7.1.b. Difficulty 2 1 0

How difficult it is (or would be) for subject to do activity on own? **0**=No difficulty. **1**=Some difficulty: needs some help, is very slow, or fatigues. **2**=Great difficulty: little or no involvement in the activity is possible.

7.2. ADL performance during last 3 days

See separate instructions for coding details. **0**=Independent. **1**=Set up help only. **2**=Supervision. **3**=Limited assistance. **4**=Extensive assistance. **5**=Maximal assistance. **6**=Total dependence. **7**=Activity did not occur.

7.2.a. Locomotion in home 7 6 5 4 3 2 1 0

If in wheelchair, self-sufficiency once in chair.

7.2.b. Eating 7 6 5 4 3 2 1 0

Includes taking in food by any method, including tube feedings.

7.2.c. Toilet use 7 6 5 4 3 2 1 0

Including using the toilet room or commode, bedpan, urinal, transferring on/off toilet, cleaning self after use, changing pad, managing any special devices required (ostomy or catheter), and adjusting clothes.

7.2.d. Personal hygiene 7 6 5 4 3 2 1 0

Including combing hair, brushing teeth, shaving, applying makeup, washing/drying face and hands. Exclude baths and showers.

7.2.e. Mobility in bed 7 6 5 4 3 2 1 0

Including moving to and from lying position, turning side to side, and positioning body while in bed.

7.2.f. Dressing upper body 7 6 5 4 3 2 1 0

How subject dresses and undresses (street clothes, underwear) above the waist, includes orthotics, fasteners, pullovers etc

7.2.g. Dressing lower body 7 6 5 4 3 2 1 0

How subject dresses and undresses (street clothes, underwear) from the waist down, includes prostheses, orthotics, belts, pants, skirts, shoes, and fasteners.

7.3. ADL Decline (compared to last assessment or 90 days ago) .... Y N

7.4. Functional Potential

7.4.a. Subject believes he/she capable of increased functional independence .... Y N

7.4.b. Caregivers believe subject is capable of increased functional independence .... Y N

7.4.c. Good prospects of recovery, improved health status expected .... Y N

7.5. Physical Function – Miscellaneous:

8. CONTINENCE

8.1. Bladder Continence

See separate instructions for coding details. (In last 7 days or since last assessment if less than 7 days.) **0**=Continent. **1**=Continent catheter. **2**=Usually continent. **3**=Occasionally incontinent. **4**=Frequently incontinent. **5**=Incontinent. **6**=No output from bladder.

8.1.a. Control of urinary bladder function 6 5 4 3 2 1 0

8.1.b. Worsening of bladder incontinence (Compared to 90 days ago or last assessment if sooner) .... Y N

8.2. Bowel Continence: control of bowel movement 4 3 2 1 0

See separate instructions for coding details. (In last 7 days or since last assessment if less than 7 days.) **0**=Continent. **1**=Usually continent. **2**=Occasionally incontinent. **3**=Frequently incontinent. **4**=Incontinent.

8.3. Continence – Miscellaneous:

9. SKIN CONDITION

9.1. Ulcers (Pressure/Stasis)

0=No ulcer. **1**=Ulcers include any area of persistent skin redness. **2**=Partial loss of skin layers. **3**=Deep craters in the skin. **4**=Breaks in skin exposing muscle or bone. If unsure, please state position on body of ulcer and visual appearance in box below.

9.1.a. Pressure ulcer 4 3 2 1 0

9.1.b. Stasis ulcer (Open lesion caused by poor circulation in the lower extremities) 4 3 2 1 0

9.2. Skin Condition – Miscellaneous: (Where is ulcer. Description of appearance.)

10. ENVIRONMENTAL ASSESSMENT

10.1. Home Environment

If home area is hazardous or uninhabitable circle Y, otherwise N.

10.1.a. Flooring and carpeting .... Y N

10.1.b. Kitchen .... Y N

10.1.c. Bathroom / Toilet .... Y N

10.1.d. Bedroom .... Y N

10.1.e. Access to home .... Y N

10.1.f. Access to rooms in house .... Y N

10.2. Living arrangement

10.2.a. Subject feels he/she would be better off in another living environment .... Y N

10.2.b. Caregiver feels subject would be better off in another living environment .... Y N

10. ENVIRONMENTAL ASSESSMENT (Continued)

10.3. Environmental Assessment – Miscellaneous:

11. SERVICE UTILISATION

11.1. Community Care

Minutes rounded to 0.25 hours. Record extent of care or care management in last 7 days, or since last assessment if less than 7 days.

	[Days]	[Hours]
11.1.a. Health Visitor		
11.1.b. Community Nurse		
11.1.c. Physiotherapist		
11.1.d. Occupational Therapist		
11.1.e. Speech Therapist		
11.1.f. Chiropodist		
11.1.g. Meals on Wheels		
11.1.h. Home care		
11.1.i. Home help		
11.1.j. Day hospital		
11.1.k. Day care centre		
11.1.l. Social worker in home		
11.1.m. IV infusion - peripheral		

11.6. Other Service Utilisation – Miscellaneous

12. DISEASE DIAGNOSIS

Disease/infection that doctor has indicated is present and affects subject's status, requires treatment, or symptom management. Also include if disease is monitored by a health professional or is the reason for a hospitalisation in last 90 days (or since last assessment if less than 90 days). **0**=No problem. **1**=Problem not treated or monitored. **2**=Problem treated or monitored.

12.1. Heart/Circulation
- 12.1.a. Cerebrovascular accident (stroke) 2 1 0
- 12.1.b. Congestive heart failure 2 1 0
- 12.1.c. Coronary artery disease 2 1 0
- 12.1.d. Hypertension 2 1 0
- 12.1.e. Irregular pulse 2 1 0
- 12.1.f. Peripheral vascular disease 2 1 0

12.2. Neurological
- 12.2.a. Alzheimer's 2 1 0
- 12.2.b. Other dementia 2 1 0
- 12.2.c. Head trauma 2 1 0
- 12.2.d. Hemiplegia/hemiparesis 2 1 0
- 12.2.e. Multiple sclerosis 2 1 0
- 12.2.f. Parkinsonism 2 1 0

12.3. Musculo-Skeletal
- 12.3.a. Arthritis 2 1 0
- 12.3.b. Hip fracture 2 1 0
- 12.3.c. Other fractures (eg: wrist, vertebral) 2 1 0
- 12.3.d. Osteoporosis 2 1 0

12.4. Senses
- 12.4.a. Cataract 2 1 0
- 12.4.b. Glaucoma 2 1 0

12.5. Infections
- 12.5.a. HIV infection 2 1 0
- 12.5.b. Pneumonia 2 1 0
- 12.5.c. Tuberculosis 2 1 0
- 12.5.d. Urinary tract infection (in last 30 days) 2 1 0

12.6. Other Diseases
- 12.6.a. Cancer (in past 5 years) not including skin cancer 2 1 0
- 12.6.b. Diabetes 2 1 0
- 12.6.c. Emphysemal/COPD/Asthma 2 1 0
- 12.6.d. Renal Failure 2 1 0
- 12.6.e. Thyroid Disease (hyper or hypo) 2 1 0
- 12.6.f. Any psychiatric diagnosis 2 1 0

12.7. Disease Diagnosis – Miscellaneous:

13. HEALTH CONDITIONS AND PREVENTATIVE HEALTH MEASURES

13.1. Falls frequency Number of times fell in last 90 days .... + 9 8 7 6 5 4 3 2 1 0

13.2. Danger of Falls

13.2.a. Unsteady gait .... Y N

13.2.b. Subject limits going outdoors due to fear of falling .... Y N

13.3. Preventative Health (In past 2 years)

13.3.a. Blood pressure measured .... Y N

13.3.b. Received influenza vaccination .... Y N

13.3.c. Test for blood in stool or screening endoscopy .... Y N

13.3.d. IF FEMALE: Received breast examination or mammography .... Y N

13.4. Problem Conditions (Present on 2 or more days out of last 3)

13.4.a. Diarrhoea .... Y N

13.4.b. Difficulty urinating or urinating 3 or more times at night .... Y N

13.4.c. Fever .... Y N

13.4.d. Loss of appetite .... Y N

13.4.e. Vomiting .... Y N

13.5. Physical Health

13.5.a. Chest pain/pressure at rest or on exertion .... Y N

13.5.b. No bowel movement in 3 days .... Y N

13.5.c. Dizziness or light headedness .... Y N

13.5.d. Oedema .... Y N

13.5.e. Shortness of breath .... Y N

13.6. Mental Health

13.6.a. Delusions .... Y N

13.6.b. Hallucinations .... Y N

13.7 Experiencing a flare-up of a recurrent or chronic problem .... Y N

13.8 Prognosis of less than six months to live .... Y N

13.9. Health Conditions – Miscellaneous:

Discharge Assessment (Version 8.1 - 161000)

(Composed of assessment items from MDS-HC © InterRAI-UK)

Intermediate Care ICON Organisation & Normalisation

1. CASE DETAILS

1.1. Completed on (Date) ______________________

1.2. Completed by (Assessor) ______________________

1.3. Completed at (Location) ______________________

1.4. Social Services (Genisys) Number ______________________

1.5. NHS Hospital Number ______________________

1.6. Name of Subject

1.6.a. Surname ______________________ 1.6.b. First Name(s) ______________________

1.13. Discharged/referred to ______________________

E.g. home with or without care package. Name of other centre or clinic.

2. COGNITIVE FUNCTION

2.1. Short-term memory recall ability **0**=OK. **1**=Not OK. 1 0

2.2. Cognitive Skills for Daily Decision Making 4 3 2 1 0

0=Independent. **1**=Some difficulty in new situations only. **2**=Decisions become poor in specific situations. **3**=Decisions consistently poor. **4**=Rarely made decisions.

3. SENSORY FUNCTION and COMMUNICATION

3.1. Vision (Ability to see in adequate light and with glasses if used) 4 3 2 1 0

0=Sees fine detail, incl. regular print. **1**=Sees large print, not regular print. **2**=Limited vision, unable to see newspaper headlines, but can identify objects. **3**=Object identification in question, but eyes appear to follow objects. **4**=No vision or sees only light, colours or shapes.

3.2. Hearing [Appliance: ______________________] 3 2 1 0

0=Hears adequately. **1**=Minimal difficulty when not in quiet setting. **2**=Hears in special situations only. **3**=Absence of useful hearing.

3.3. Making Self Understood 3 2 1 0

0=Expresses ideas without difficulty. **1**=Difficulty finding words or finishing thoughts, but in time, little prompting required. **2**=Difficulty finding words or finishing thoughts, prompting usually required. **3**=Ability is limited to making concrete requests. **4**=Rarely understood.

3.4. Ability to Understand Others 4 3 2 1 0

0=Clear comprehension. **1**=Misses some part of message, but comprehends most conversation with little or no prompting. **2**-=Misses some part of message, with prompting can often comprehend conversation. **3**=Responds adequately to simple, directions. **4**=Rarely understands.

3.5. Swallowing 4 3 2 1 0

0=Normal. Safe and efficient swallowing of all diet consistencies. **1**=Requires diet modification to swallow solid foods. **2**=Requires modification to swallow solid foods and liquids. **3**=Combined oral and tube feeding. **4**=No oral intake.

4. MOOD AND BEHAVIOUR PATTERNS

4.1. Indicators of Mood

0=Indicator not exhibited in last 3 day. **1**=Exhibited 1-2 of last 3 days. **2**=Exhibited on each of last 3 days.

4.1.a. A feeling of sadness or being depressed 2 1 0

4.1.b. Repetitive anxious complaints, concerns 2 1 0

4.2. Behavioural Symptoms

If exhibited, ease of altering symptoms. **0**=Did not occur in last 3 days. **1**=Occurred, easily altered.**2**=Occurred, not easily altered.

4.2.a. Wandering 2 1 0

4.2.b. Verbally abusive behavioural symptoms 2 1 0

4.2.c. Physically abusive behavioural symptoms 2 1 0

4.2.d. Socially inappropriate/disruptive behaviour 2 1 0

4.2.e. Resists care 2 1 0

5. SOCIAL FUNCTIONING

5.1. Involvement

5.1.a. At ease interacting with others (eg: likes to spend time with others) .... Y N

5.1.b. Openly expresses conflict or anger with family/friend .... Y N

5.2. Change in Social Activities 3 2 1 0

As compared last assessment or 90 days ago, decline in level of social, religious or occupational activities. **0**=No decline. **1**=Decline, subject not distressed. **2**=Decline, subject distressed in morning. **3**=Decline, subject distressed all of the time.

5.3. Isolation 3 2 1 0

Time subject is alone during day. **0**= hardly ever. **1**=About one hour morning. **2**=Long periods of time, e.g. all morning. **3**=All of the time.

5.4. Subject says or indicates that he/she feels lonely .... Y N

7. PHYSICAL FUNCTIONING

7.1. Meal preparation during the last 7 days

7.1.a. Performance 4 3 2 1 0

0=Independent: did on own. **1**=Some help: help some of the time. **2**=Full help: performed with help all of the time. **3**=Performed by others. **4**=Activity did not occur.

7.1.b. Difficulty 2 1 0

How difficult it is (or would be) for subject to do activity on own? **0**=No difficulty. **1**=Some difficulty: needs some help, is very slow, or fatigues. **2**=Great difficulty: little or no involvement in the activity is possible.

7.2. ADL performance during last 3 days

0. Independent .... No help, setup, or oversight – OR – Help, setup, oversight provided only 1 or 2 times during last 3 days (with any task or subtask).
1. Setup help only .... Article or device provided within reach of client 3 or more times.
2. Supervision .... Oversight, encouragement or cueing provided 3 or more times during last 3 days – OR – Supervision (1 or more times) plus physical assistance provided only 1 or 2 times during last 3 days (for a total of 3 or more episodes of help or supervision).
3. Limited assistance .... Client highly involved in activity, received physical help in guided manoeuvring of limbs or other non-weight bearing assistance 3 or more times – OR – combination of non-weight bearing help with more help provided only 1 or 2 times during period (for a total of 3 or more episodes of physical help).
4. Extensive assistance .... Client performed part of activity on own (50% or more of subtasks), period, but help of following type(s) were provided 3 or more times:- Weight-bearing support – OR —Full performance by another during part (but not all) of last 3 days.
5. Maximal assistance .... Client involved and completed less than 50% of subtasks on own (includes 2+ person assist), received weight bearing help or full performance of certain subtasks 3 or more times.
6. Total dependence .... Full performance of activity by another.
7. Activity did not occur .... Regardless of ability.

7.2.a. Locomotion in home 7 6 5 4 3 2 1 0

If in wheelchair, self-sufficiency once in chair.

7.2.b. Eating 7 6 5 4 3 2 1 0

Includes taking in food by any method, including tube feedings.

7.2.c. Toilet use 7 6 5 4 3 2 1 0

Including using the toilet room or commode, bedpan, urinal, transferring on/off toilet, cleaning self after use, changing pad, managing any special devices required (ostomy or catheter), and adjusting clothes.

7.2.d. Personal hygiene 7 6 5 4 3 2 1 0

Including combing hair, brushing teeth, shaving, applying makeup, washing/drying face and hands. Exclude baths and showers.

7.2.e. Mobility in bed 7 6 5 4 3 2 1 0

Including moving to and from lying position, turning side to side, and positioning body while in bed.

7.2.f. Dressing upper body 7 6 5 4 3 2 1 0

How subject dresses and undresses (street clothes, underwear) above the waist, includes orthotics, fasteners, pullovers etc

7.2.g. Dressing lower body 7 6 5 4 3 2 1 0

How subject dresses and undresses (street clothes, underwear) from the waist down, includes prostheses, orthotics, belts, pants, skirts, shoes, and fasteners.

7.3. ADL Decline (compared to last assessment or 90 days ago) .... Y N

7.4. Functional Potential

7.4.a. Subject believes he/she capable of increased functional independence .... Y N

7.4.b. Caregivers believe subject is capable of increased functional independence .... Y N

7.4.c. Good prospects of recovery, improved health status expected .... Y N

8. CONTINENCE

8.1. Bladder Continence (In last 7 days or since last assessment if less than 7 days.)

8.1.a. Control of urinary bladder function 6 5 4 3 2 1 0

0. Continent .... Complete control; DOES NOT USE any type of catheter or other urinary collection device.
1. Continent with catheter .... Complete control with use of any type of catheter or urinary device that does not leak urine.
2. Usually continent .... Incontinent episodes once a week or less.
3. Occasionally incontinent .... Incontinent episodes 2 or more times a week but not daily.
4. Frequently incontinent .... Tends to be incontinent daily, but some control present.
5. Incontinent .... Inadequate control, multiple daily episodes.
6. Did not occur .... No urine output from bladder.

8.1.b. Worsening of bladder incontinence (Compared to 90 days ago or last assessment if sooner) .... Y N

8.2. Bowel Continence: control of bowel movement (In last 7 days or since last assessment.) 4 3 2 1 0

0. Continent .... Complete control.
1. Usually continent .... Bowel incontinent episodes less than weekly.
2. Occasionally incontinent ..... Bowel incontinent once a week.
3. Frequently incontinent .... Bowel incontinent episodes 2-3 times a week.
4. Incontinent .... Bowel incontinent all (or almost all) of the time.

9. SKIN CONDITION

9.1. Ulcers (Pressure/Stasis)

0=No ulcer. **1**=Ulcers include any area of persistent skin redness. **2**=Partial loss of skin layers. **3**=Deep craters in the skin. **4**=Breaks in skin exposing muscle or bone. If unsure, please state position on body of ulcer and visual appearance in box below.

9.1.a. Pressure ulcer 4 3 2 1 0

9.1.b. Stasis ulcer (Open lesion caused by poor circulation in the lower extremities) 4 3 2 1 0

9.2. Skin Condition – Miscellaneous: (Where is ulcer. Description of appearance.)

11. SERVICE UTILISATION

11.1. Community Care Minutes rounded to 0.25 hours. Record extent of care in last 7 days, or since last assessment if less than 7 days.

	[Days]	[Hours]
11.1.a. Health Visitor		
11.1.b. Community Nurse		
11.1.c. Physiotherapist		
11.1.d. Occupational Therapist		
11.1.e. Speech Therapist		
11.1.f. Chiropodist		
11.1.g. Meals on Wheels		
11.1.h. Home care		
11.1.i. Home help		
11.1.j. Day hospital		
11.1.k. Day care centre		
11.1.l. Social worker in home		
11.1.m. IV infusion - peripheral		

13. HEALTH CONDITIONS AND PREVENTATIVE HEALTH MEASURES

13.1. Falls frequency Number of times fell in last 90 days .... + 9 8 7 6 5 4 3 2 1 0

13.2. Danger of Falls

13.2.a. Unsteady gait .... Y N

13.2.b. Subject limits going outdoors due to fear of falling .... Y N

13.4. Problem Conditions (Present on 2 or more days out of last 3)

13.4.a. Diarrhoea .... Y N

13.4.b. Difficulty urinating or urinating 3 or more times at night .... Y N

13.4.c. Fever .... Y N

13.4.d. Loss of appetite .... Y N

13.4.e. Vomiting .... Y N

13.5. Physical Health

13.5.a. Chest pain/pressure at rest or on exertion .... Y N

13.5.b. No bowel movement in 3 days .... Y N

13.5.c. Dizziness or light headedness .... Y N

13.5.d. Oedema .... Y N

13.5.e. Shortness of breath .... Y N

13.6. Mental Health

13.6.a. Delusions .... Y N

13.6.b. Hallucinations .... Y N

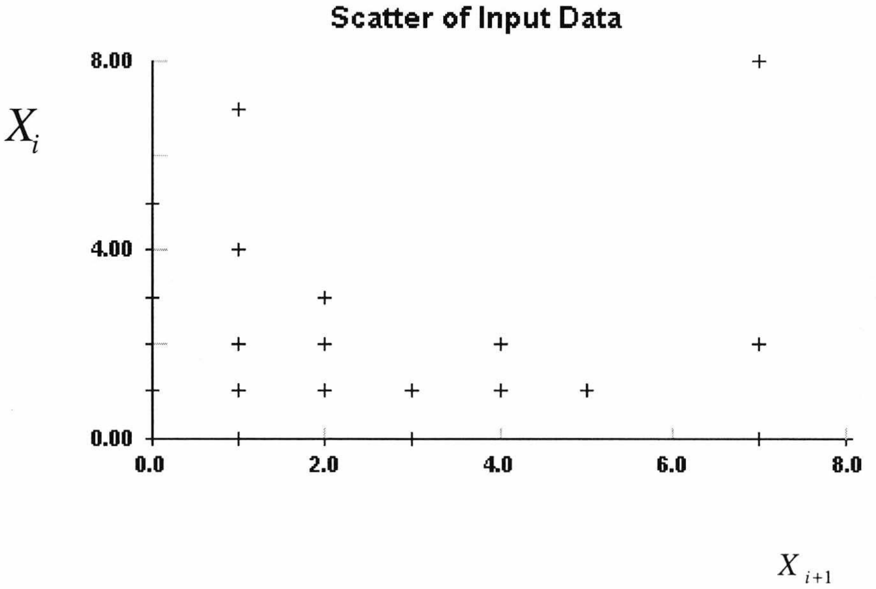
13.7. Experiencing a flare-up of a recurrent or chronic problem .... Y N

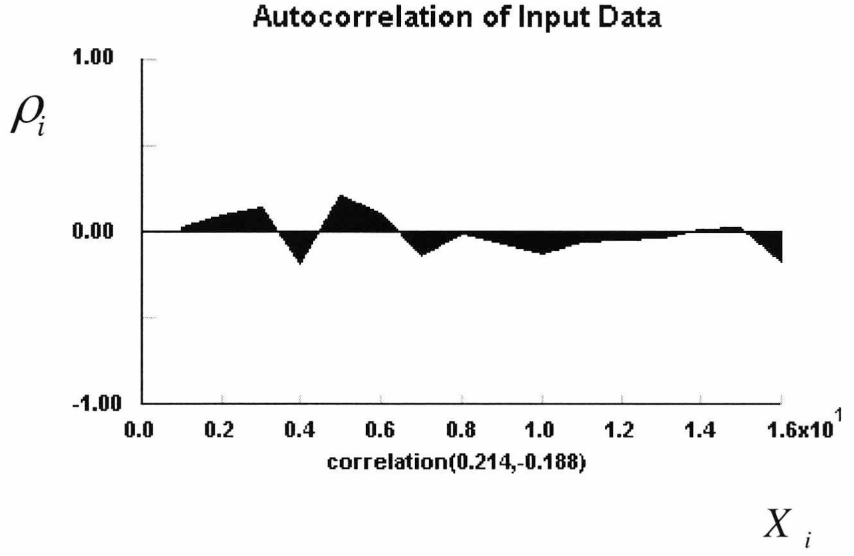
13.8 Prognosis of less than six months to live .... Y N

Appendix I – Generating Interarrival and Length of Stay Distributions for each service

Generating the CART Interarrival and Length of Stay Distributions

The three main steps for generating the Interarrival distribution





Activity 1 – Hypothesising families of distributions

Table I.1 Summary Statistics for CART

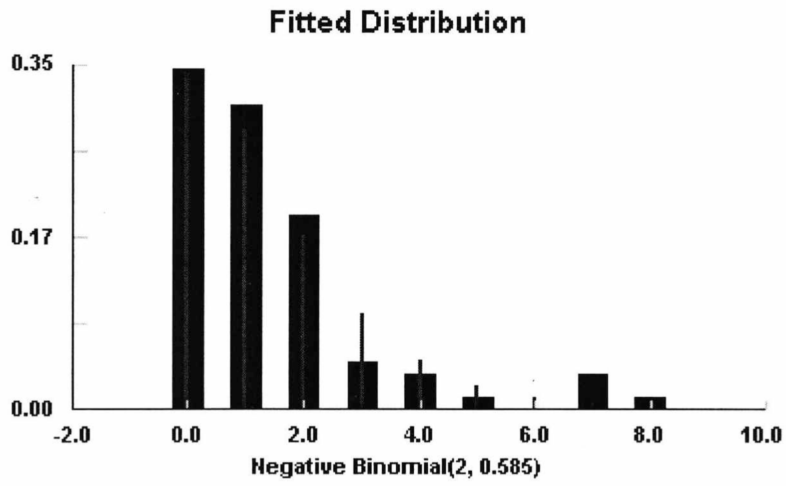
Data points	81
minimum	0
maximum	8
mean	1.41975
median	1
mode	0
Standard deviation	1.7526
variance	3.0716
Coefficient of variation	123.444
skewness	1.92771
kurtosis	3.83365
Lexis ratio (variance/mean)	2.16

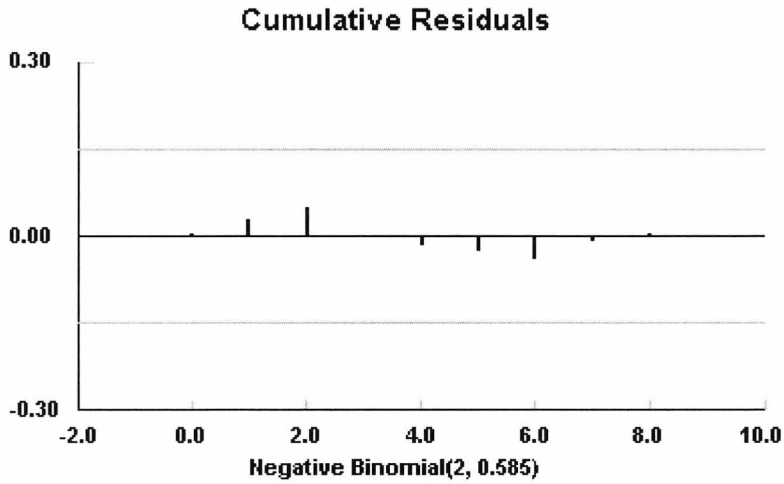
Activity 2 Estimation of the parameters from the data

Table I.2 Maximum Likelihood Estimation

Discrete Uniform (0,8)
Geometric (p=0.413265)
Negative Binomial (k=2, p=0.584838)
Poisson (lambda 1.41975)

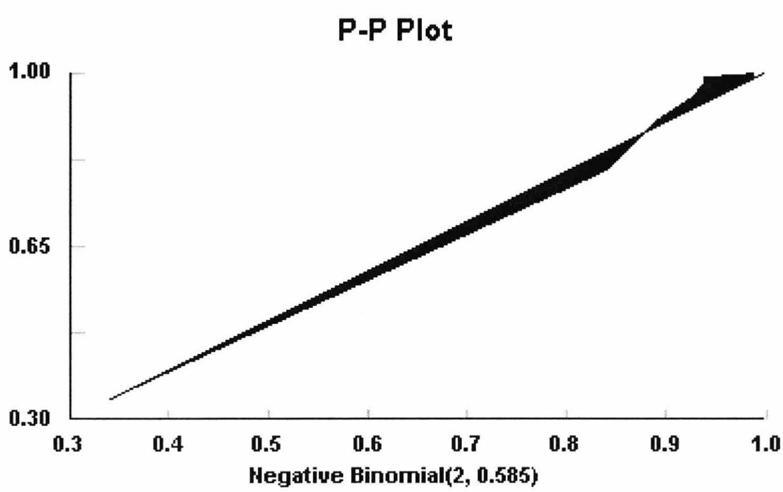
n=81





Activity 3 – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



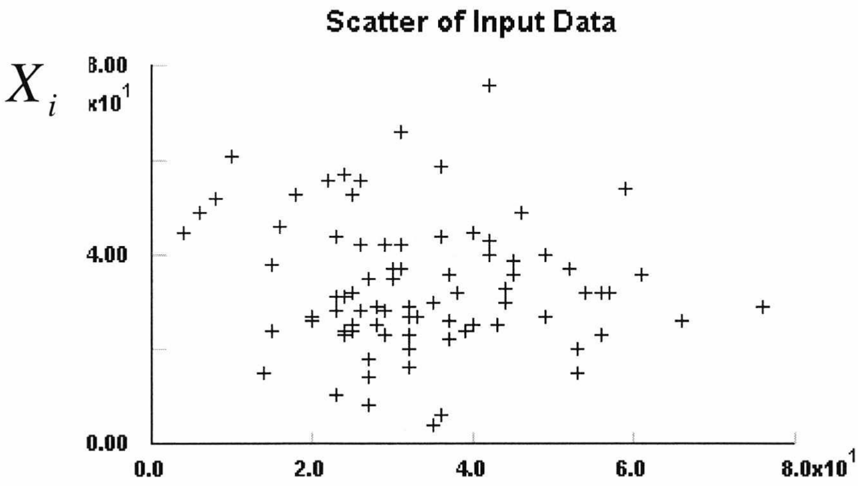
Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

Table I.3 Distribution generated to fit CART

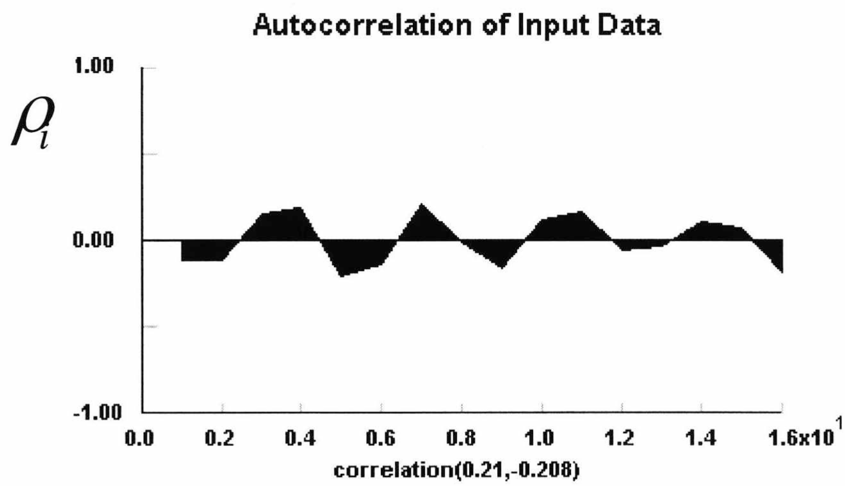
Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (2,0.585)	2.32(4 d.f.)	0.241 Do not reject	0.049	0.985 Do not reject	Accept
Geometric (0.413)	5.49 (4 d.f.))	0.241 Do not reject	0.0676	0.829 Do not reject	Accept
Poisson (1.41975)	4.86 (3 d.f.)	0.182 Do not reject	0.104	0.323 Do not reject	Accept

The three main steps for generating the LOS distribution

This stage is to examining whether the data are correlated in order to determine if the sample values are Independently Identically Distributed.



X_{i+1}



X_i

Activity 1 – Hypothesising families of distributions

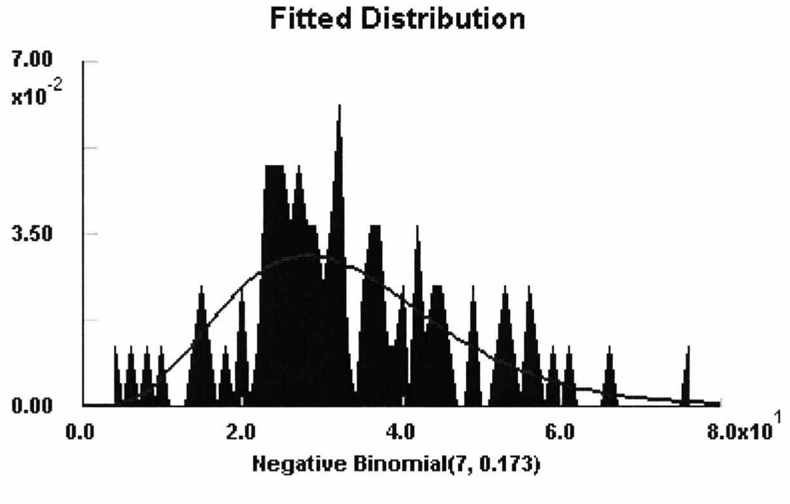
Table I.4 Summary Statistics for CART Length of Stay

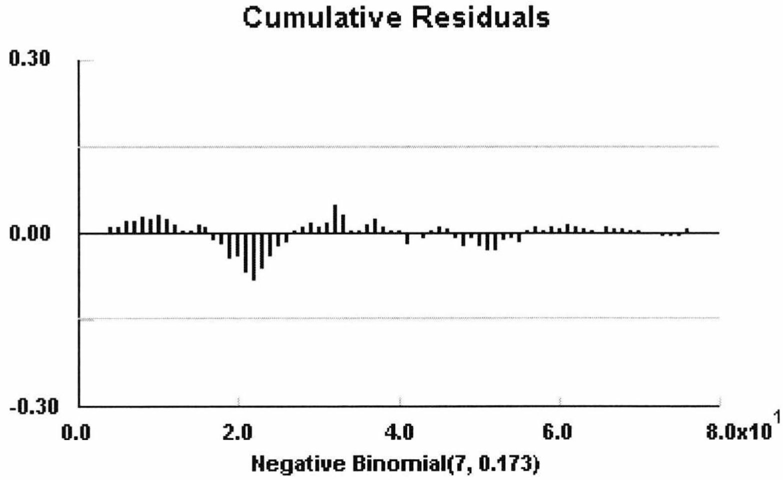
Data points	82
minimum	4
maximum	76
mean	33.40
median	31.00
mode	32
Standard deviation	13.86
variance	192.00
Coefficient of variation	41.4828
skewness	0.531
kurtosis	0.254987
Lexis ratio (variance/mean)	5.75

Activity 2 Estimation of the parameters from the data

Table I.5 Maximum Likelihood Estimation

Discrete Uniform (4,76)
Geometric (p=0.0290677)
Negative Binomial (k=7, p=0.173257)
Poisson (lambda 33.4024)





Activity 3 – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures

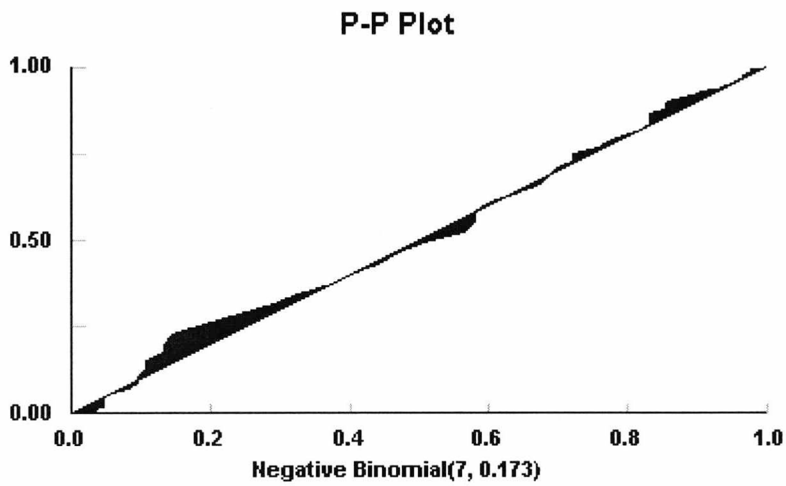


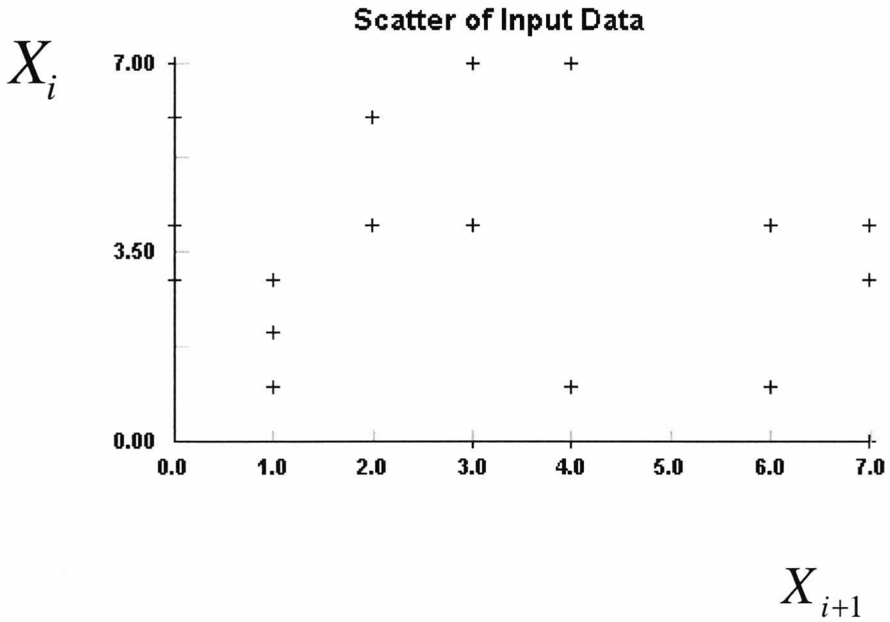
Table I.6 Distribution generated to fit CART data

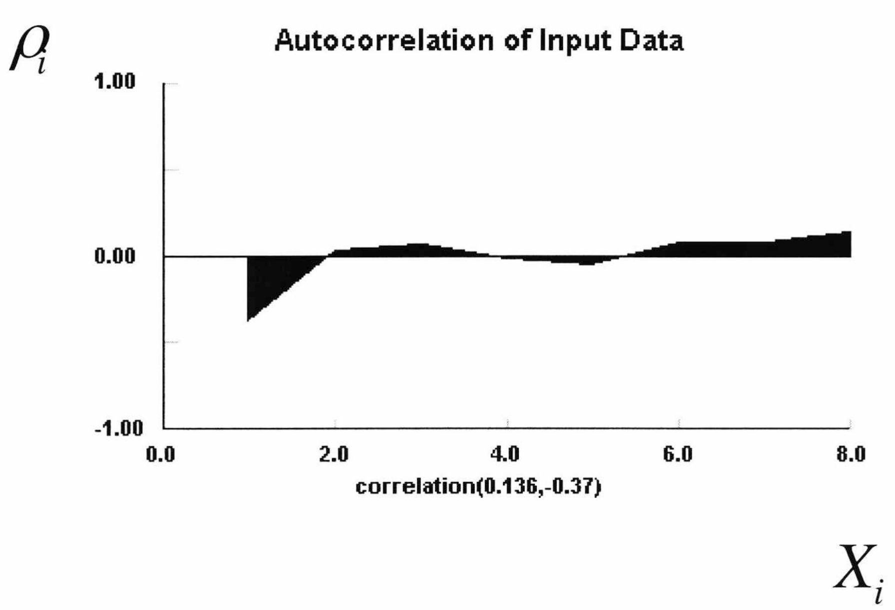
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (7,0.173)	10.5 (12 d.f)	0.572 Do not reject	0.0803	0.636 Do not reject	Accept

Generating the Day Hospital Interarrival and Length of Stay distributions

Generating the Day Hospital Interarrival distribution

The Scatter and Autocorrelation graphs of input data show that the Day Hospitals interarrival data is comprised of Independent Identically Distributed Random Variables. The Autocorrelation range has a minimum value of –0.37 and a maximum of 0.136.





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is almost symmetrical as the mean is 2.81 and median is 3, as the difference is less than 1 day. The skewness is 0.37, which means that the distribution is skewed very slightly to the right and the kurtosis is –1.11. The Lexis ratio is 2.14, which suggests that it may be a Negative Binomial Distribution.

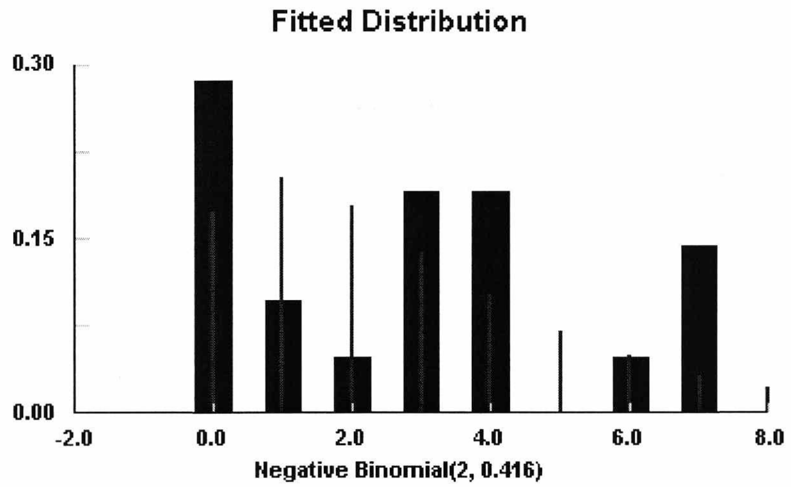
Table I.7 Summary Statistics for interarrival data

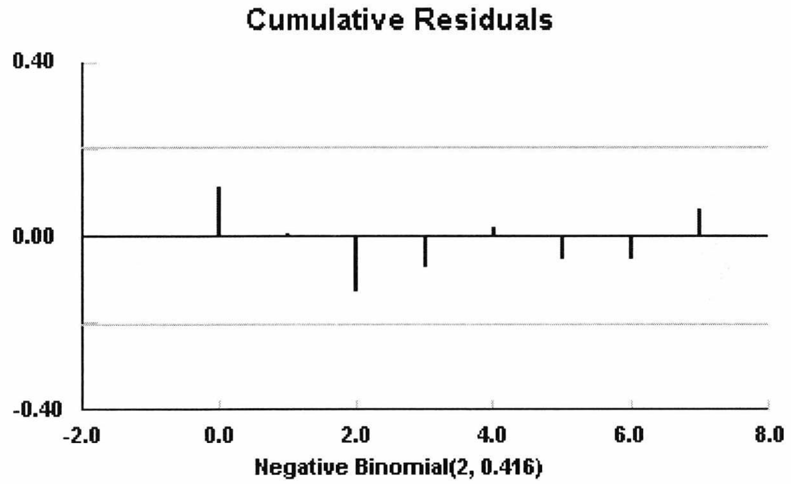
Data points	42
minimum	0
maximum	7
mean	2.80952
median	3
mode	0
Standard deviation	2.45186
variance	6.01161
Coefficient of variation	87.2696
skewness	0.370129
kurtosis	-1.11256
Lexis ratio (variance/mean)	2.14

Activity 2 Estimation of the parameters from the data

Table I.8 Maximum Likelihood Estimation

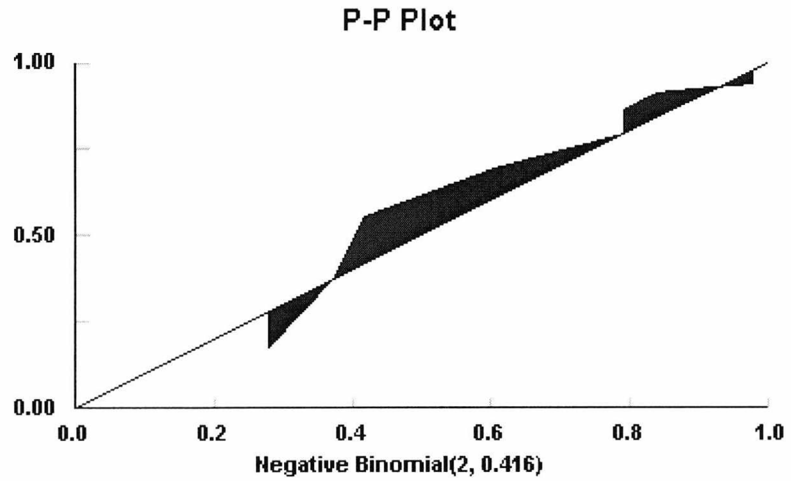
Discrete Uniform (0,7)
Geometric (p=0.2625)
Negative Binomial (k=2, p=0.415842)
Poisson (lambda 2.80952)





Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

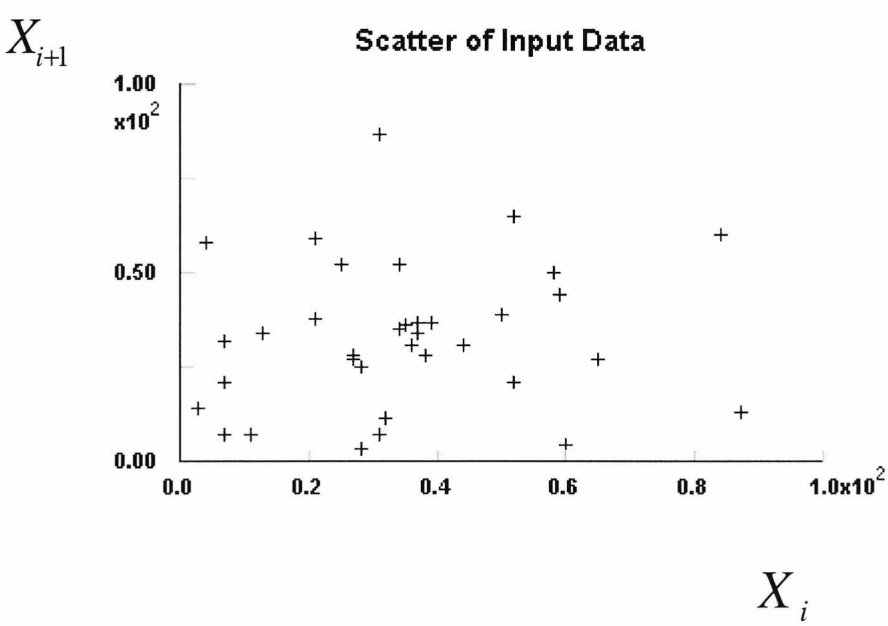
Stat::fit ranked the distributions in order of best fit and the Negative Binomial was first, the Geometric was second and the Discrete Uniform was third. The frequency comparison and the P-P plot showed that none of the above distribution is a perfect fit.

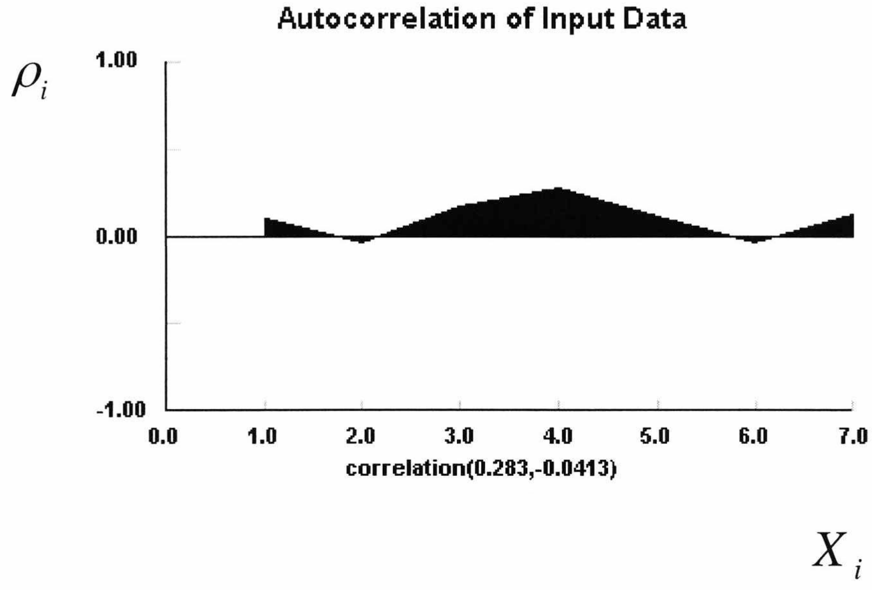
Table I.9 Interarrival Distributions generated for the Day Hospital

Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (2,0.416)	11.2(5 d.f.)	0.0481 reject	0.123	0.505 Do not reject	Accept
Geometric (0.263)	14 (4 d.f.)	0.00731 reject	0.17	0.156 Do not reject	Accept
Discrete Uniform (0,7)	21.2(7 d.f.)	0.00343 reject	0.185	0.1 Do not reject	Accept

Generating a distribution for the Day Hospital Length of Stay

The scatter plot for the Day Hospital Length of Stay data suggests that the data is IID and this is also confirm by the Autocorrelation plot with a minimum value of –0.0413 and a maximum value of 0.283.





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution nearly symmetrical as the mean is 34.39 and median is 33, a difference less than 2 days. The skewness is 0.61, which means that the distribution is skewed very slightly to the right and the kurtosis is –0.034. The Lexis ratio is 12.66, which suggests that it may be a Negative Binomial Distribution.

Table I.10 Descriptive statistics for the Day Hospital LOS data

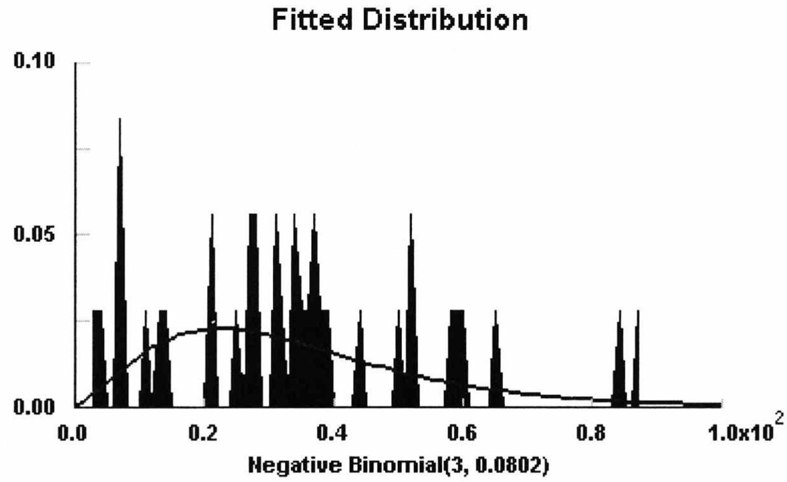
Data points	36
minimum	3
maximum	87
mean	34.3889
median	33
mode	7
Standard deviation	20.8659
variance	435.387
Coefficient of variation	60.6764
skewness	0.60649
kurtosis	-0.033958
Lexis ratio (variance/mean)	12.66

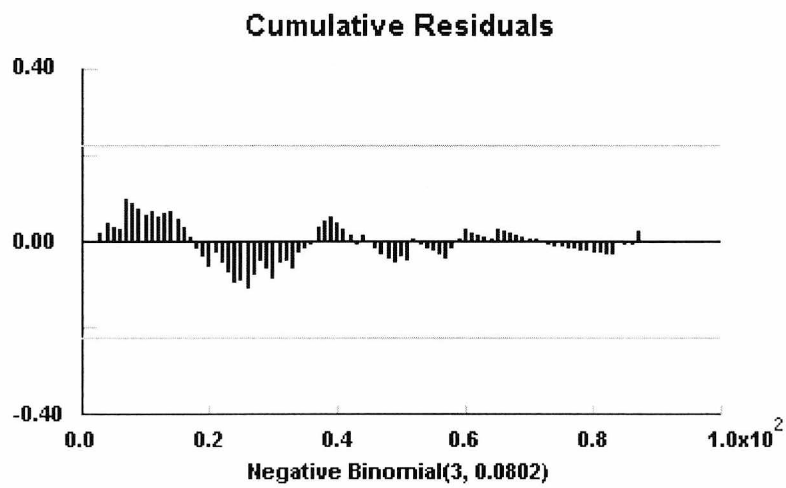
Estimation of the parameters from the data

Table I.11 Maximum Likelihood Estimation

Discrete Uniform (3,87)
Geometric (p=0.0282575)
Negative Binomial (k=3, p=0.0802377)
Poisson (lambda 34.3889)

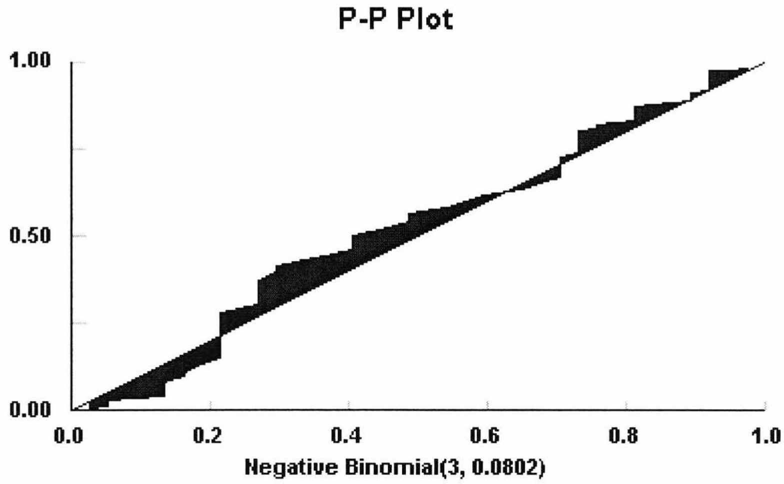
Fitting the system (real) data to a statistical distribution.





Activity 3 – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

Stat::fit ranked the distributions in order of best fit and accepted only the Negative Binomial distribution. The frequency comparison and the P-P plot showed that the distribution is a reasonable fit.

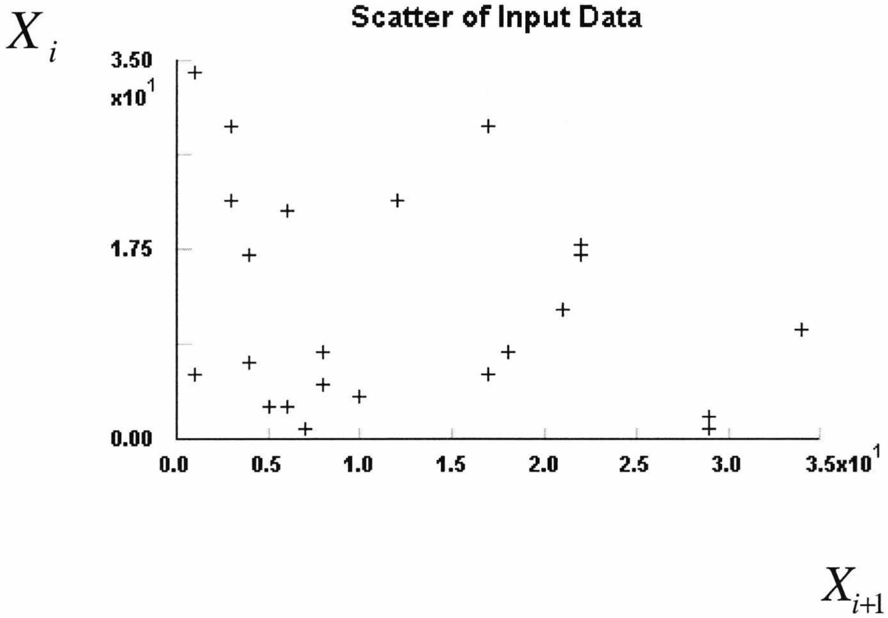
Table I.12 Distribution generated to fit Day Hospital LOS data

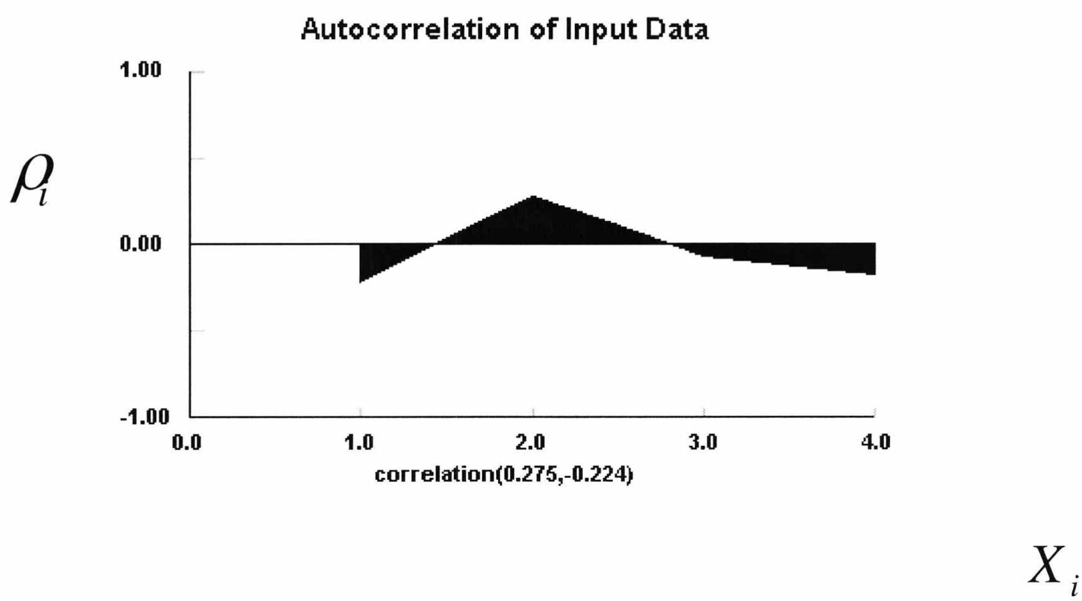
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (3,0.0802)	8.78 (6 d.f)	0.186 Do not reject	0.106	0.708 Do not reject	Accept

Generating the Recuperative Care Interarrival and Length of Stay Distribution

Generating the Interarrival distribution

The Scatter and Autocorrelation graphs of input data (-0.224,0.275) generated from Stat::Fit illustrate that the Recuperative care interarrival data is comprised of Independent Identically Distributed Random Variables





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is not symmetrical as the mean is 12.0417 and median is 8. However, the difference is only 4 days. The skewness is 0.70, which means that the distribution is skewed to slightly to the right and the kurtosis is –0.83. The Lexis ratio is 8.098, which suggests that it may be a Negative Binomial Distribution.

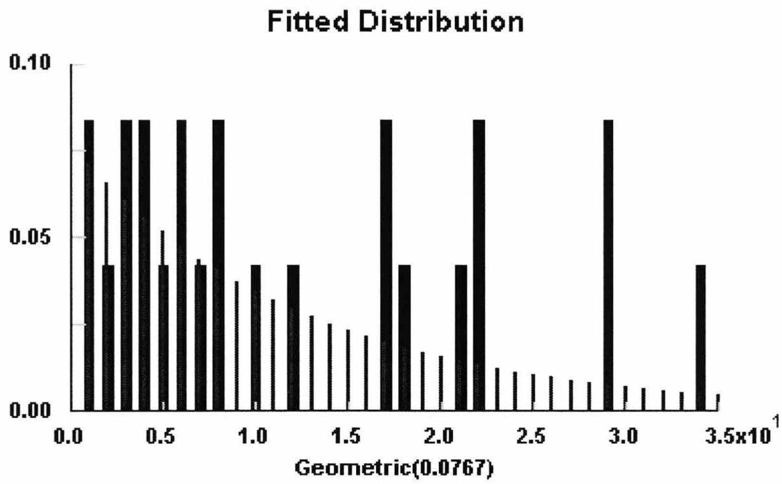
Table I.13 Summary Statistics for Recuperative Care

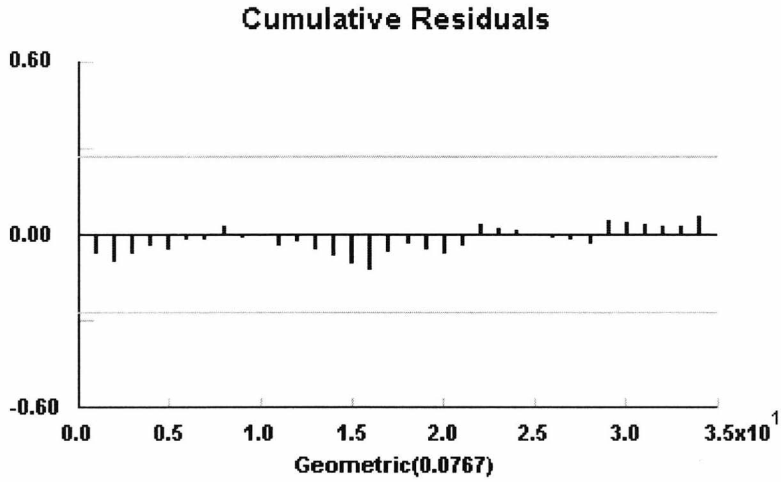
Data points	24
minimum	1
maximum	34
mean	12.0417
median	8
mode	1
Standard deviation	9.87522
variance	97.5199
Coefficient of variation	82.0087
skewness	0.701286
kurtosis	-0.833793
Lexis ratio (variance/mean)	8.098

Activity 2 Estimation of the parameters from the data Maximum Likelihood Estimation

Table I.14 Maximum Likelihood Estimation

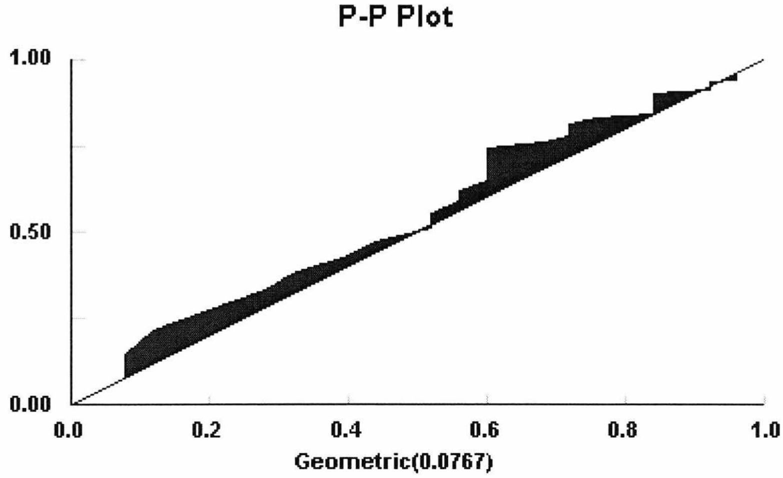
Discrete Uniform (1,34)
Geometric (p=0.0766773)
Negative Binomial (k=2, p=0.142433)
Poisson (lambda 12.0417)





Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

Stat::fit ranked the distributions in order of best fit and the Geometric was first and the Negative Binomial is second. The frequency comparison and the P-P plot showed that the Geometric distribution is a reasonable fit. The goodness of fit tests revealed that both the Geometric and the Negative Binomial were suitable distributions as the Chi squared p-values and the Kolmogorov-Smirnov p-values resulted in a Do Not Reject Result. Although both distributions can be used the Geometric is preferred because of the higher p-values.

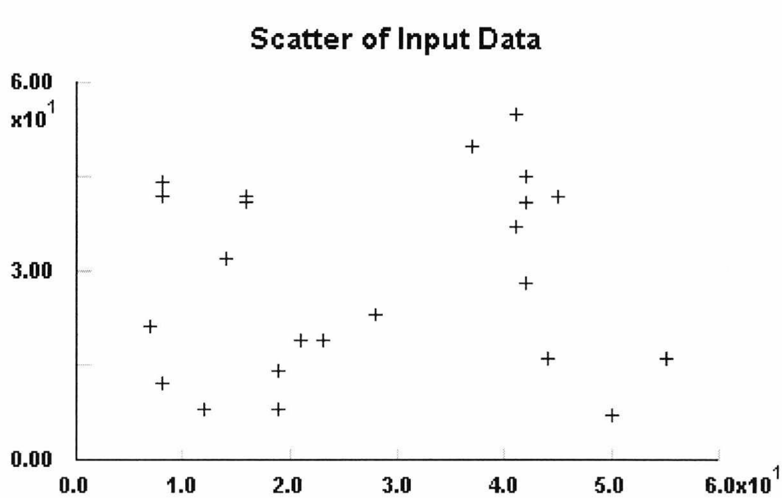
Table I.15 Distribution generated to fit Recuperative Care

Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Geometric (0.0767)	1.56(3 d.f.)	0.668 Do not reject	0.117	0.858 Do not reject	Accept
Negative Binomial (2,0.142)	2.57 (3 d.f.)	0.463 Do not reject	0.124	0.811 Do not reject	Accept

The process of determining the LOS distribution

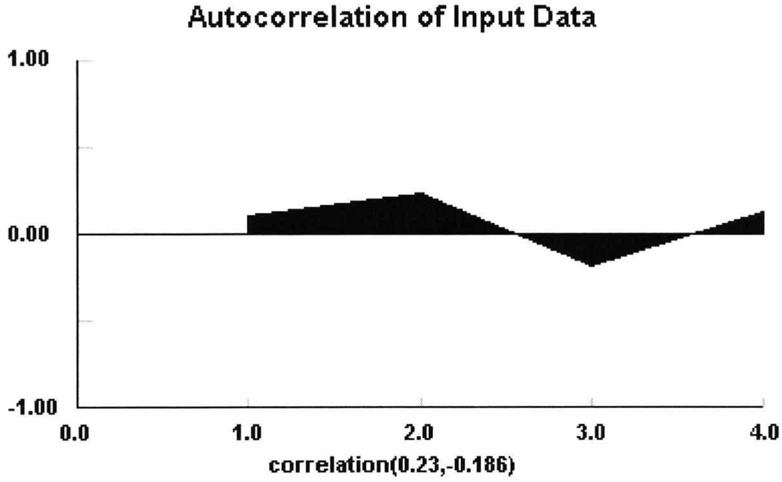
The Recuperative care LoS data can be considered to be IID by examining the scatter of input data and the Autocorrelation data (min=-0.186, max=0.23).

X_i



X_{i+1}

ρ_i



X_i

Activity 1 – Hypothesising families of distributions

The mean is 27.92 and the median is 25.5, a difference of less than 3 days that means that the distribution is nearly symmetrical. In fact, the skewness is 0.0999 and the kurtosis is –1.54. The Lexis ratio is 8.41, which suggests a Negative Binomial Distribution.

Table I.16 Summary Statistics for Recuperative Care LOS

Data points	24
minimum	7
maximum	55
mean	27.9167
median	25.5
mode	8
Standard deviation	15.3195
variance	234.688
Coefficient of variation	54.876
skewness	0.0999618
kurtosis	-1.53797
Lexis ratio (variance/mean)	8.41

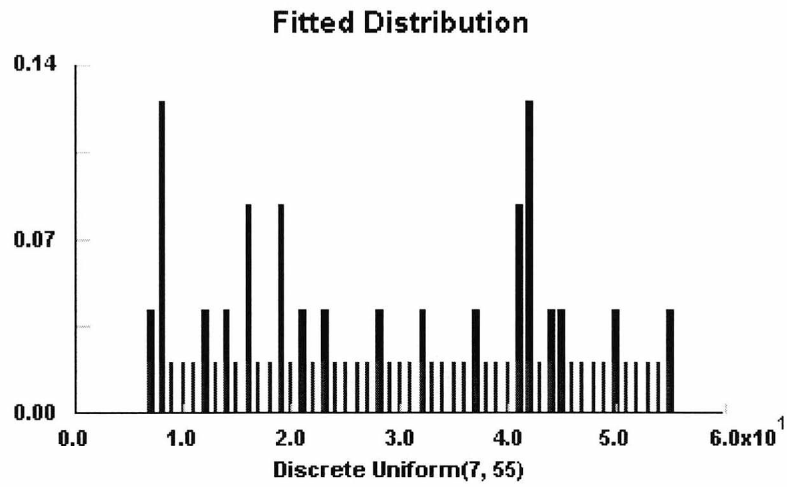
Activity 2 – estimating the distribution

Table I.17 Maximum Likelihood Estimation

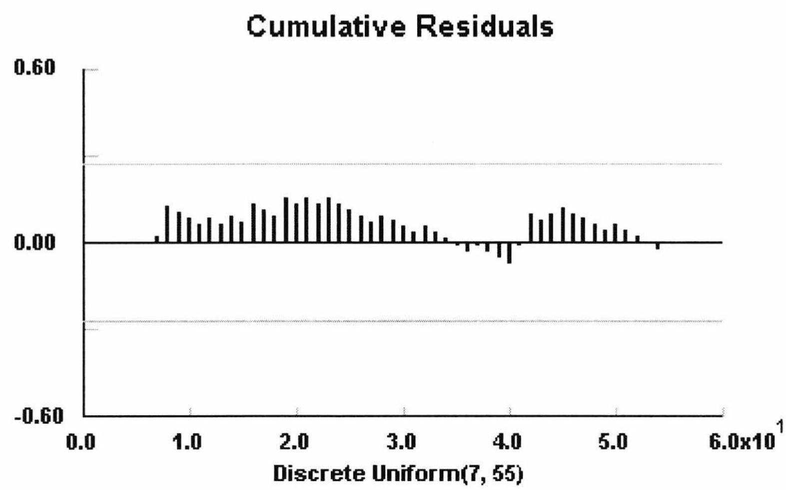
Discrete Uniform (7,55)
Geometric (p=0.0345821)
Negative Binomial (k=3, p=0.097035)
Poisson (lambda 27.9167)

Fitting the system (real) data to a statistical distribution.

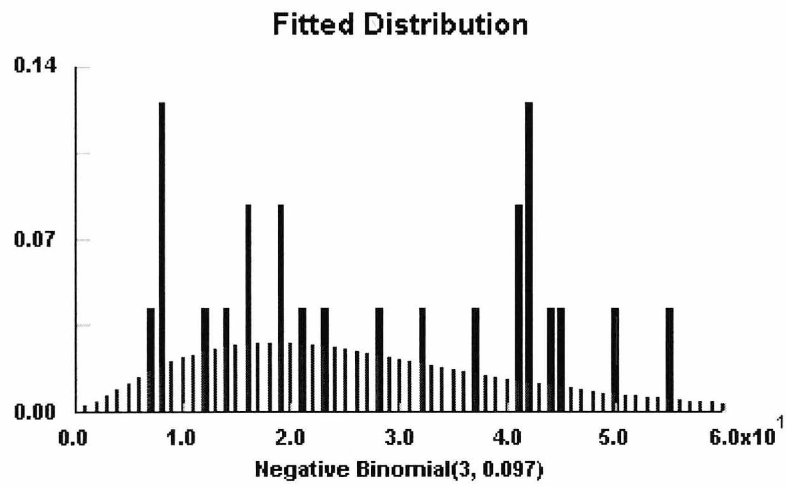
n= 24



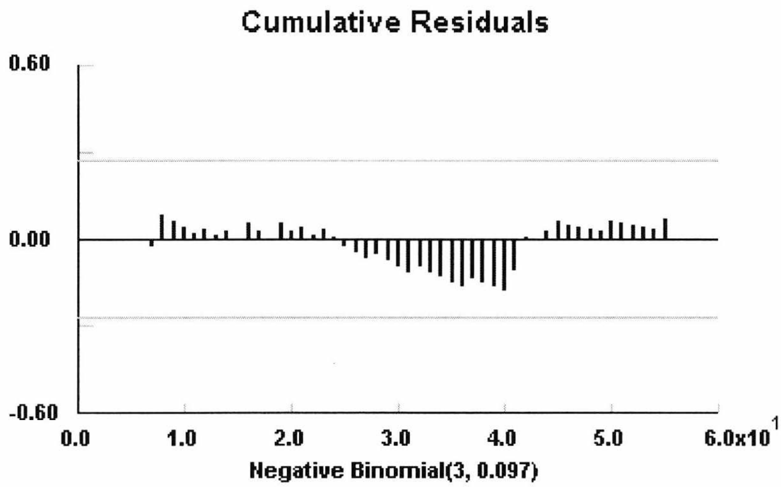
Fitted Distribution
0.14
0.07
0.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0x10^1
Discrete Uniform(7, 55)



Cumulative Residuals
0.60
0.00
-0.60
0.0
1.0
2.0
3.0
4.0
5.0
6.0x10^1
Discrete Uniform(7, 55)

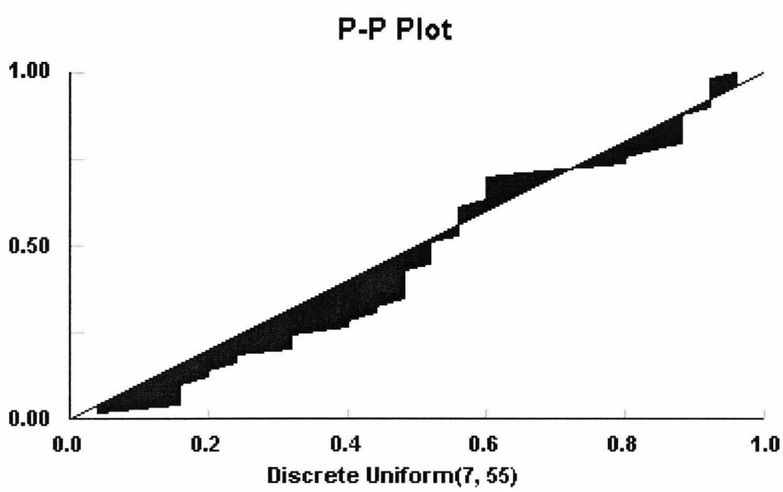


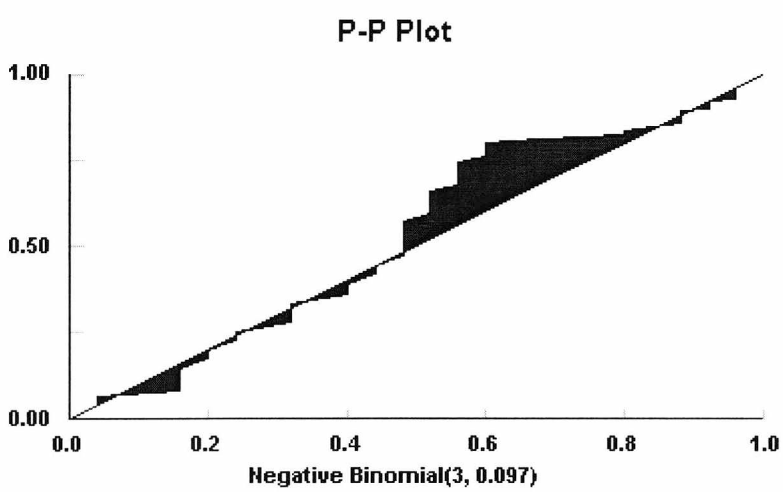
Fitted Distribution
0.14
0.07
0.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0x10^1
Negative Binomial(3, 0.097)



Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures





Stat::fit accepted the Discrete Uniform and the Negative Binomial distribution as suitable. The frequency comparison and the P-P plot showed that the distributions are a reasonable fit.

The goodness of fit tests showed that both the Discrete Uniform and the Negative Binomial distribution are suitable as the Chi squared value and the Kolmogorov-Smirnov value as well as their p-values, respectably resulted in a Do Not Reject Result. Therefore, both these distributions with their specific parameters calculated from the MLE are considered adequate for their intended purpose.

Table I.18 Distribution generated to fit Recuperative care LOS data

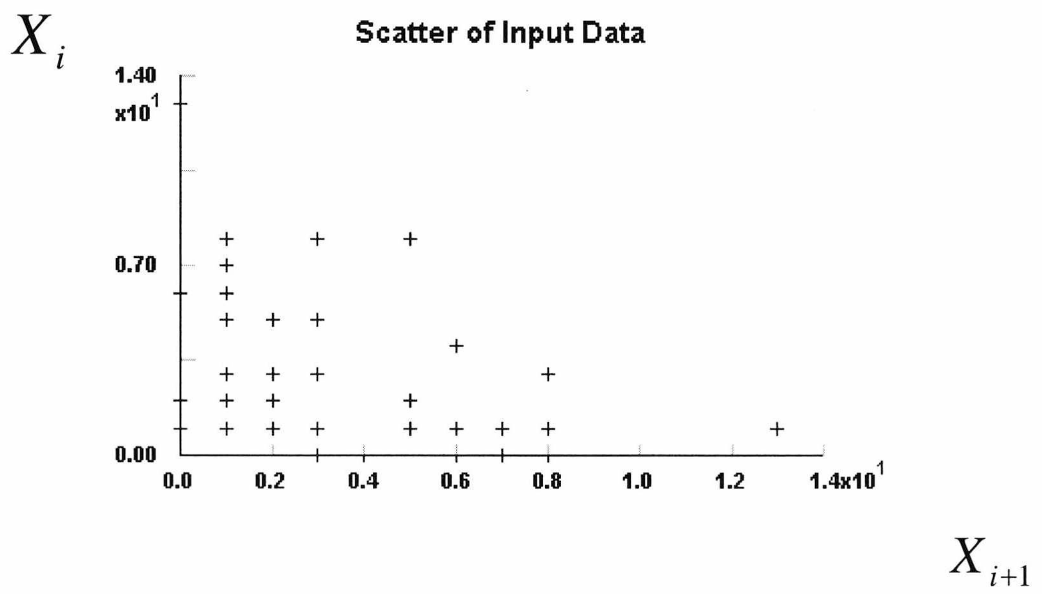
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Discrete Uniform (7,55)	3.6 (3 d.f)	0.308 Do not reject	0.153	0.575 Do not reject	Accept
Negative Binomial (3,0.097)	2.81 (3 d.f)	0.422 Do not reject	0.176	0.402 Do not reject	Accept

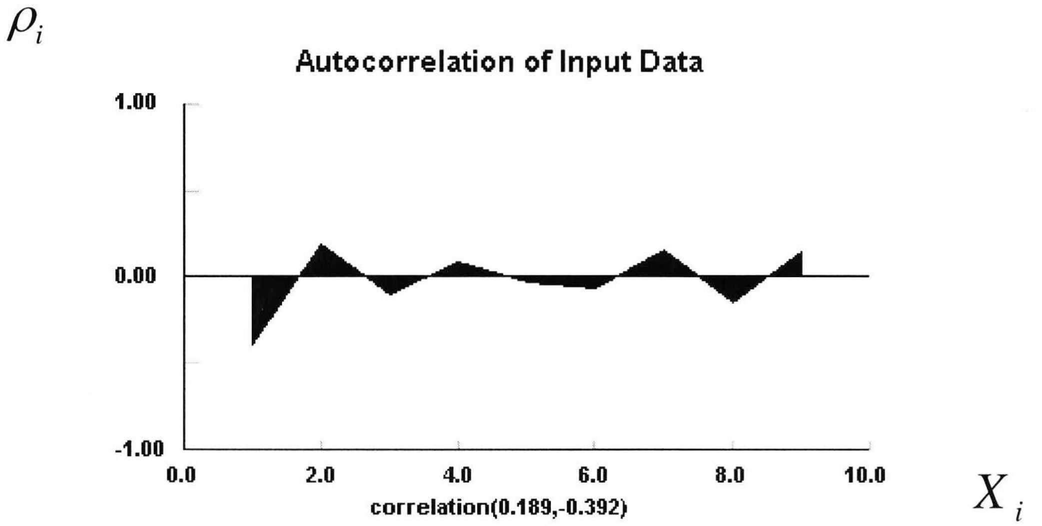
Generating the Fitton (orthopaedic) ward Interarrival and Length of Stay Distributions

Generating the Orthopaedic ward's inter-arrival distribution

The Scatter and Autocorrelation graphs of input data generated from Stat::Fit show that this wards interarrival data is comprised of Independent Identically Distributed Random Variables.

Fitton Interarrival





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is not symmetrical as the mean is 3.06 and median is 2, a difference of more than 1 day. The skewness is 1.16, which means that the distribution is skewed to the right and the kurtosis is 1.02. The Lexis ratio is 2.76, which suggests that it may be a Negative Binomial Distribution.

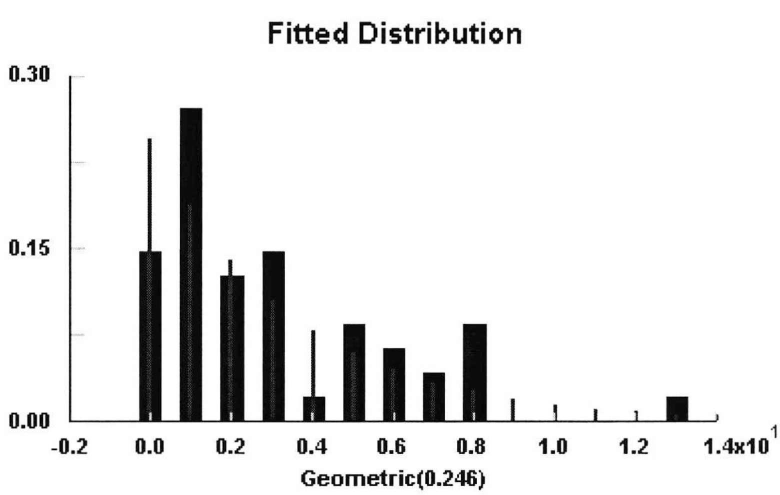
Table I.19 Summary Statistics for Fitton ward

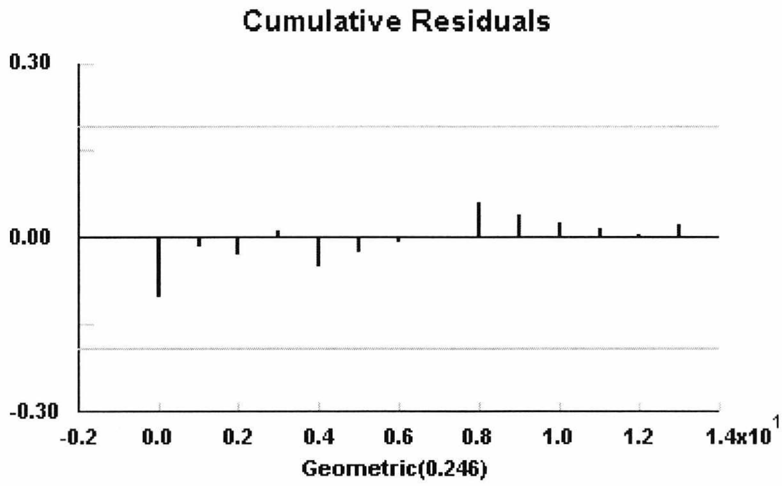
Data points	48
minimum	0
maximum	13
mean	3.0625
median	2
mode	1
Standard deviation	2.90565
variance	8.44282
Coefficient of variation	94.8785
skewness	1.16225
kurtosis	1.01858
Lexis ratio (variance/mean)	2.76

Activity 2 Estimation of the parameters from the data

Table I.20 Maximum Likelihood Estimation

Discrete Uniform (0,13)
Geometric (p=0.246154)
Negative Binomial (k=3, p=0.49485)
Poisson (lambda 3.0625)

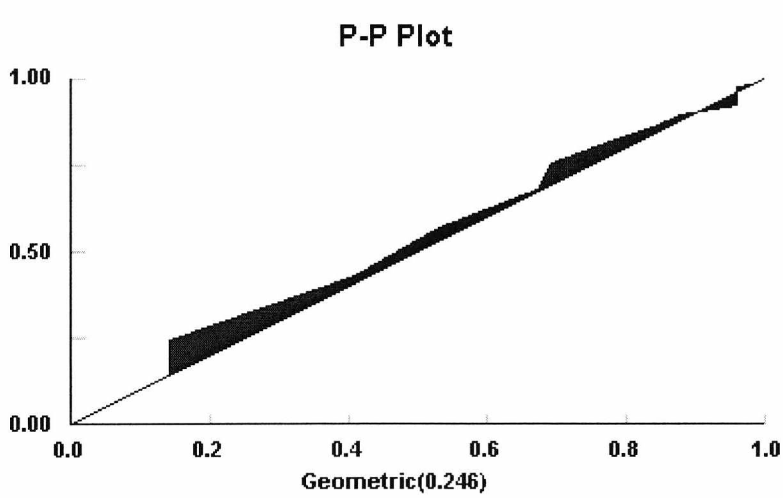




Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Stat::Fit ranked the distributions in order of best fit and the Geometric was first and the Negative Binomial was second. The frequency comparison and the P-P plot showed that the Geometric distribution is a reasonable fit

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

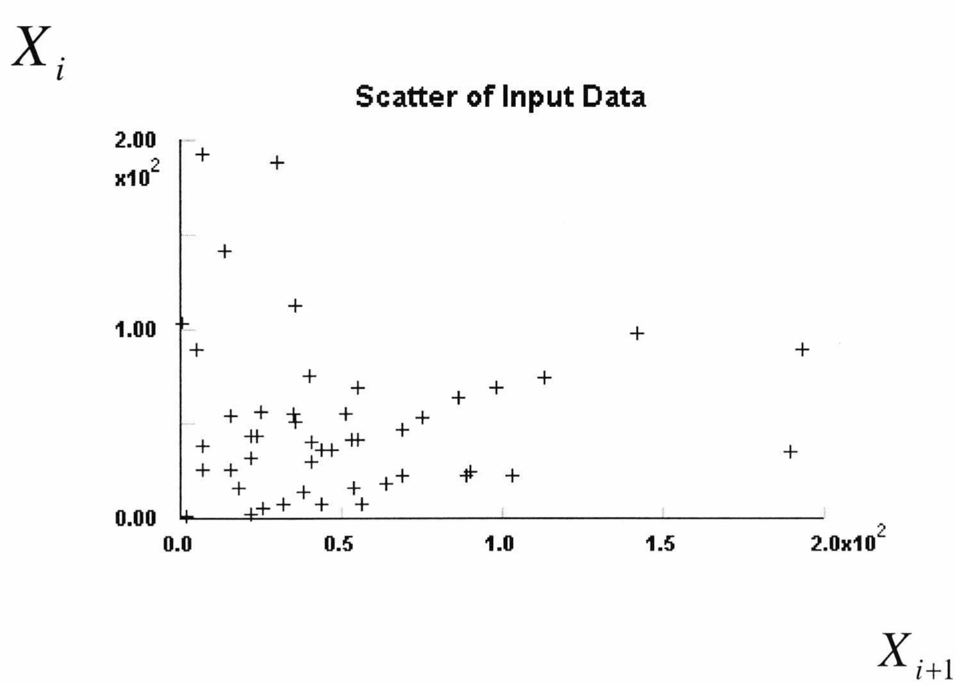
The goodness of fit tests showed that both the Geometric and Negative Binomial distributions were suitable as the Chi squared values and the Kolmogorov-Smirnov values as well as their p-values resulted in a Do Not Reject Result. Therefore both distributions can be used.

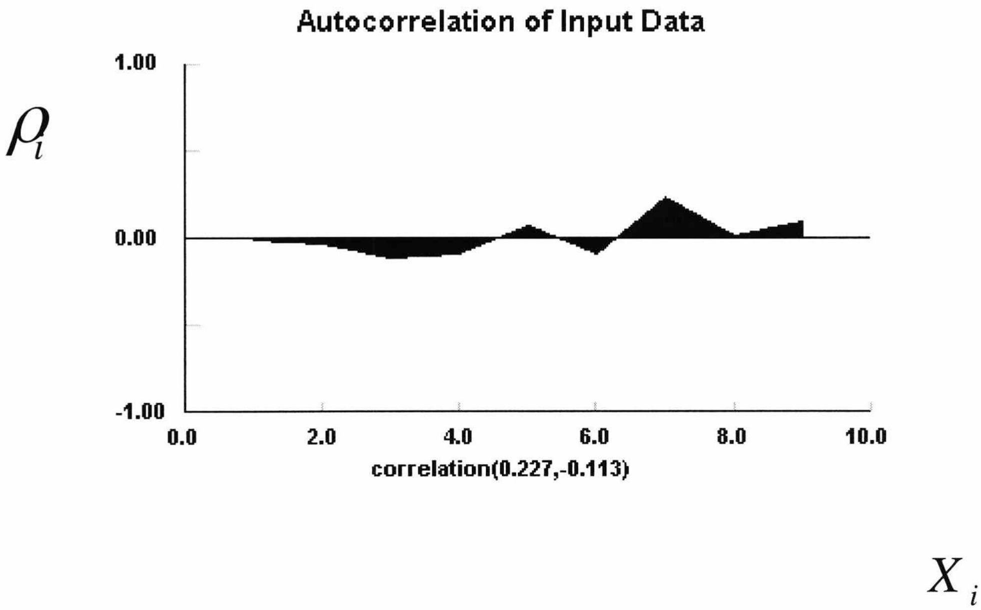
Table I.21 Distributions generated for Fitton orthopaedic ward

Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Geometric (0.246)	5.25(5 d.f.)	0.386 Do not reject	0.1	0.682 Do not reject	Accept
Negative Binomial (3,0.495)	7.72(5 d.f.))	0.172 Do not reject	0.112	0.548 Do not reject	Accept

Generating the Fitton LOS distribution

The scatter plot for the Fitton Length of Stay data suggests that the data is IID and this is also confirm by the Autocorrelation plot with a minimum value of –0.113 and a maximum value of 0.227





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is not symmetrical as the mean is 51.62 and median is 41, a difference of almost 10 days. The skewness is 1.53, which means that the distribution is skewed to the right and the kurtosis is 2.45. The Lexis ratio is 35.82, which suggests that it may be a Negative Binomial Distribution.

Table I.22 Summary Statistics for Fitton LOS data

Data points	48
minimum	1
maximum	193
mean	51.625
median	41
mode	7
Standard deviation	43.001
variance	1849.01
Coefficient of variation	83.2931
skewness	1.52979
kurtosis	2.4522
Lexis ratio (variance/mean)	35.82

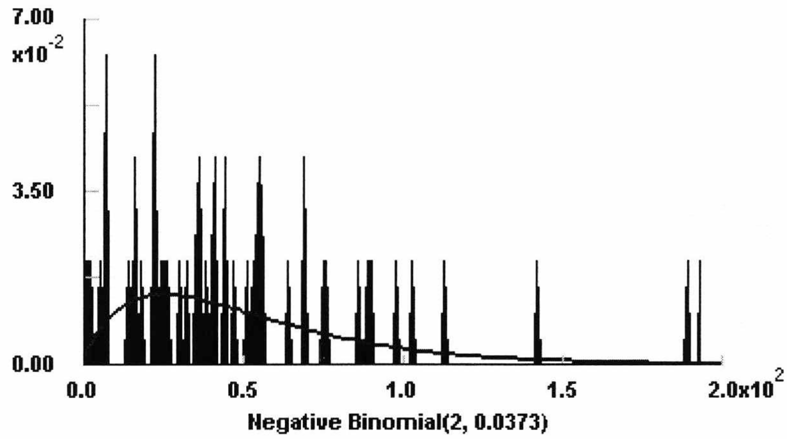
Activity 2 Estimation of the parameters from the data

Table I.23 Maximum Likelihood Estimation

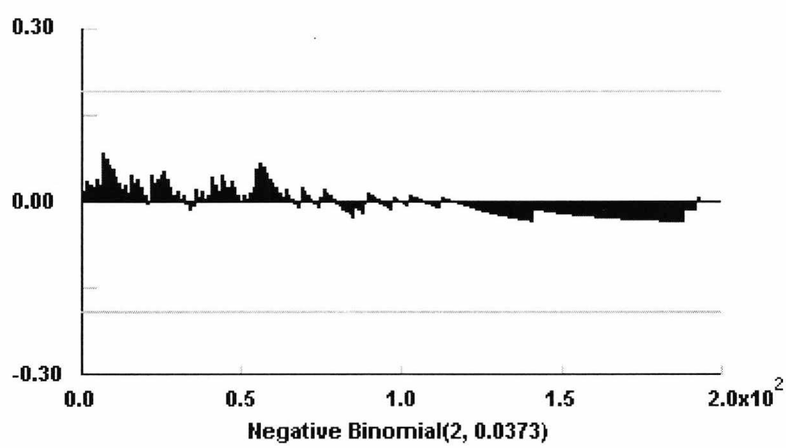
Discrete Uniform (1,193)
Geometric (p=0.0190024)
Negative Binomial (k=2, p=0.0.037296)
Poisson (lambda 51.625)

Fitting the system (real) data to a statistical distribution. n= 48

Fitted Distribution

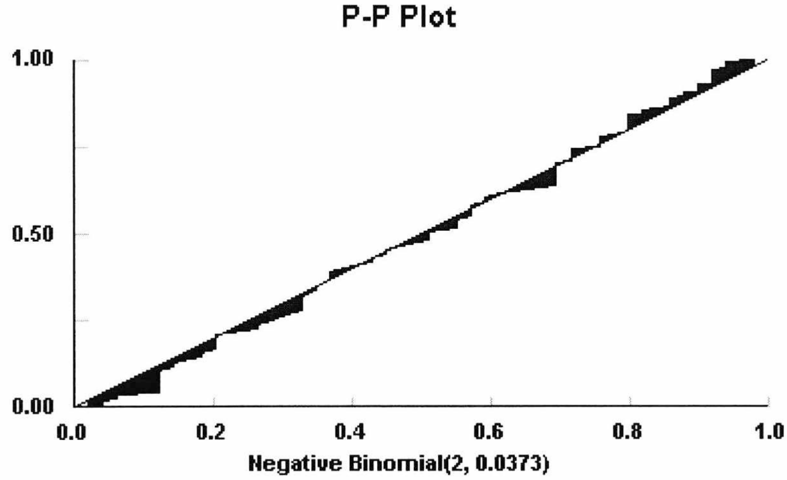


Cumulative Residuals



Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Stat::fit ranked the distributions in order of best fit and the Negative Binomial was first and the Geometric was second. The frequency comparison and the P-P plot illustrate that the distribution is a good fit.

The goodness of fit tests showed that both the Negative Binomial and Geometric distributions were suitable as the Chi squared values and the Kolmogorov-Smirnov values as well as their p-values resulted in a Do Not Reject Result. Therefore both distributions can be used.

Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

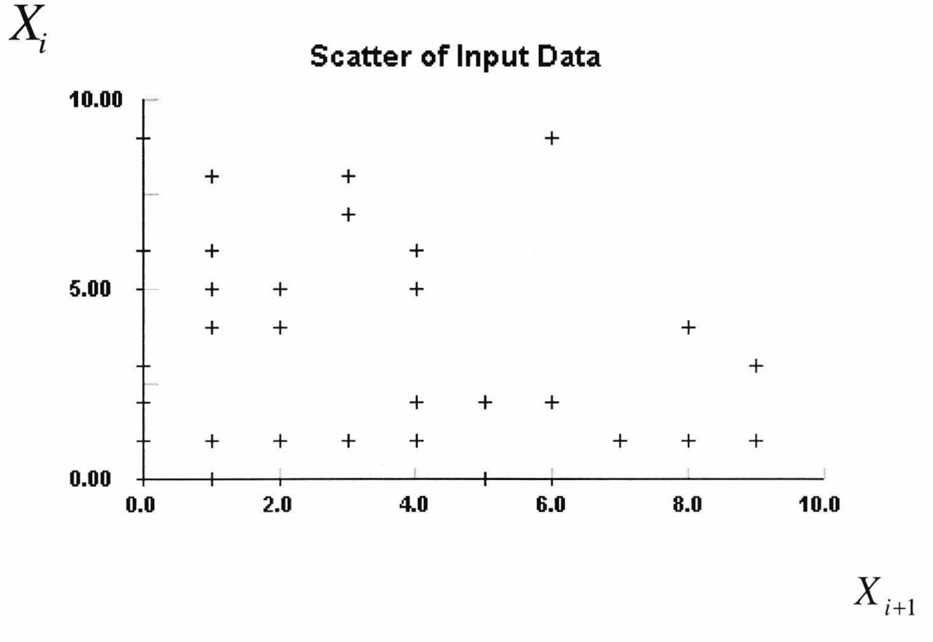
Table I.24 Distribution generated to fit Fitton ward data

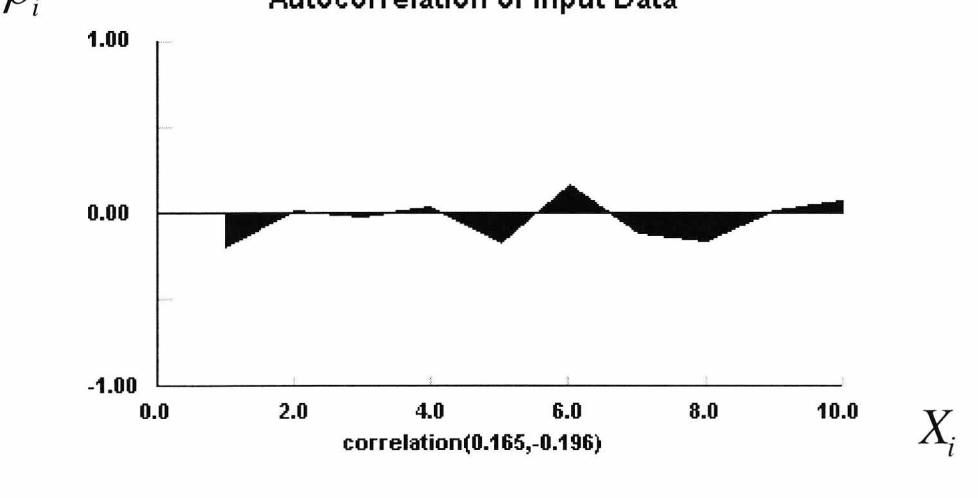
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (2,0.0373)	2.08(8d.f)	0.979 Do not reject	0.0829	0.869 Do not reject	Accept
Geometric(0.019)	6.6(8d.f)	0.58 Do not reject	0.136	0.309 Do not reject	Accept

Generating the Richard Stevens (Stroke) ward Interarrival and Length of Stay Distributions

Generating the Richard Stevens Interarrival distribution

The Scatter and Autocorrelation graphs of input data show that this wards interarrival data is comprised of Independent Identically Distributed Random Variables. The Autocorrelation range has a minimum value of –0.196 and a maximum of 0.165.





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is not quite symmetrical as the mean is 2.84 and median is 2, although the difference is less than 1 day. The skewness is 0.75, which means that the distribution is skewed slightly to the right and the kurtosis is -0.54. The Lexis ratio is 2.43, which suggests that it may be a Negative Binomial Distribution.

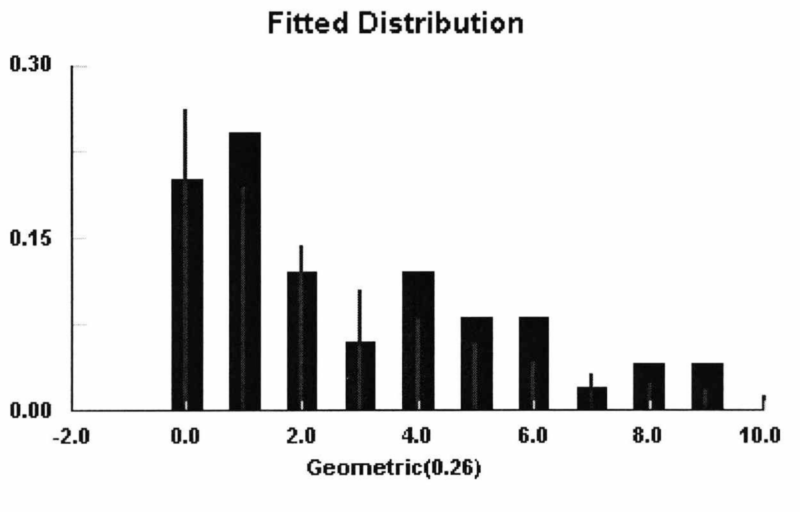
Table I.25 Summary Statistics for the Stroke Ward

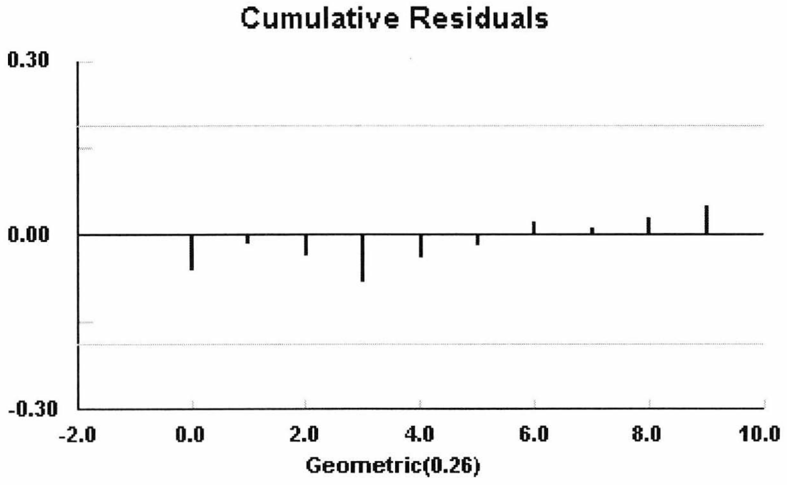
Data points	50
minimum	0
maximum	9
mean	2.84
median	2
mode	1
Standard deviation	2.62919
variance	6.91265
Coefficient of variation	92.5772
skewness	0.751364
kurtosis	-0.536903
Lexis ratio (variance/mean)	2.43403169

Activity 2 Estimation of the parameters from the data

Table I.26 Maximum Likelihood Estimation

Discrete Uniform (0,9)
Geometric (p=0.260417)
Negative Binomial (k=2, p=0.413223)
Poisson (lambda 2.84)

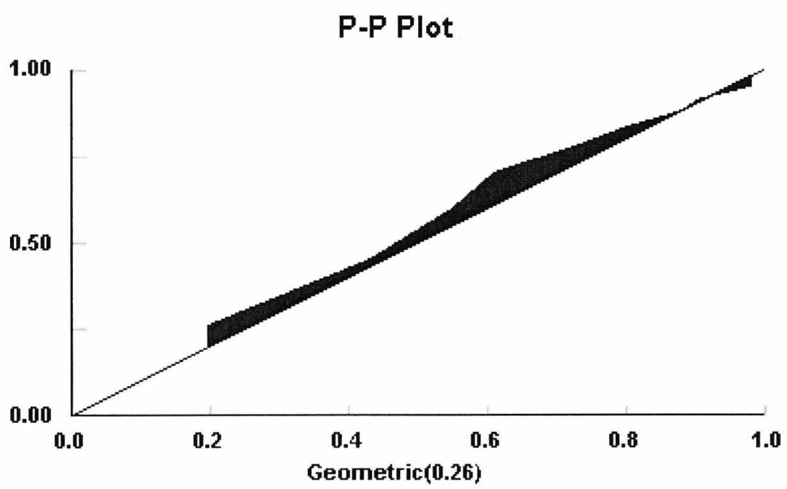




Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

The distributions in order of best fit are the Geometric was first and the Negative Binomial was second. The frequency comparison and the P-P plot showed that the Geometric distribution is a reasonable fit.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

The goodness of fit tests showed that both the Geometric and Negative Binomial distributions were suitable as the Chi squared p-values were 0.542 and 0.489 giving a Do Not Reject result. The Kolmogorov-Smirnov values were p-values 0.874 and 0.959, which resulted again in a Do Not Reject result. Therefore, both distributions can be used although the Geometric is ranked slightly higher by Stat::Fit.

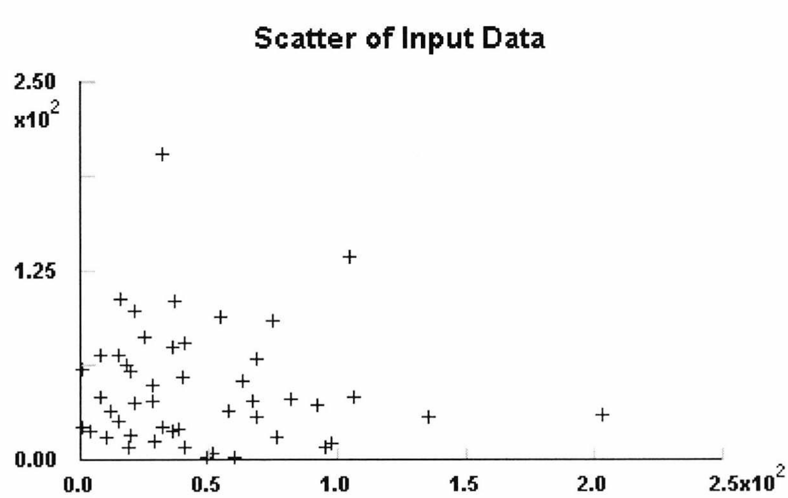
Table I.27 Distribution generated to fit Richard Stevens Ward (stroke ward)

Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Geometric (0.26)	4.05(5 d.f.)	0.542 Do not reject	0.0808	0.874 Do not reject	Accept
Negative Binomial (2,0.413)	4.43 (5 d.f.)	0.489 Do not reject	0.0689	0.959 Do not reject	Accept

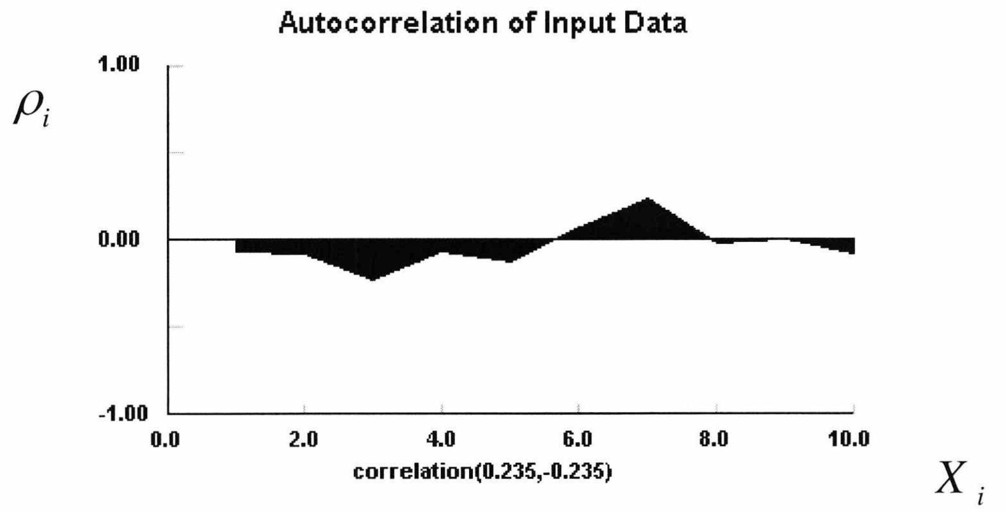
Generating the Richard Stevens (Stroke) LOS distribution

The Stroke wards LOS data can be considered to be IID by examining the scatter of input data and the Autocorrelation data (min=-0.235, max=0.235).

X_i



X_{i+1}



Activity 1 – Hypothesising families of distributions

The Lexis ratio is 32.7268, which suggests a Negative Binomial Distribution.

Table I.28 Summary Statistics for the Stroke Ward

Data points	50
minimum	1
maximum	203
mean	46.16
median	36.5
mode	8
Standard deviation	38.8673
variance	1510.67
Coefficient of variation	84.2013
skewness	1.60912
kurtosis	3.49232
Lexis ratio (variance/mean)	32.726819757

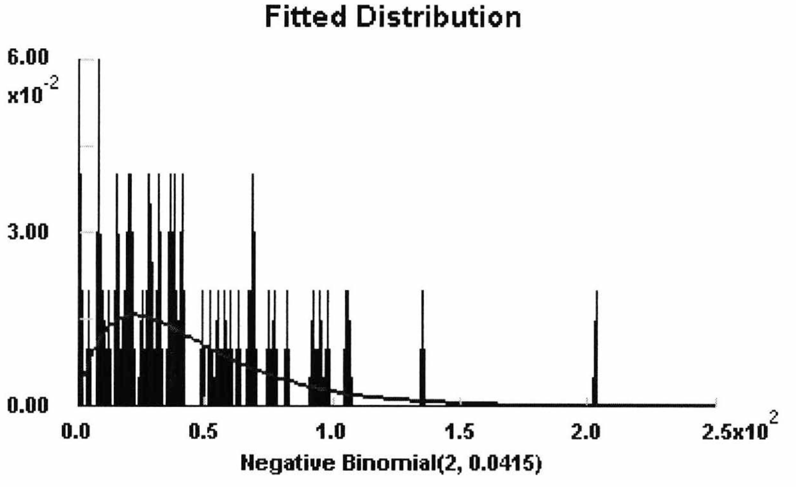
Activity 2 Estimation of the parameters from the data

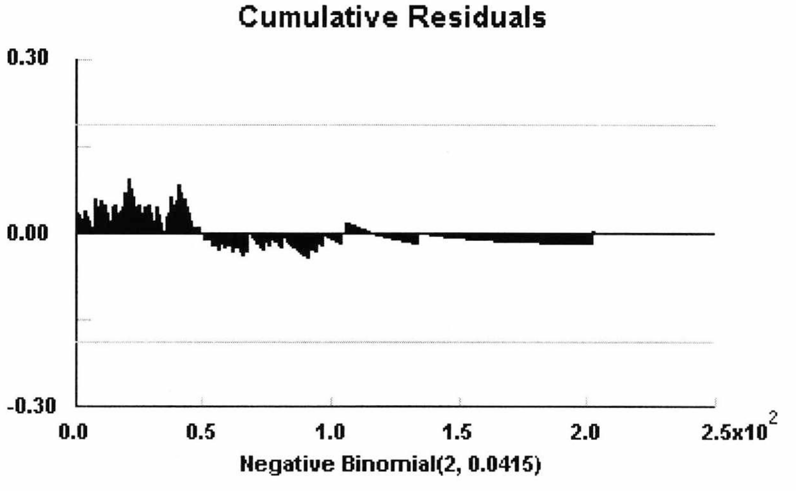
Stat::Fit calculated the Maximum Likelihood Estimation, which provided the main discrete distribution parameters. Stat::fit accepted only the Negative Binomial distribution as suitable. The frequency comparison and the P-P plot showed that the distribution is a good fit

Table I.29 Maximum Likelihood Estimation

Discrete Uniform (1,203)
Geometric (p=0.0212044)
Negative Binomial (k=2, p=0.0415282)
Poisson (lambda 45.16)

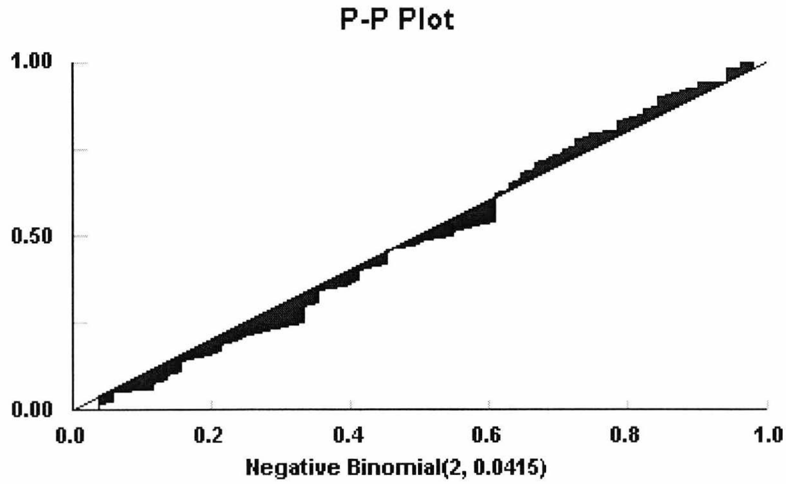
n= 50





Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



The goodness of fit tests showed that the Negative Binomial distribution was suitable as the Chi squared value and the Kolmogorov-Smirnov value as well as their p-values, 0.644 and 0.749 respectably resulted in a Do Not Reject Result. Therefore, this distribution with its parameter calculated from the MLE is considered adequate for its intended purpose.

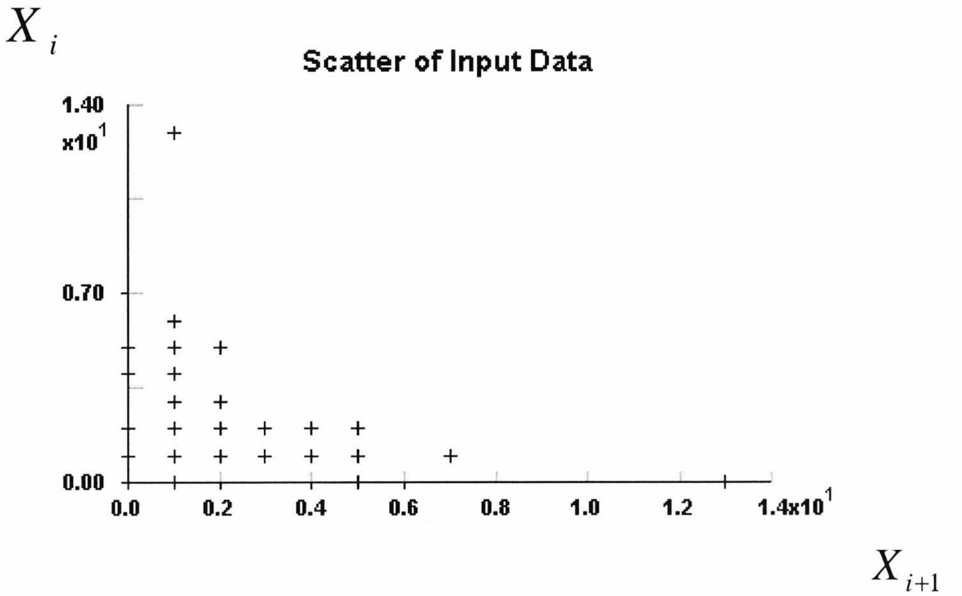
Table I.30 Distribution generated to fit Richard Stevens Ward (stroke ward)

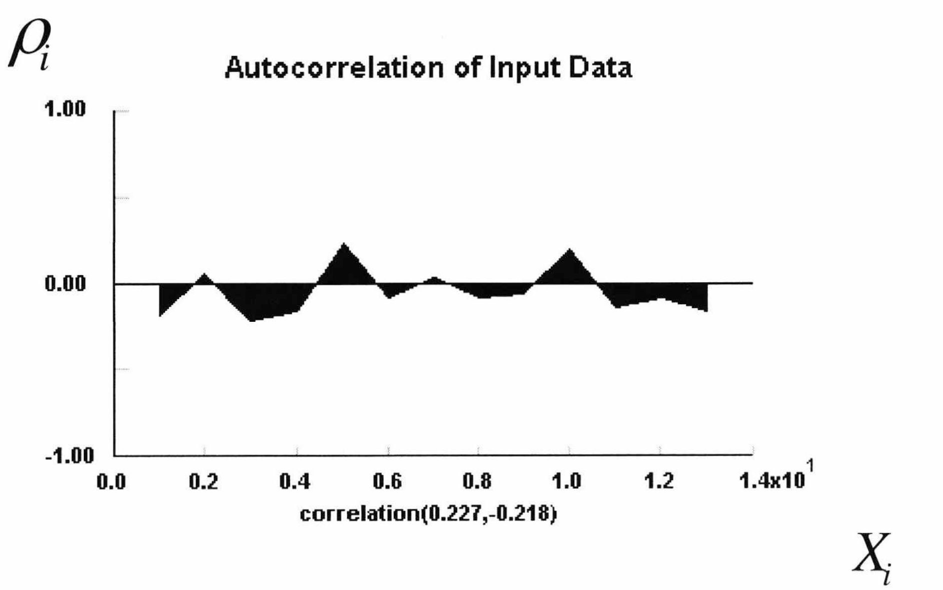
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (2,0.0415)	6.03 (8d.f)	0.644 Do not reject	0.0927	0.749 Do not reject	Accept

Generating Interarrival and Length of Stay distributions for Edinburgh ward

Generating the Interarrival distribution

The Scatter and Autocorrelation graphs of input data show that this wards interarrival data is comprised of Independent Identically Distributed Random Variables. The Autocorrelation range has a minimum value of –0.218 and a maximum of 0.227.





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is not quite symmetrical as the mean is 1.73 and median is 1, although the difference is less than 1 day. The skewness is 2.64, which means that the distribution is skewed slightly to the right and the kurtosis is 9.97. The Lexis ratio is 3.87, which suggests that it may be a Negative Binomial Distribution.

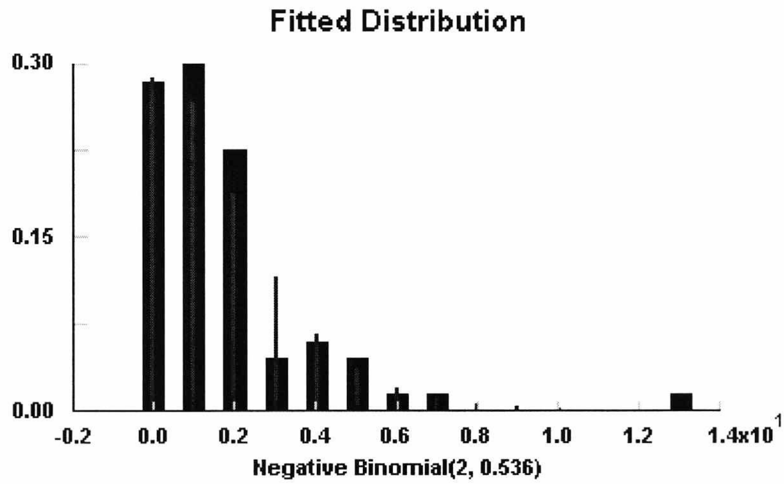
Table I.31 Summary Statistics for the Edinburgh Ward

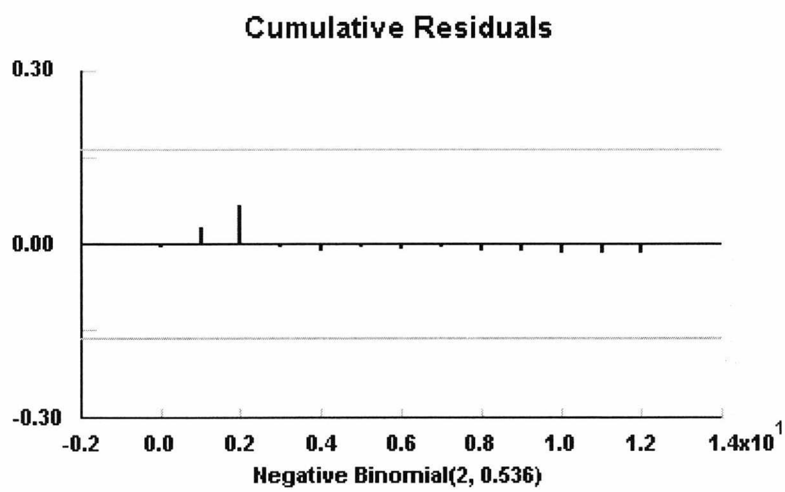
Data points	67
minimum	0
maximum	13
mean	1.73134
median	1
mode	1
Standard deviation	2.12904
variance	4.53279
Coefficient of variation	122.97
skewness	2.63914
kurtosis	9.97394
Lexis ratio (variance/mean)	3.87

Activity 2 Estimation of the parameters from the data

Table I.32 Maximum Likelihood Estimation

Discrete Uniform (0,13)
Geometric (p=0.036612)
Negative Binomial (k=2, p=0.536)
Poisson (lambda = 1.73134)

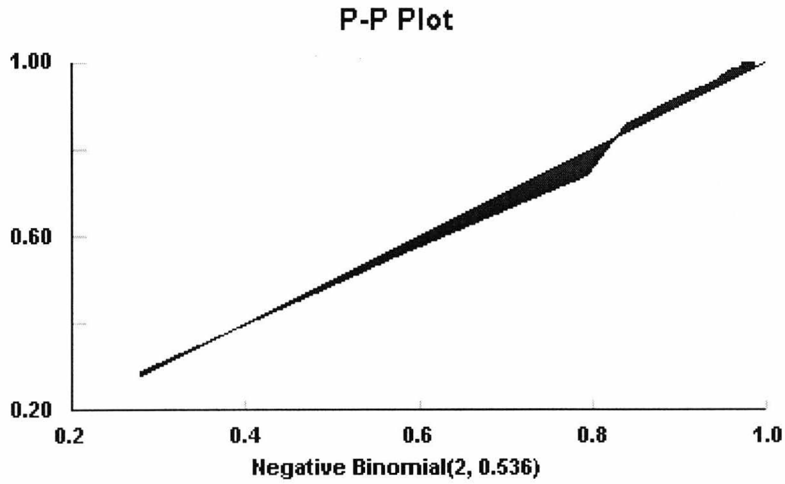




The distributions in order of best fit are the Negative Binomial first, the Geometric second and the Poisson third. The frequency comparison and the P-P plot showed that the Negative Binomial distribution is a good fit.

Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

The goodness of fit tests showed that the Negative Binomial and Geometric were suitable as the Chi squared p-values were 0.454 and 0.138 giving a Do Not Reject result. The Kolmogorov-Smirnov values were p-values 0.909 and 0.72 that resulted again in a Do Not Reject result. The Negative Binomial distribution is clearly a better fit than the Geometric when comparing the p-values. The Poisson distribution has a chi-squared p-value of 0.0199 which is a Reject result and the K-S p-value is 0.404 which is a Do not Reject result. In this research, I will accept a distribution that has a Do Not Reject result for either test. Therefore, any of the above distributions can be used although the Negative Binomial is preferred.

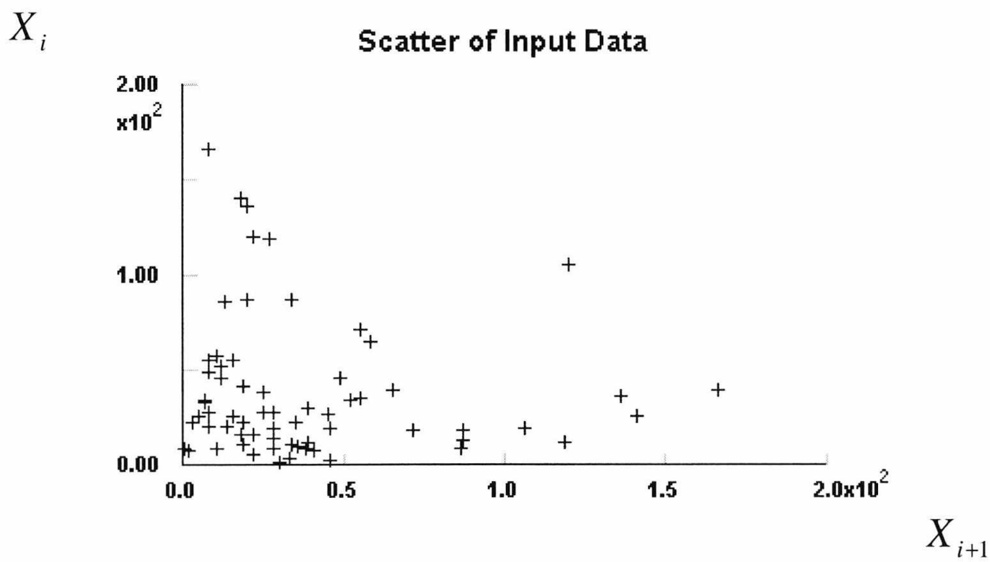
Table I.33 Distribution generated to fit Edinburgh Ward

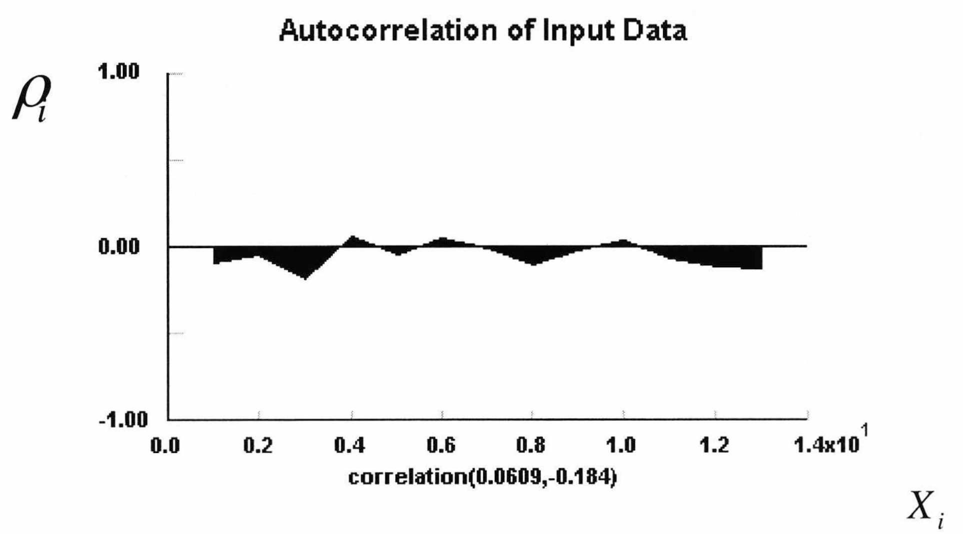
Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (2,0.536)	3.66(4 d.f.)	0.454 Do not reject	0.0665	0.909 Do not reject	Accept
Geometric (0.366)	6.96(4 d.f.)	0.138 Do not reject	0.0825	0.72 Do not reject	Accept
Poisson (1.73)	11.7(4 d.f.)	0.0199 reject	0.107	0.404 Do not reject	Accept

Generating the Edinburgh LOS distribution

This wards LOS data can be considered to be IID by examining the scatter of input data and the Autocorrelation data (min=-0.184, max=0.0609).

Correlation Plot





Activity 1 – Hypothesising families of distributions

The mean of 37.9403 and median of 27 a difference of almost 10 days, which mean that the graph is not symmetrical. Also the skewness is 1.69, which mean that the distribution is skewed to the right. The Lexis ratio is 34.56, which suggests a Negative Binomial Distribution.

Table I.34 Summary Statistics for the Edinburgh Ward

Data points	67
minimum	1
maximum	166
mean	37.9403
median	27
mode	8
Standard deviation	36.2102
variance	1311.18
Coefficient of variation	95.4399
skewness	1.69048
kurtosis	2.385
Lexis ratio (variance/mean)	34.56

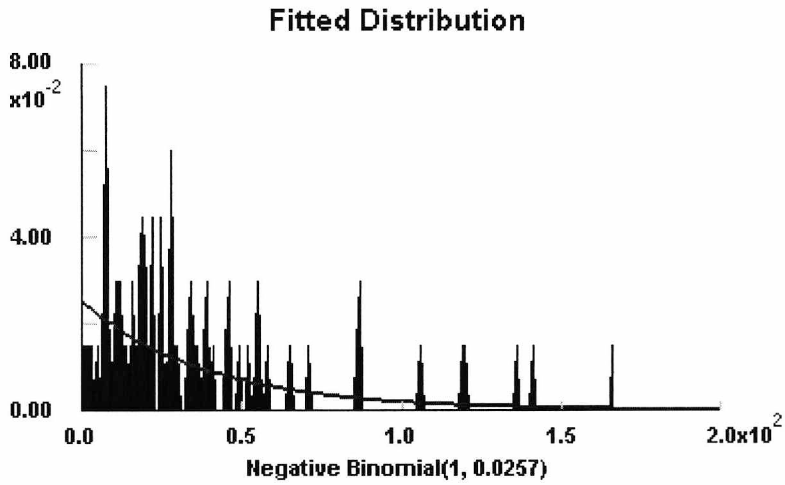
Activity 2 Estimation of the parameters from the data

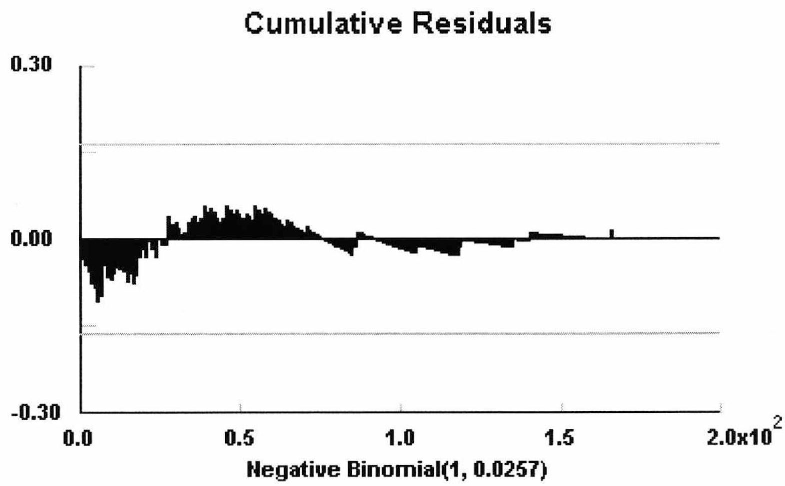
From all the distribution parameters calculated from the Maximum Likelihood by Stat::Fit, only the Negative Binomial and Geometric were accepted. In this case the Negative Binomial is reduced to the Geometric as the number of desired events is equal to 1. The frequency comparison and the P-P plot showed that the Negative Binomial distribution is a reasonable fit.

Table I. 35 Maximum Likelihood Estimation

Discrete Uniform (0,166)
Geometric (p=0.0256803)
Negative Binomial (k=1, p=0.0257)
Poisson (lambda 37.9403)

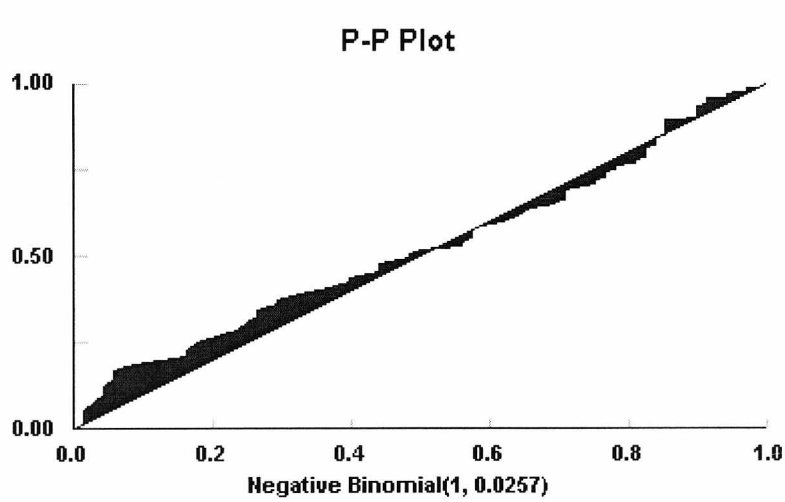
Fitting the system (real) data to a statistical distribution.





Activity 3 – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



The goodness of fit tests showed that both the Negative Binomial and Geometric distribution were suitable as the Chi squared value and the Kolmogorov-Smirnov value as well as their p-values, respectably resulted in a Do Not Reject Result. Therefore, either of these distributions with their parameter calculated from the MLE are considered adequate for their intended purpose.

Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

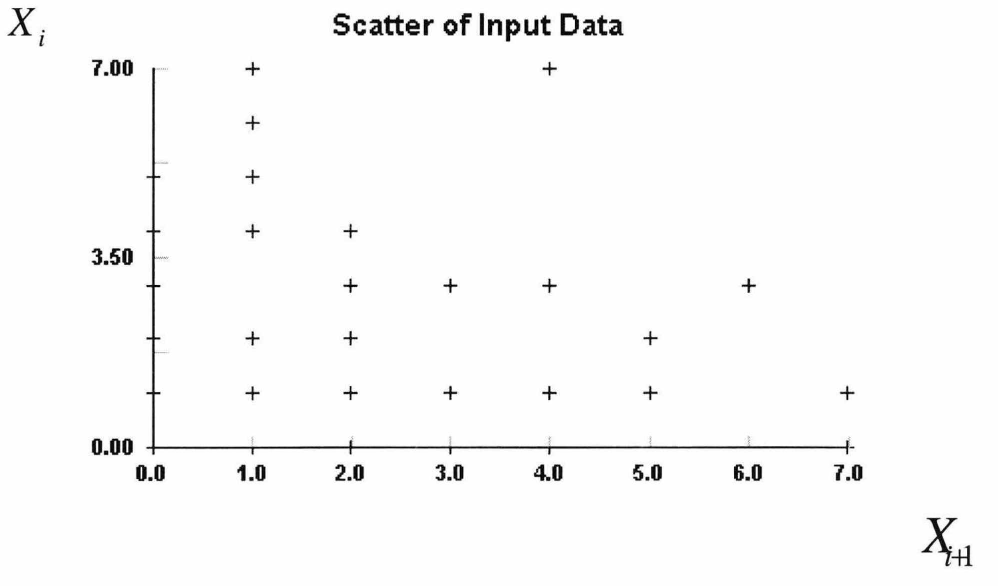
Table I.36 Distribution generated to fit Edinburgh ward

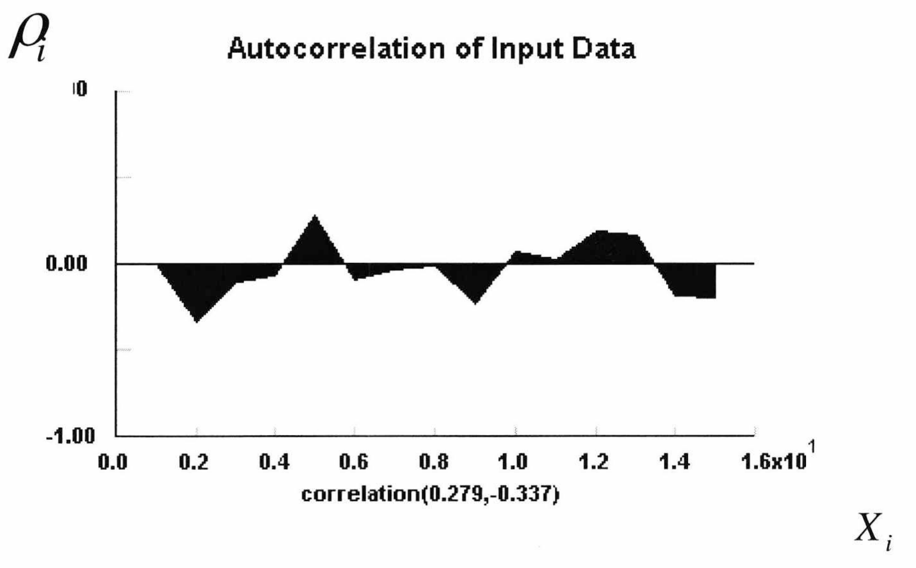
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (1,0.0257)	12.3(11 d.f)	0.338 Do not reject	0.107	0.401 Do not reject	Accept
Geometric (0.0257)	12.3(11d.f)	0.338 Do not reject	0.107	0.401 Do not reject	Accept

Generating distributions for the rehabilitation ward of the Acute Hospital. (Bethersden)

Generating the Interarrival distribution

The Scatter and Autocorrelation graphs of input data show that this wards interarrival data is comprised of Independent Identically Distributed Random Variables. The Autocorrelation range has a minimum value of –0.337 and a maximum of 0.279.





Activity I- Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is not quite symmetrical as the mean is 1.58 and median is 1, although the difference is less than 1 day. The skewness is 1.46, which means that the distribution is skewed slightly to the right and the kurtosis is 1.64. The Lexis ratio is 31.79, which suggests that it may be a Negative Binomial Distribution.

Table I.37 Summary Statistics

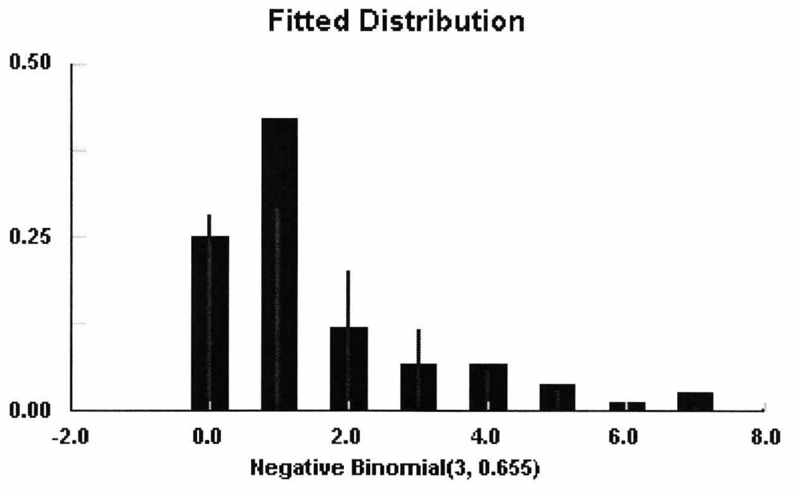
Data points	76
minimum	0
maximum	7
mean	1.57895
median	1
mode	1
Standard deviation	1.68336
variance	2.83368
Coefficient of variation	106.612
skewness	1.46231
kurtosis	1.64455
Lexis ratio (variance/mean)	31.79

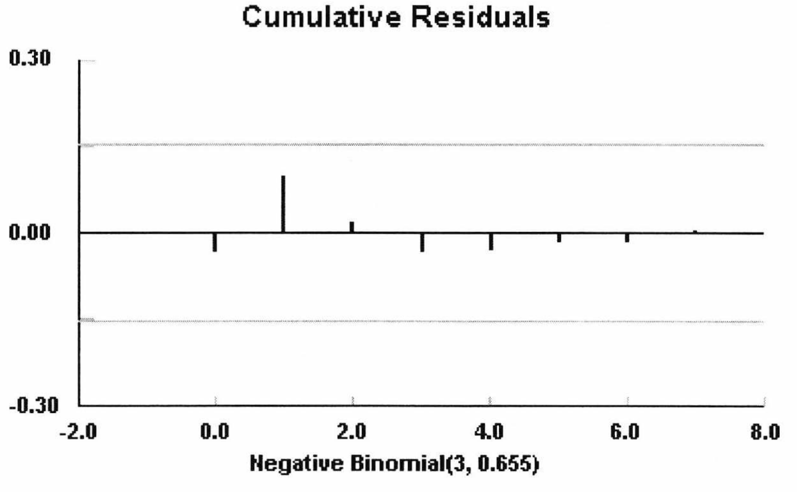
Activity 2 Estimation of the parameters fro the data

The distributions in order of best fit are the Negative Binomial first, the Geometric second and the Poisson third. The frequency comparison and the P-P plot showed that the Negative Binomial distribution is a reasonable fit.

Table I.38 Maximum Likelihood Estimation

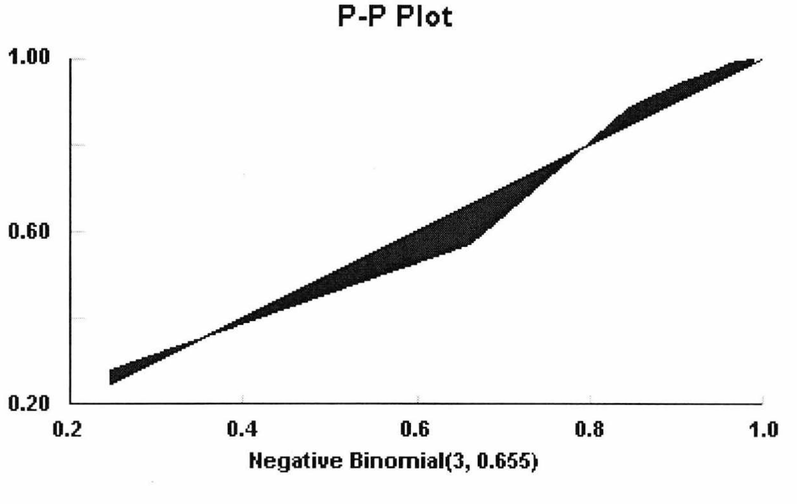
Discrete Uniform (0,7)
Geometric (p=0.387755)
Negative Binomial (k=3, p=0.655172)
Poisson (lambda 1.57895)





Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

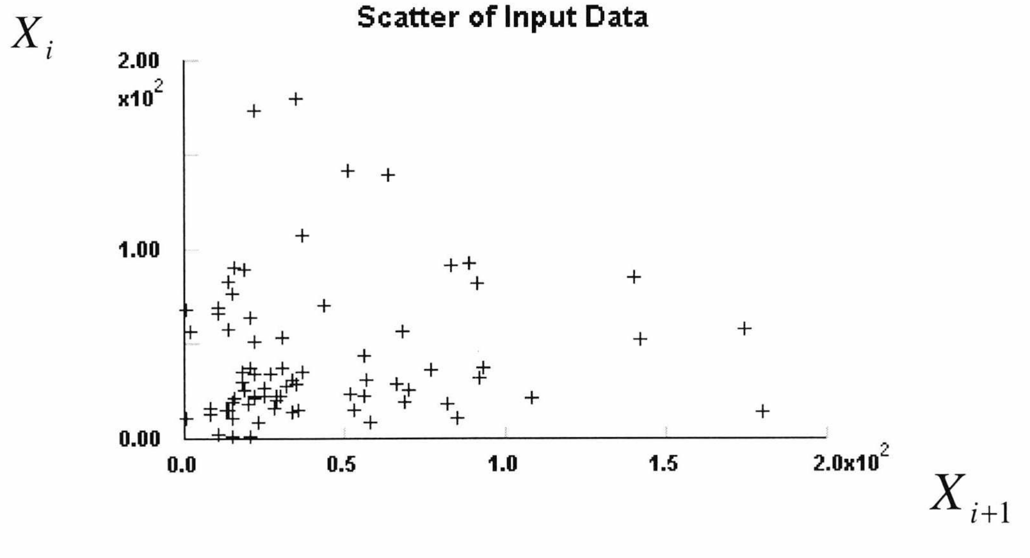
The goodness of fit tests showed that the Negative Binomial and Geometric and Poisson have a Reject result for their Chi squared p-values. However their Kolmogorov-Smirnov p-values resulted is a Do Not Reject result. The Negative Binomial distribution is clearly a better fit than the Geometric and Poisson when comparing the p-values. In this research, I will accept a distribution that has a Do Not Reject result for either test. Therefore, any of the above distributions can be used although the Negative Binomial is preferred.

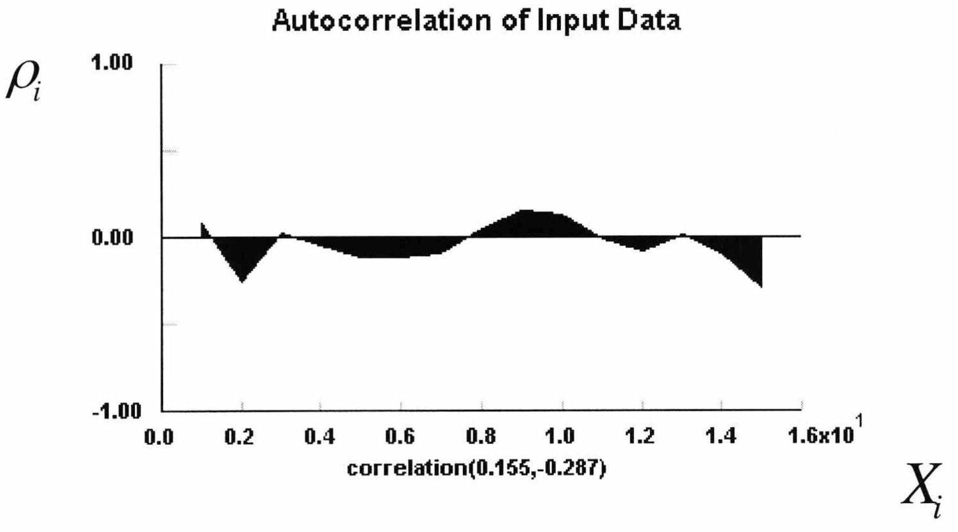
Table I.38 Distribution generated to fit Bethersden Ward

Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (3,0.655)	9.6(4 d.f.)	0.0478 reject	0.0989	0.42 Do not reject	Accept
Geometric (0.388)	15.4(4 d.f.)	0.004 reject	0.138	0.102 Do not reject	Accept
Poisson(1.58)	16.4(4 d.f.)	0.00306 reject	0.139	0.095 Do not reject	Accept

Generating the LOS distribution

This wards LOS data can be considered to be IID by examining the scatter of input data and the Autocorrelation data (min=-0.155, max=0.287).





Activity 1 – Hypothesising families of distributions

The mean is 37.94 and the median is 29.5 a difference of more than 13 days, which means that the graph is not symmetrical. Also the skewness is 1.69 that means that the distribution is skewed to the right. The Lexis ratio is 33.24, which suggests a Negative Binomial Distribution.

Table I.40 Summary Statistics for the Ward

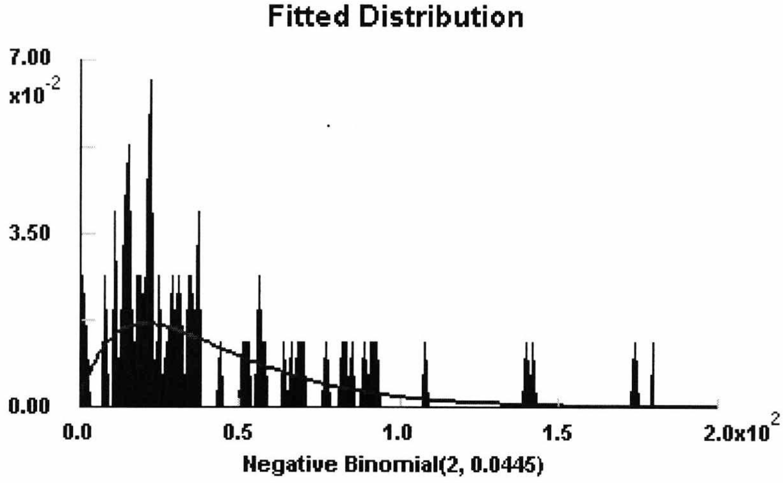
Data points	76
minimum	1
maximum	180
mean	42.9211
median	29.5
mode	22
Standard deviation	37.7736
variance	1426.85
Coefficient of variation	88.0072
skewness	1.69813
kurtosis	2.88307
Lexis ratio (variance/mean)	33.24

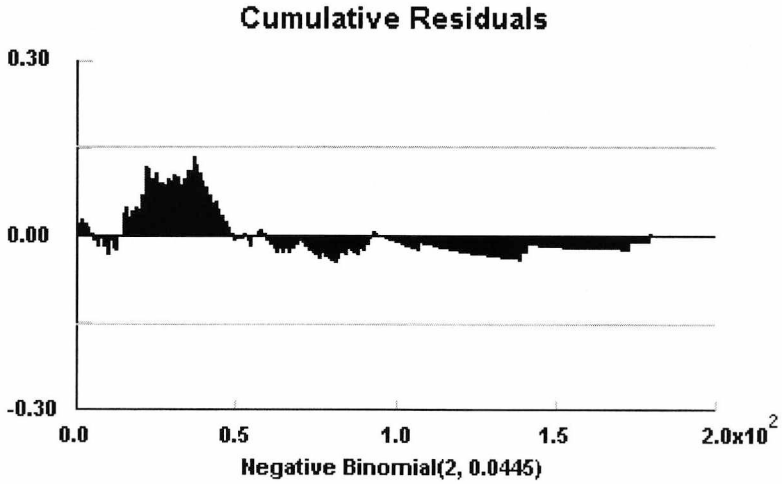
Activity 2 – Estimation of the parameters from the data

From all the distribution parameters calculated from the Maximum Likelihood by Stat::Fit, only the Negative Binomial was accepted. The frequency comparison and the P-P plot showed that the Negative Binomial distribution is a reasonable fit

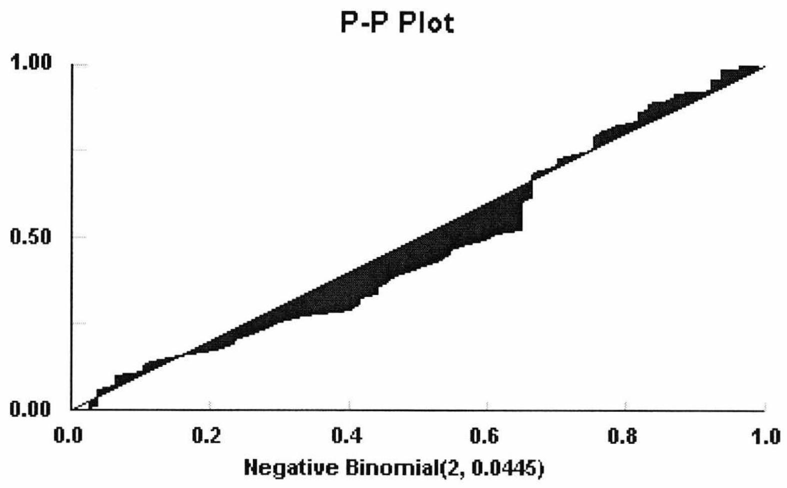
Table I. 41Maximum Likelihood Estimation

Discrete Uniform (5,205)
Geometric (p=0.0219194)
Negative Binomial (k=2, p=0.0428989)
Poisson (lambda 44.6212)





Heuristic procedures



Activity 3 Determining how representative the fitted distribution is of the true underlying distribution for the data

Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

The p-value of the chi–squared goodness of fit test showed a Reject that may be a result of the larger sample size (76 entries) but the Kolmogorov-Smirnov p-values resulted in a Do Not Reject Result. Therefore, the distribution calculated from the MLE is considered adequate for its intended purpose.

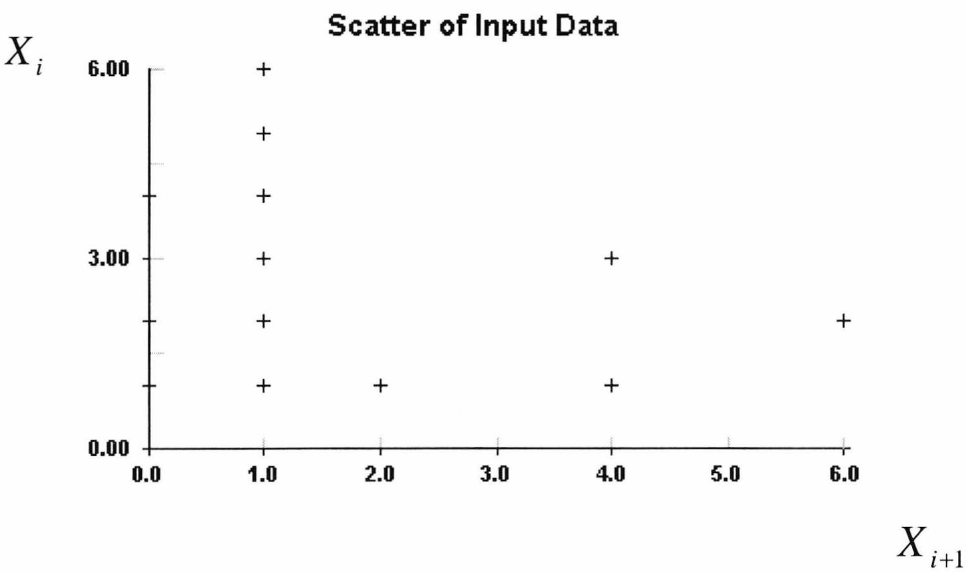
Table I.42 Distribution generated to fit Bethersden Ward

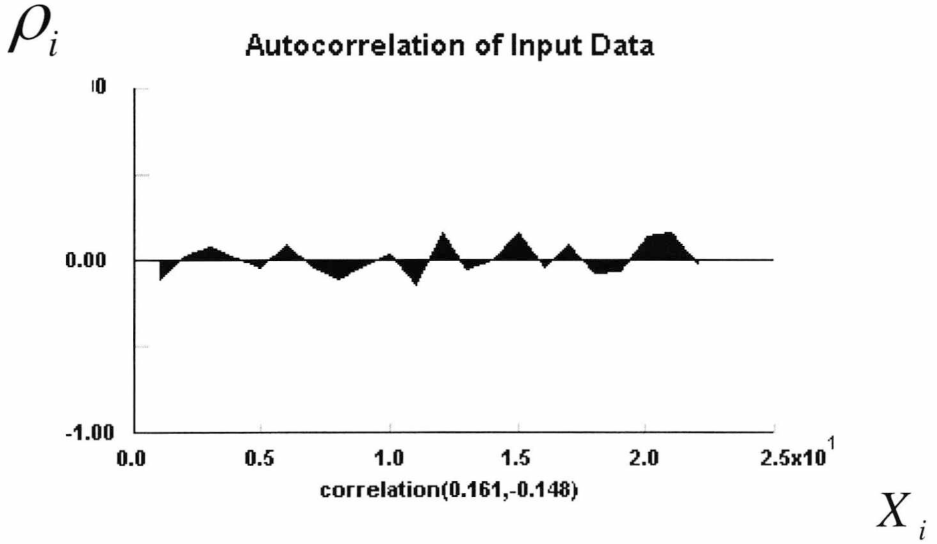
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (2,0.0445)	18.4 (13 d.f)	0.142 reject	0.135	0.115 Do not reject	Accept

Generating distributions of the interarrival and LOS for Brook ward general rehabilitation ward in the acute hospital

Generating an inter-arrival distribution for the second rehabilitation ward of the acute hospital (Brook)

The Scatter and Autocorrelation graphs of input data show that this wards interarrival data is comprised of Independent Identically Distributed Random Variables. The Autocorrelation range has a minimum value of –0.148 and a maximum of 0.161.





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is nearly symmetrical as the mean is 1.08 and median is 1. The skewness is 1.67, which means that the distribution is skewed slightly to the right and the kurtosis is 2.67. The Lexis ratio is 1.63, which suggests that it may be a Negative Binomial Distribution.

Table I.43 Summary Statistics for the Brook Ward

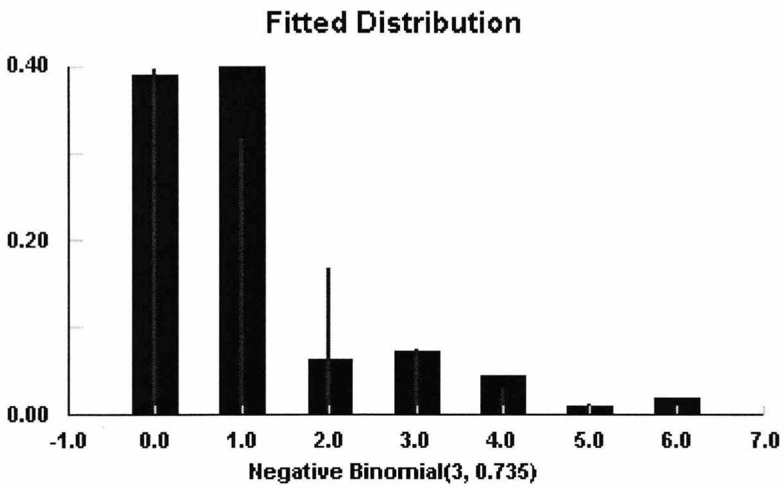
Data points	110
minimum	0
maximum	6
mean	1.08182
median	1
mode	1
Standard deviation	1.32811
variance	1.76389
Coefficient of variation	122.767
skewness	1.66769
kurtosis	2.67033
Lexis ratio (variance/mean)	1.63

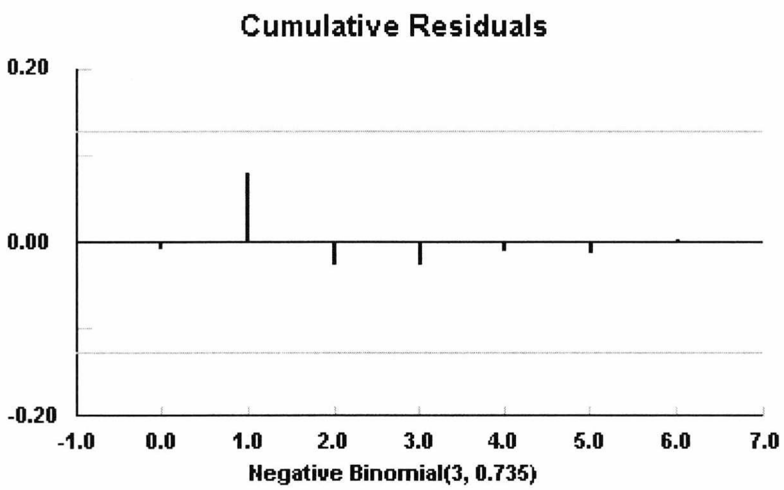
Activity 2 Estimation of the parameters from the data

The distributions in order of best fit are the Negative Binomial first, the Geometric second and the Poisson third. The frequency comparison and the P-P plot showed that the Negative Binomial distribution is a reasonable fit

Table I.44 Maximum Likelihood Estimation

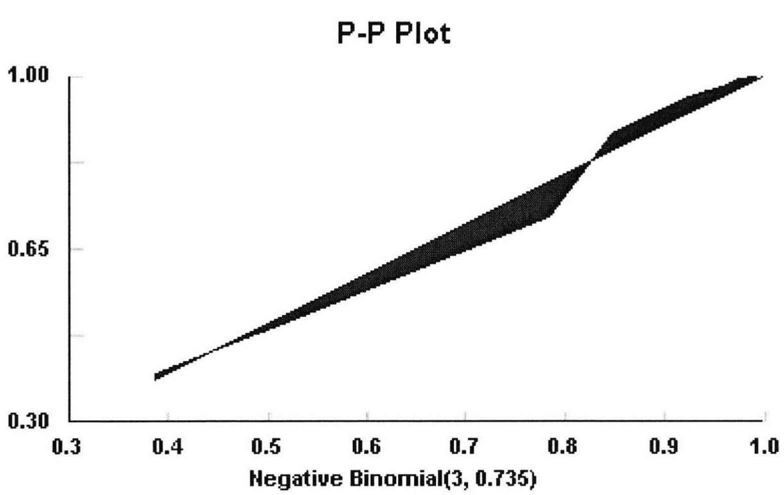
Discrete Uniform (0,6)
Geometric (p=0.480349)
Negative Binomial (k=3, p=0.734967)
Poisson (lambda 1.08182)





Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

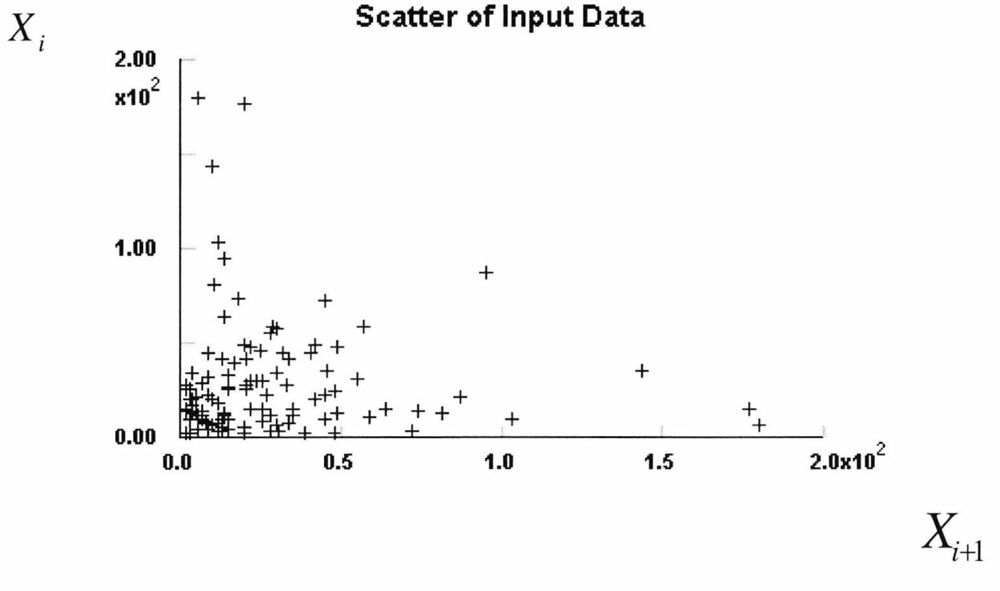
The goodness of fit tests showed that the Negative Binomial and Geometric and Poisson have a Reject result for their Chi squared p-values. However their Kolmogorov-Smirnov p-values resulted is a Do Not Reject result. The Negative Binomial distribution is clearly a better fit than the Geometric and Poisson when comparing the p-values. Therefore, any of the above distributions can be used although the Negative Binomial is preferred.

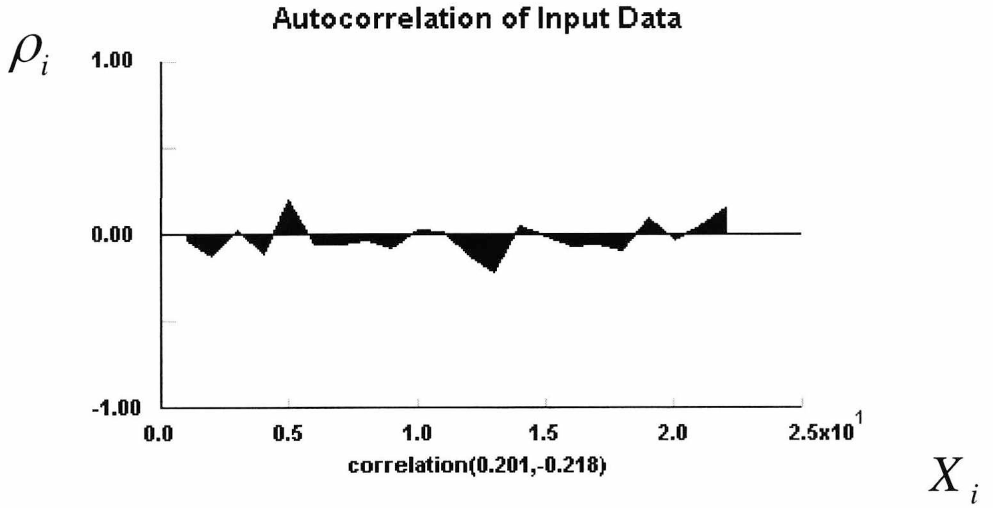
Table I.45 Distribution generated to fit Brook Ward

Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (3,0.735)	11.3(4 d.f.)	0.0239 reject	0.0782	0.478 Do not reject	Accept
Geometric (0.48)	15.5(4 d.f.)	0.00369 reject	0.0894	0.313 Do not reject	Accept
Poisson (1.08)	14.1(3 d.f.)	0.0028 reject	0.0852	0.37 Do not reject	Accept

Generating a distribution for the acute hospitals rehabilitation ward's LOS (Brook)

This wards LOS data can be considered to be IID by examining the scatter of input data and the Autocorrelation data (min=-0.218, max=0.201).





Activity 1 – Hypothesising families of distributions

The mean of 28.45 and median of 20 a difference of more than 8 days which mean that the graph is not symmetrical. Also the skewness is 2.66 which mean that the distribution is skewed to the right. The Lexis ratio is 35.19, which suggests a Negative Binomial Distribution.

Table I.46 Summary Statistics for the Brook Ward

Data points	110
minimum	2
maximum	180
mean	28.4455
median	20
mode	15
Standard deviation	31.6383
variance	1000.98
Coefficient of variation	111.225
skewness	2.65965
kurtosis	8.67558
Lexis ratio (variance/mean)	35.19

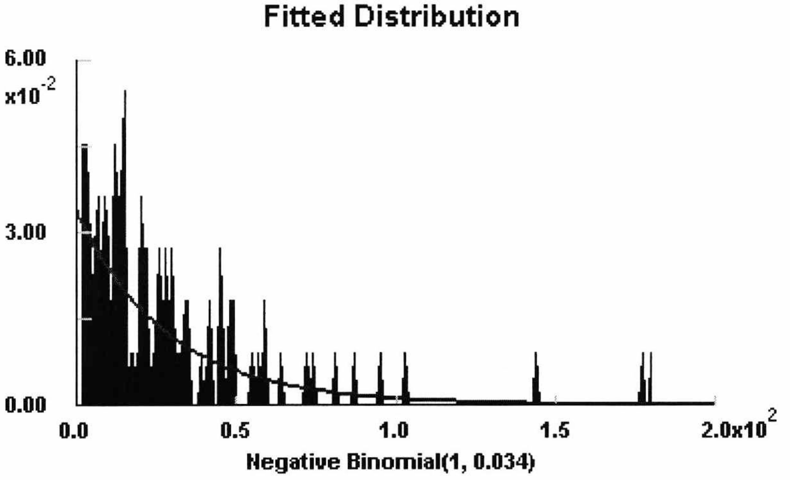
Activity 2 Estimation of the parameters from the data

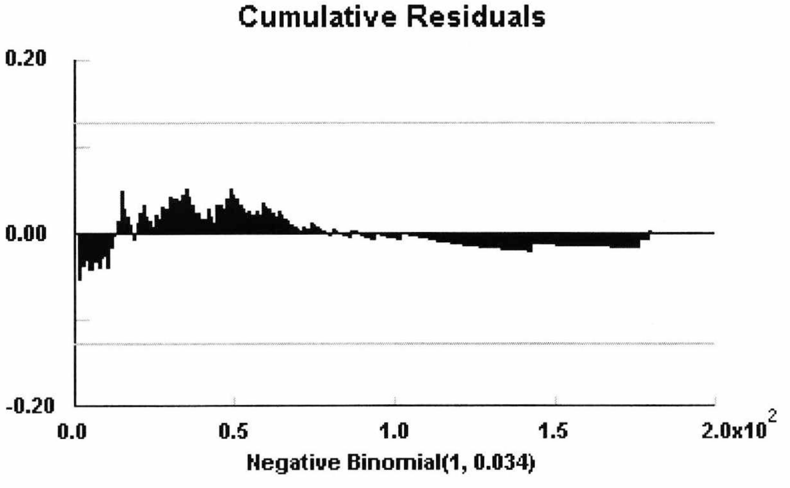
From all the distribution parameters calculated from the Maximum Likelihood by Stat::Fit, the Negative Binomial and the Geometric distributions were accepted. In fact the Negative Binomial is reduced to the Geometric as the number of desired events is equal to 1. The frequency comparison and the P-P plot showed that both the Negative

Binomial and Geometric distribution is a good fit.

Table I.47 Maximum Likelihood Estimation

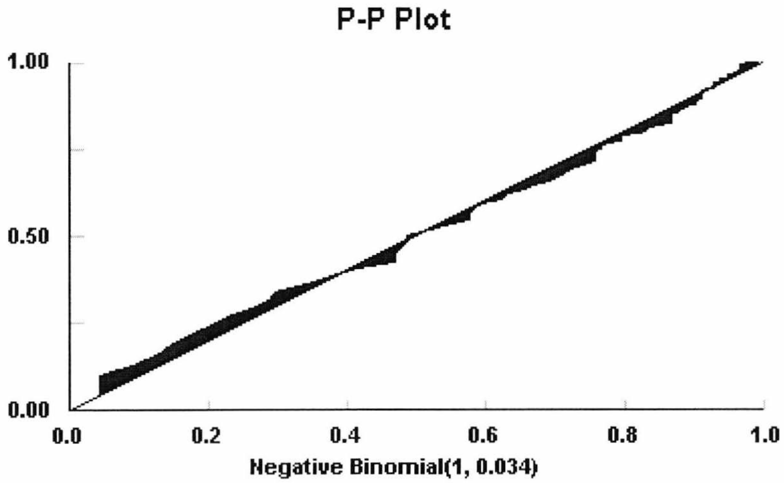
Discrete Uniform (2,180)
Geometric (p=0.0399611)
Negative Binomial (k=1, p=0.0339611)
Poisson (lambda 28.4455)





Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions. The chi–squared and Kolmogorov-Smirnov p-values for the goodness of fit test showed a Do Not Reject result. Therefore, both the distribution calculated from the MLE are considered suitable for their intended purpose.

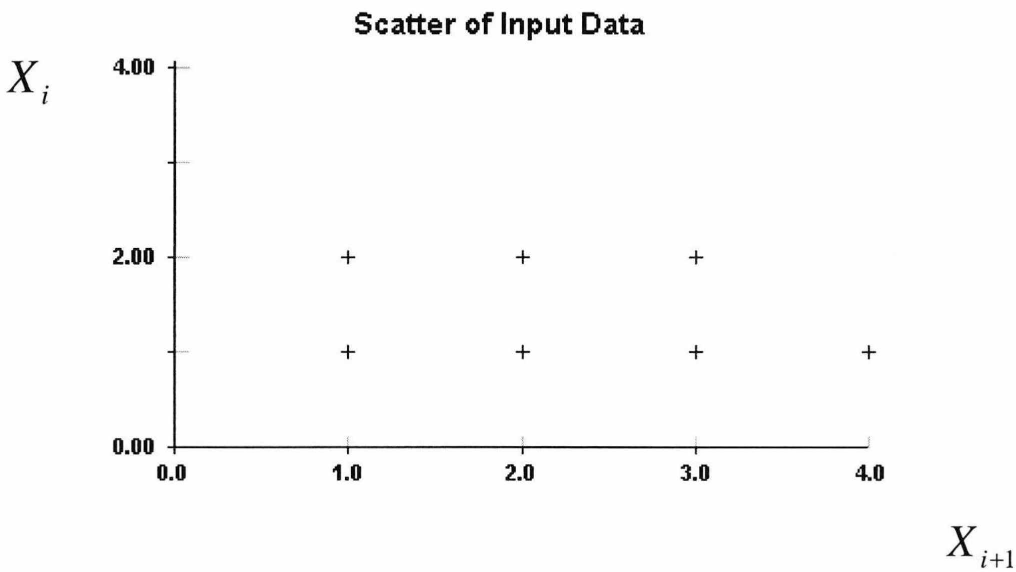
Table I.48 Distribution generated to fit Brook Ward

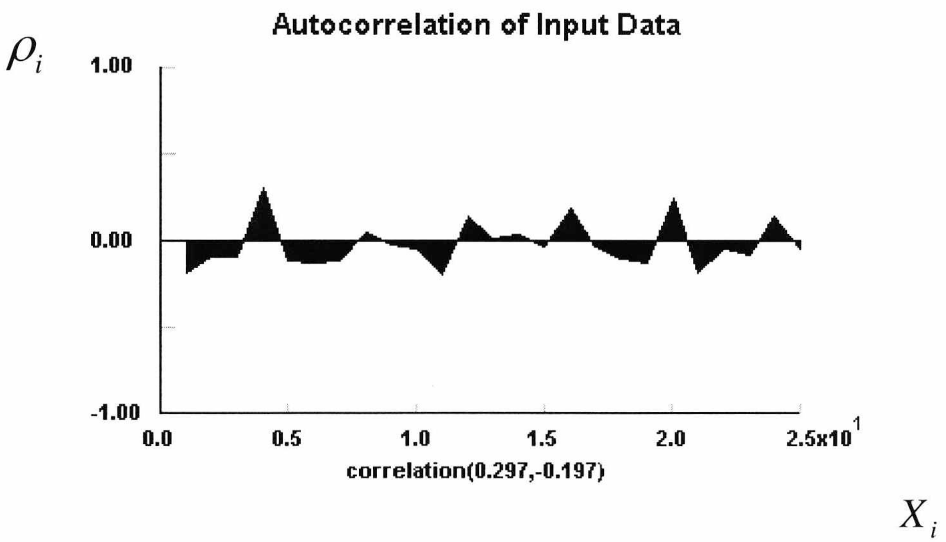
Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (1,0.034)	20.6 (17 d.f)	0.247 Do not reject	0.0.053	0.901 Do not reject	Accept
Geometric (0.034)	20.6 (17 d.f)	0.247 Do not reject	0.0.053	0.901 Do not reject	Accept

Generating Interarrival and Length of Stay distributions for the Montgomery and Ramsey wards). (Rehabilitation wards)

Generating an inter-arrival distribution for the two wards of the other Rehab Hospital (Montgomery and Ramsey)

The Scatter and Autocorrelation graphs of input data show that these wards interarrival data is comprised of Independent Identically Distributed Random Variables. The Autocorrelation range has a minimum value of –0.197 and a maximum of 0.297.





Activity 1 – Hypothesising families of distributions

The descriptive statistics for this wards data reveal that the distribution is not quite symmetrical as the mean is 0.714286 and median is 0. The skewness is 1.29, which means that the distribution is skewed slightly to the right and the kurtosis is 1.25. The Lexis ratio is 1.14.

Table I.49 Summary Statistics for Montgomery and Ramsey

Data points	126
minimum	0
maximum	4
mean	0.714286
median	0
mode	0
Standard deviation	0.902061
variance	0.813714
Coefficient of variation	126.289
skewness	1.29881
kurtosis	1.25063
Lexis ratio (variance/mean)	1.14

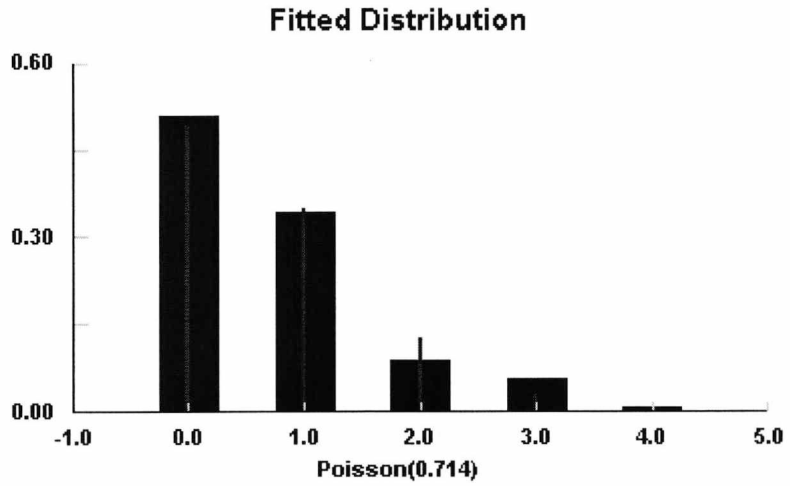
Activity 2 Estimation of the parameters from the data Maximum Likelihood Estimation

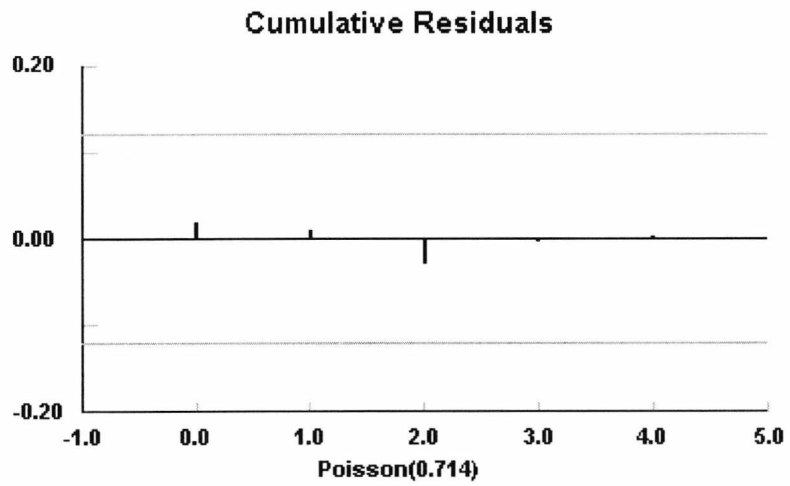
The distributions in order of best fit are the: Poisson, the Negative Binomial and Geometric. The frequency comparison and the P-P plot showed that the Poisson is a good fit.

Table I.50

Discrete Uniform (0,4)
Geometric (p=0.583333)
Negative Binomial (k=6, p=0.0.893617)
Poisson (lambda 0.714286)

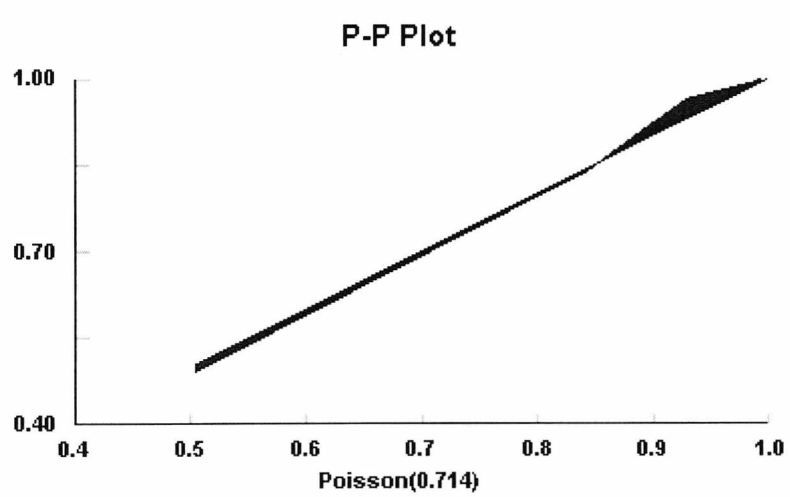
n=126





Activity 3 – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

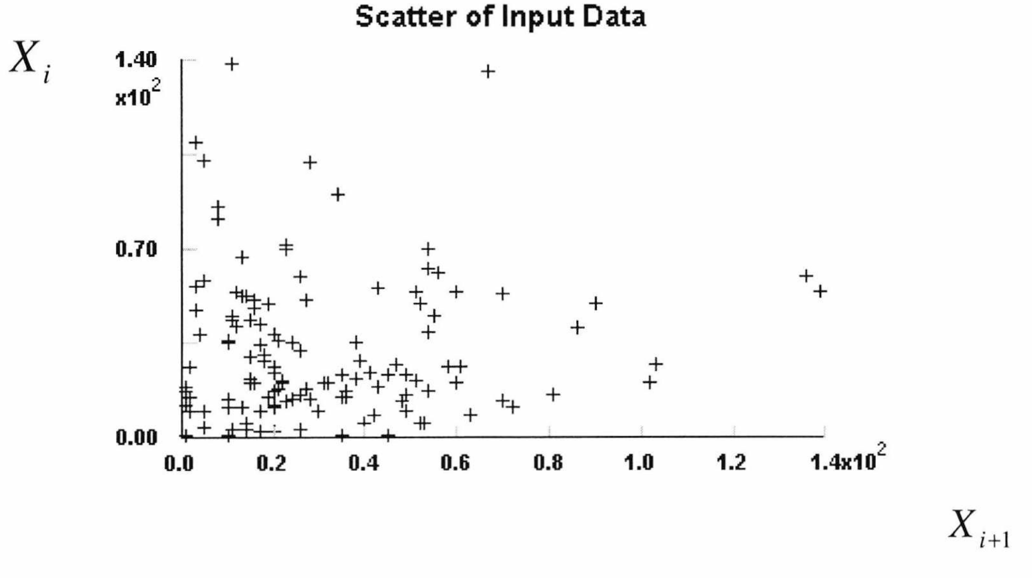
The goodness of fit tests showed that the Poisson, Negative Binomial and Geometric have a Do Not Reject result for their Chi squared p-values. Also their Kolmogorov-Smirnov p-values resulted is a Do Not Reject result. The Poisson and Negative Binomial distribution are clearly a very good fit as their p-values K-S p-values are 1. Although, any of the above distributions can be used Poisson is preferred because of its very high p-values.

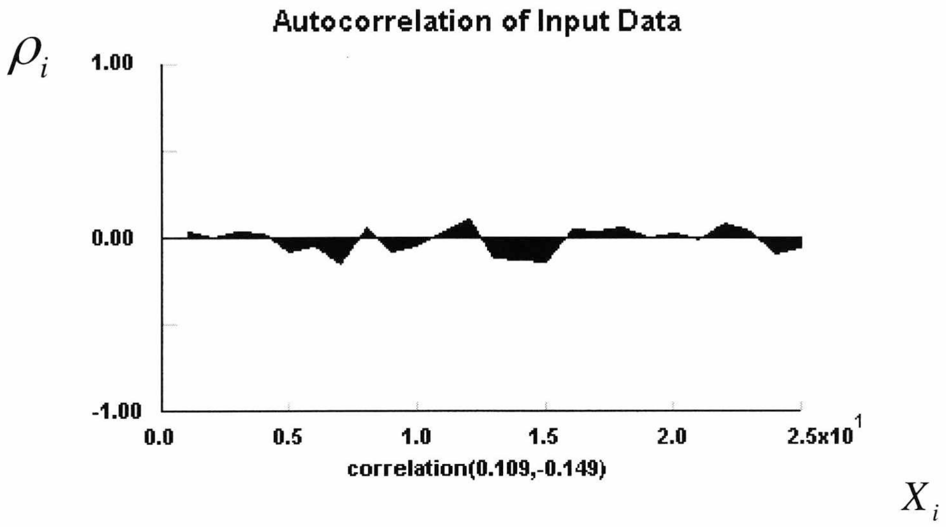
Table I.51 Distribution generated to fit Montgomery and Ramsey

Test	Chi2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Poisson(0.714)	0.191(2 d.f.)	0.909 Do not reject	0.0276	1 Do not reject	Accept
Negative Binomial (6,0.894)	2.28(3 d.f.)	0.516 Do not reject	0.0188	1 Do not reject	Accept
Geometric (0.583)	6.61(3 d.f.)	0.0855 Do not reject	0.0754	0.44 Do not reject	Accept

Generating the Rehabilitation Hospital wards (Montgomery and Ramsey) LOS distribution

The LOS data can be considered to be IID by examining the scatter of input data and the Autocorrelation data (min=-0.149, max=0.109).





Activity 1 – Hypothesising families of distributions

The data has a mean of 32.21 and median of 23 a difference of more than 9 days, which mean that the graph is not symmetrical. In addition, the skewness is 1.53, which mean that the distribution is skewed to the right. The Lexis ratio is 22.55, which suggests a Negative Binomial Distribution.

Table I.52 Summary Statistics

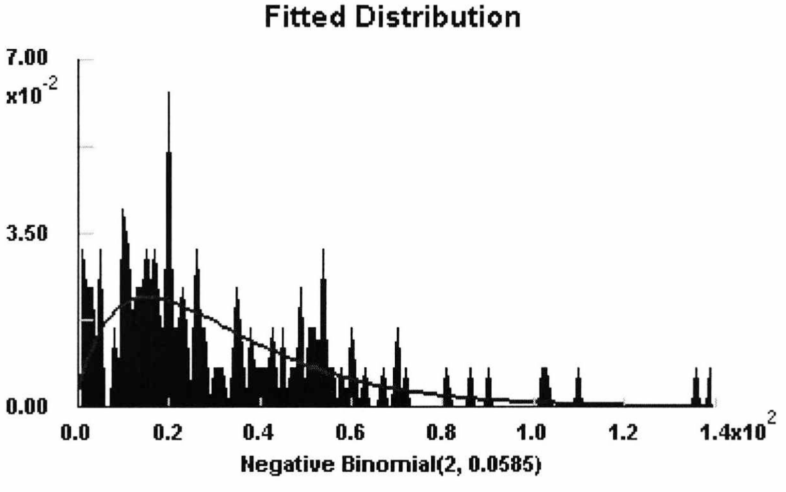
Data points	126
minimum	0
maximum	139
mean	32.2143
median	23
mode	20
Standard deviation	26.9508
variance	726.346
Coefficient of variation	83.661
skewness	1.53466
kurtosis	2.8204
Lexis ratio (variance/mean)	22.55

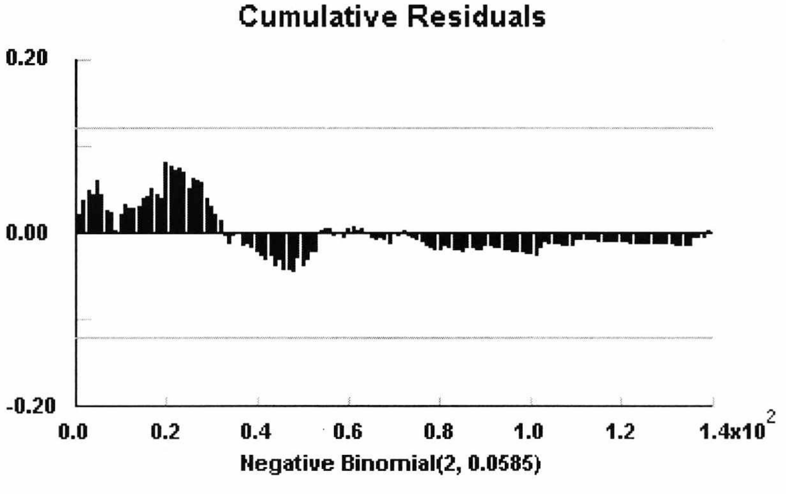
Activity 2 Maximum Likelihood Estimation

From all the distribution parameters calculated from the Maximum Likelihood by Stat::Fit, only the Negative Binomial was accepted. The frequency comparison and the P-P plot showed that the Negative Binomial distribution is a reasonable fit.

Table I.53 Maximum Likelihood Estimation

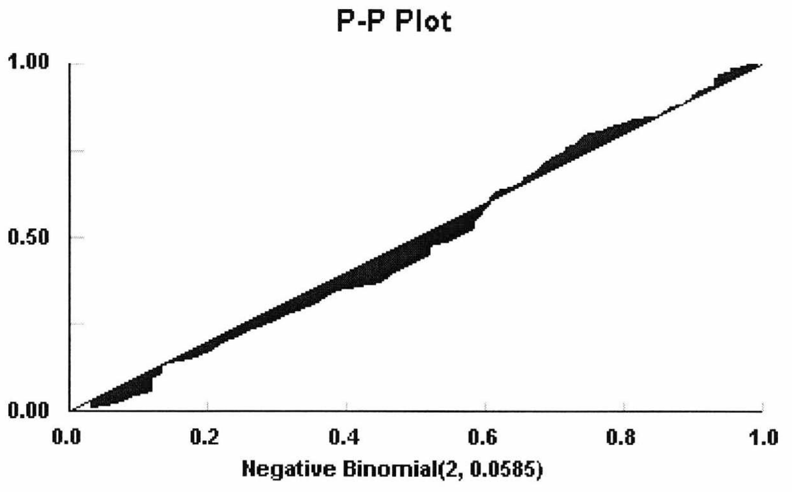
Discrete Uniform (1,139)
Geometric (p=0.030175)
Negative Binomial (k=2, p=0.0584551)
Poisson (lambda 32.2143)





Activity III – Determining how representative the fitted distribution is of the true underlying distribution for the data.

Heuristic procedures



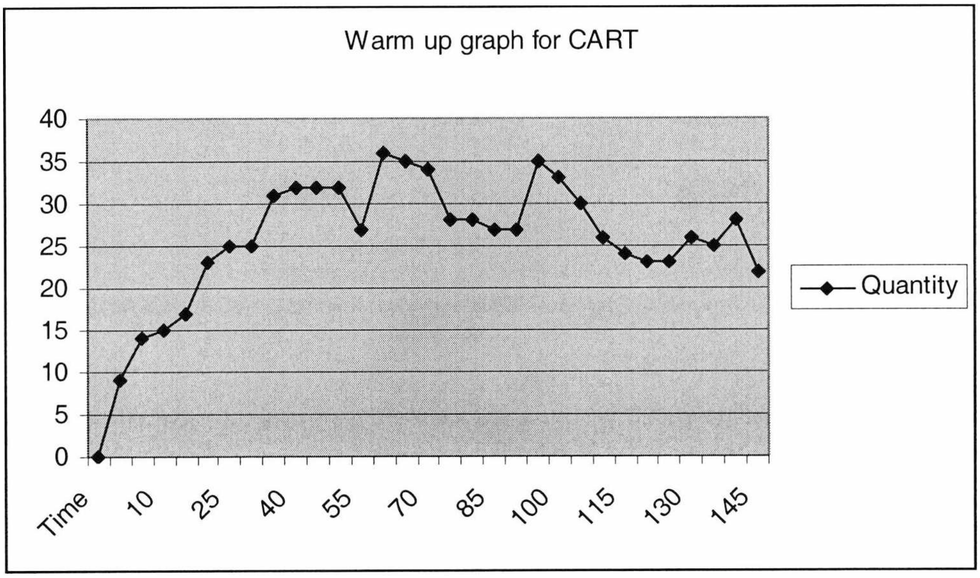
Goodness of fit and hypothesis tests to determine the quality of fitted distributions.

The p-values for the chi–squared and Kolmogorov-Smirnov goodness of fit test showed a Do Not Reject Result. Therefore, the distribution calculated from the MLE is considered adequate for its intended purpose.

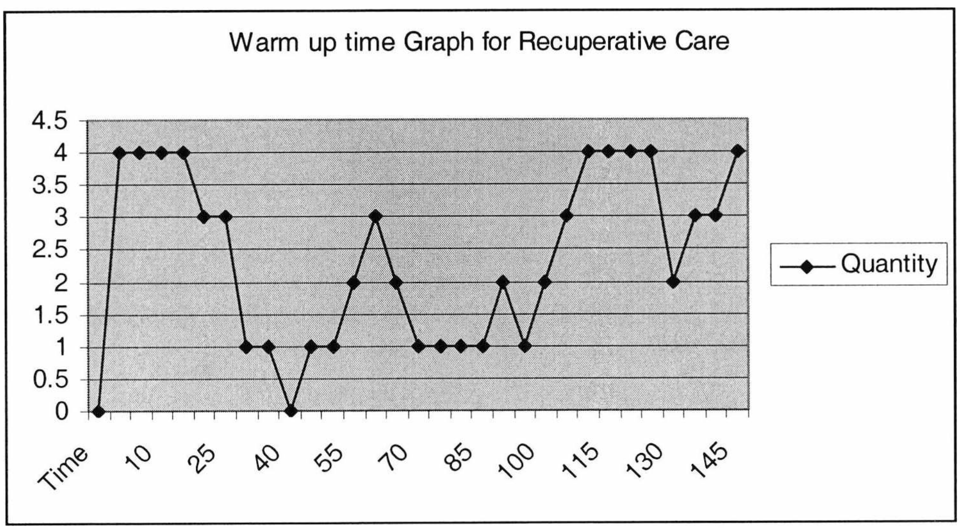
Table Distribution generated to fit Ward

Test	Chi^2	p-value	Kolmogorov-Smirnov	p-value	Acceptance
Negative Binomial (2,0.0585)	22.2 (21 d.f)	0.387 Do not reject	0.0811	0.349 Do not reject	Accept

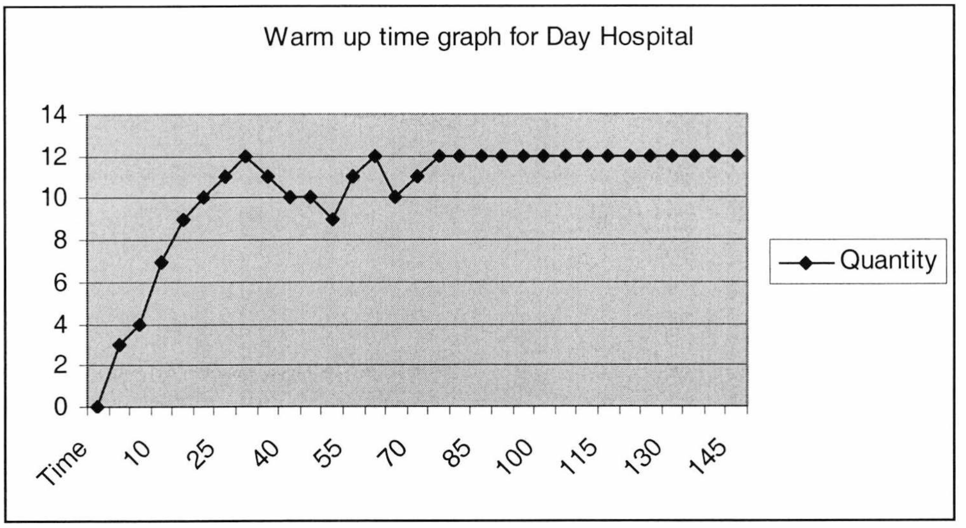
Appendix J (graphs of warm up time)



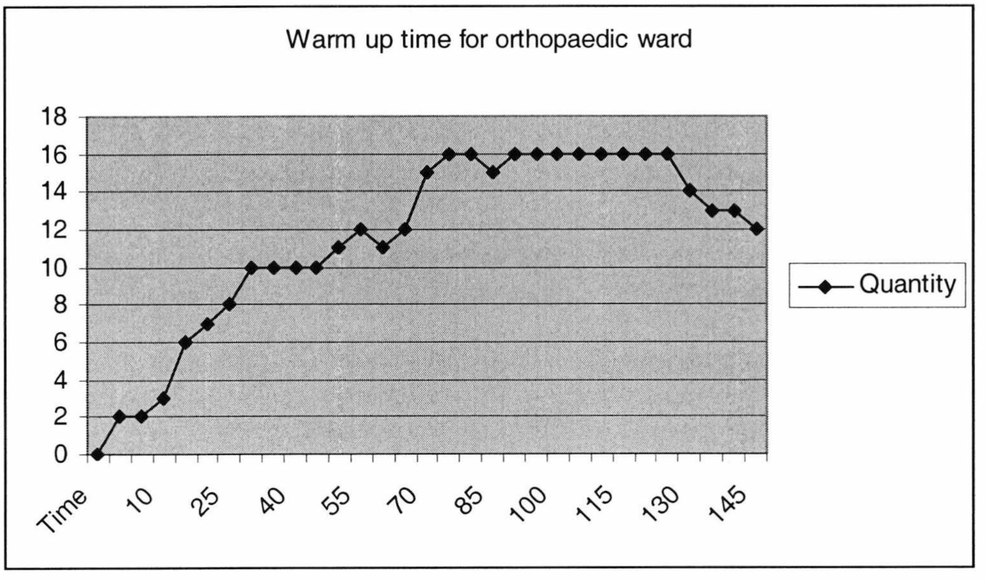
The warm up time for CART is 45 days



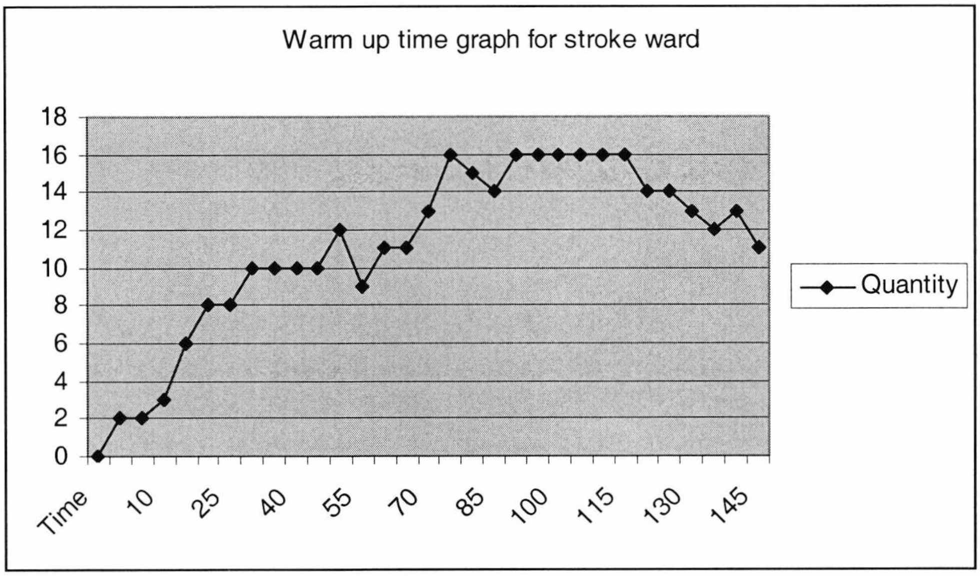
Warm up time for Recuperative Care is 10 days.



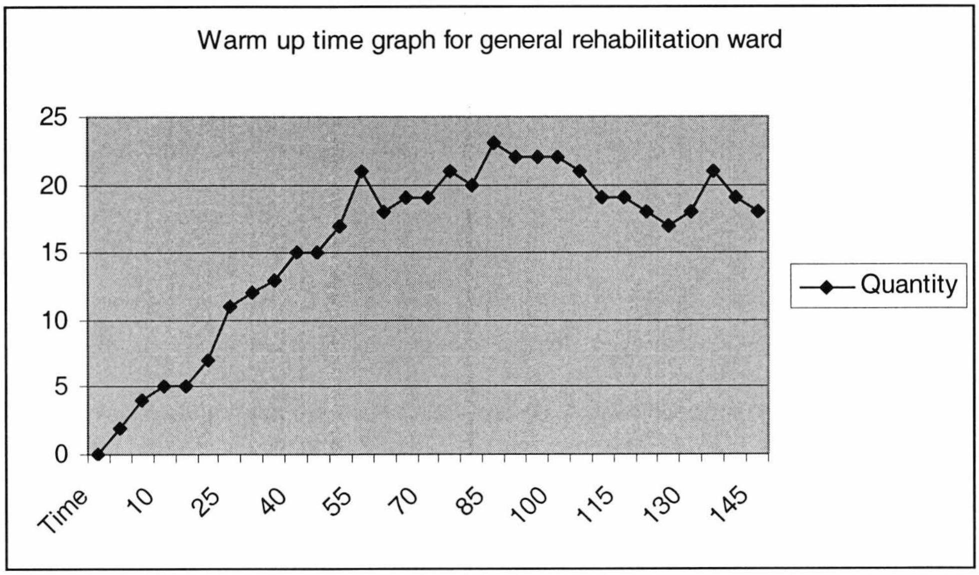
Warm up time for the Day Hospital is 80 days.



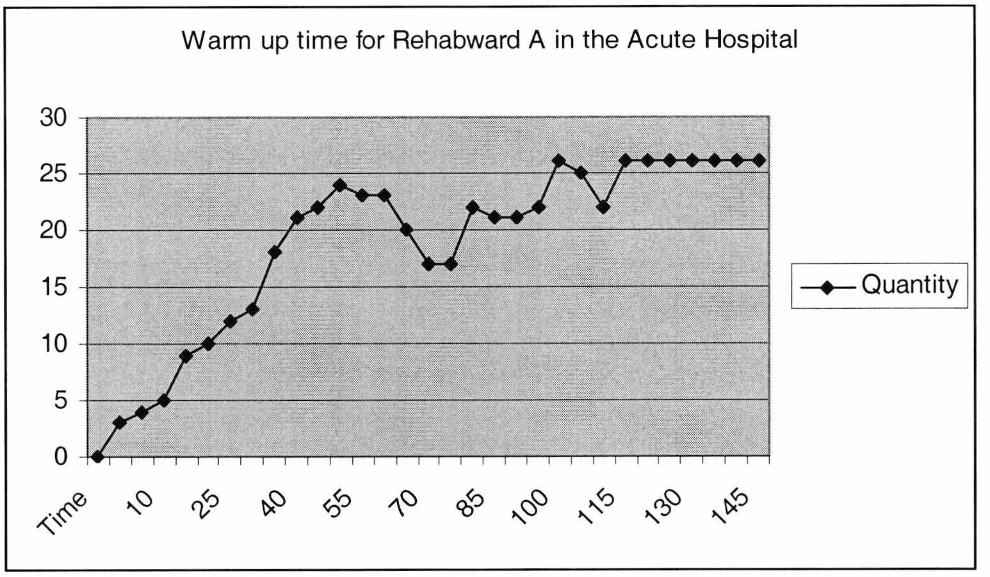
Warm up time for the orthopaedic ward (Fitton) is 90 days



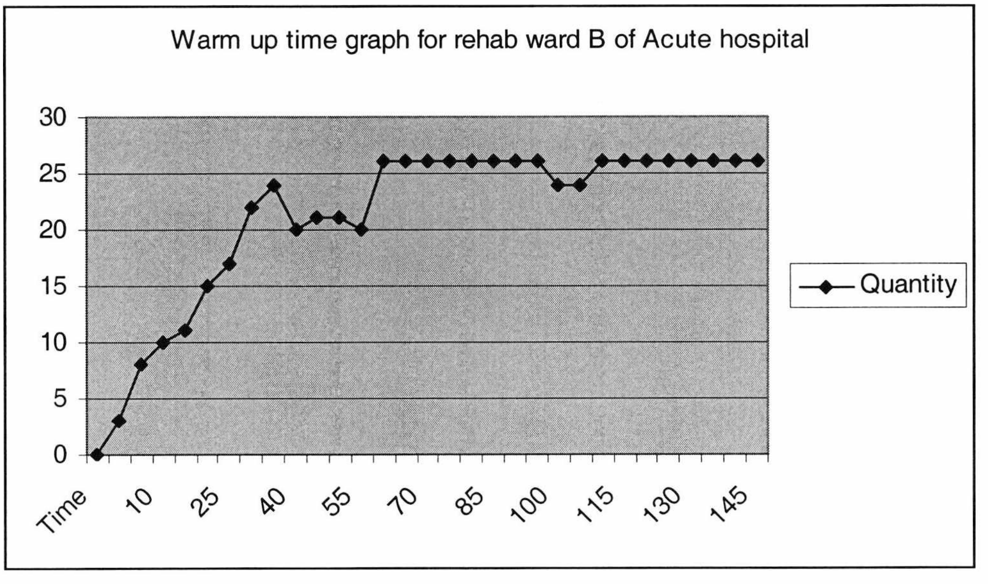
The warm up time for Richard Stevens ward is 90 days



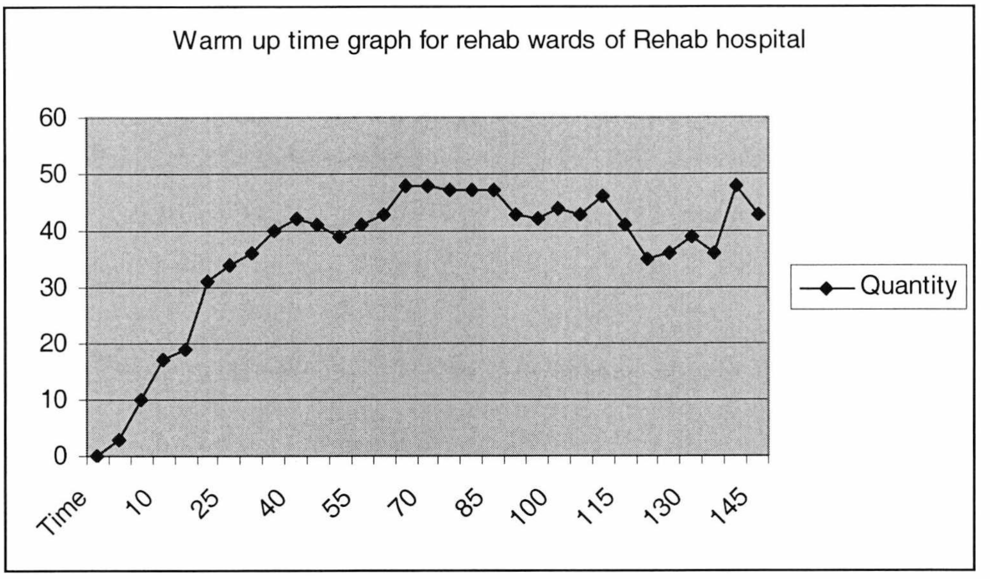
The warm up time for Edinburgh is 90 days



The warm up time for Bethersden is 55 days



The warm up time for Brook is 70 days

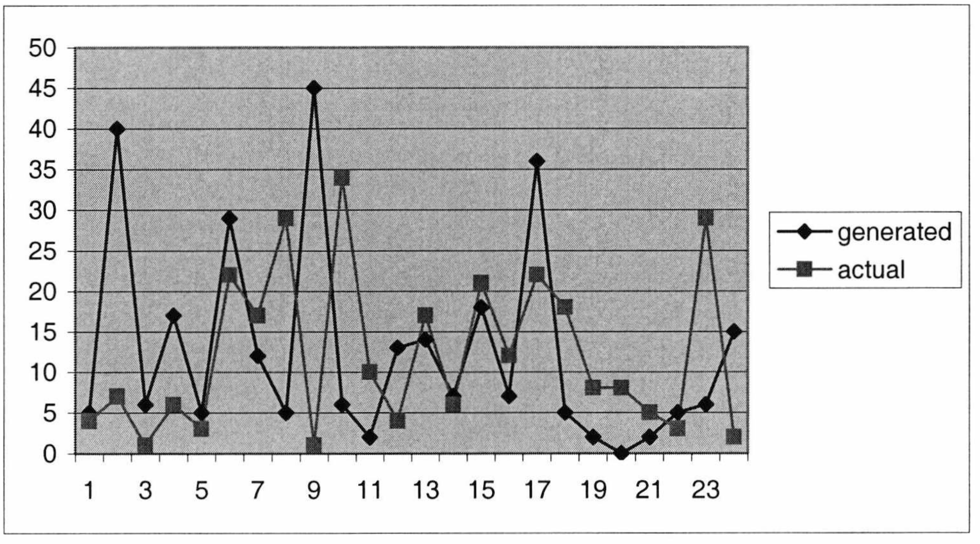


The warm up time for Montgomery and Ramsey is 70 days

Appendix K Appendix validation and verification of data

Validation and Verification of Recuperative Care

The Recuperative Care inter-arrival data fitted the Negative Binomial Distribution best. The Recuperative Care patients are expected to be around 11 over 5 months. The distribution generated a low 95% range of 10.81, an average of 12.73 and a high 95% range of 14.66, which similar manner to the real life admission numbers. This can also be seen in the graph illustrating the actual and generated data.

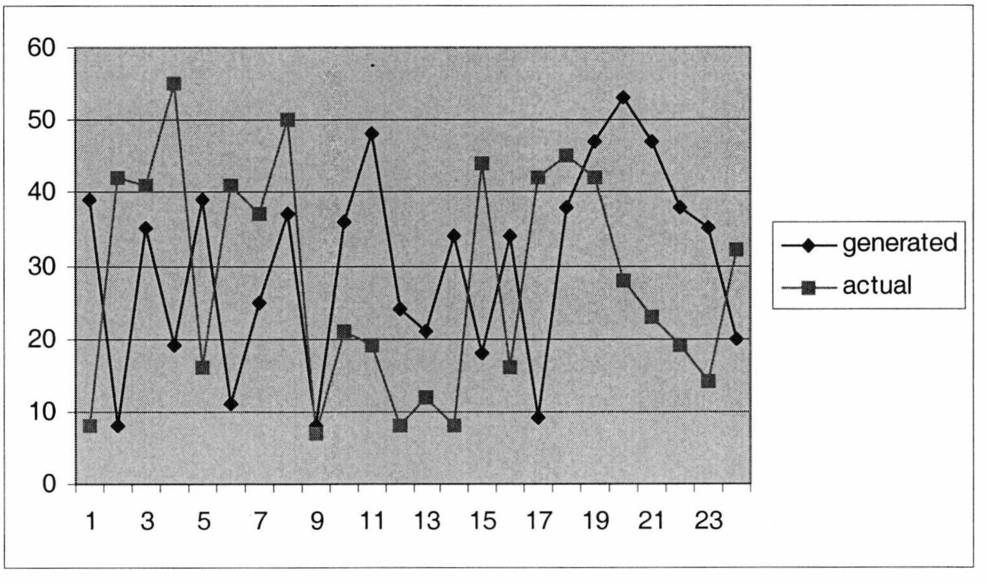


Graph comparing the actual Recuperative Care inter-arrival days with the ones generated by the Negative Binomial distribution.

The recuperative care data collection started in July month and ended in April month. Due to the small amount of patients that recuperative care receives all data from patients was used to in order to have a sufficient number of data to generate the LOS and inter-arrival distributions. The LOS distribution chosen for Recuperative Care was the Negative Binomial (7, 0.173) because it gave the most realistic simulation results. The real LOS data (collected through assessment forms) when analysed with both Stat::Fit and SPSS gave a mean of 27.91, a median of 25.5 and a mode of 8. The generated distribution when put into simul8 and run produced a confidence interval with a low 95% range of average time in the system of 20.03 an average result of 25.57 and a high 95% range of 31.11. The real data's mean and median are within the confidence interval and the generated distribution can therefore be deemed as appropriate. The low 95%

range of maximum time in the Recuperative care system model was 33.64 the average was 58.80 and the high 95% range was 83.96. The real data used to model the distribution had a maximum value for LOS of 55 days, which is within the range.

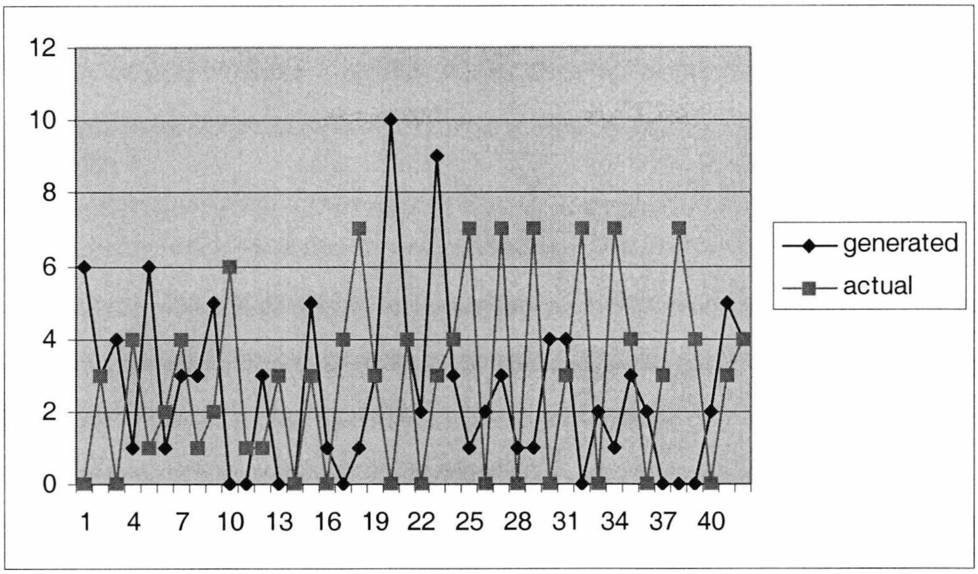
The recuperative care manager indicated that the care was offered for a max of 6 weeks approximately 45 days and the real data used had a max of 55 days of care. The simulation model showed a low 95% range for patients receiving treatment less than 45 days is 83.96% of the patients. An average of 92.92% and a high 95% of the range as in the system less than 45 days as 100% of the patients. The real data had only 2 of the patients or 8% staying over 45 days and this is an unusual phenomenon according to the manager. So perhaps the distribution is good enough for its purpose.



Graph comparing the actual Recuperative Care LOS days with the ones generated by the distribution.

Validation and Verification of Day Hospital

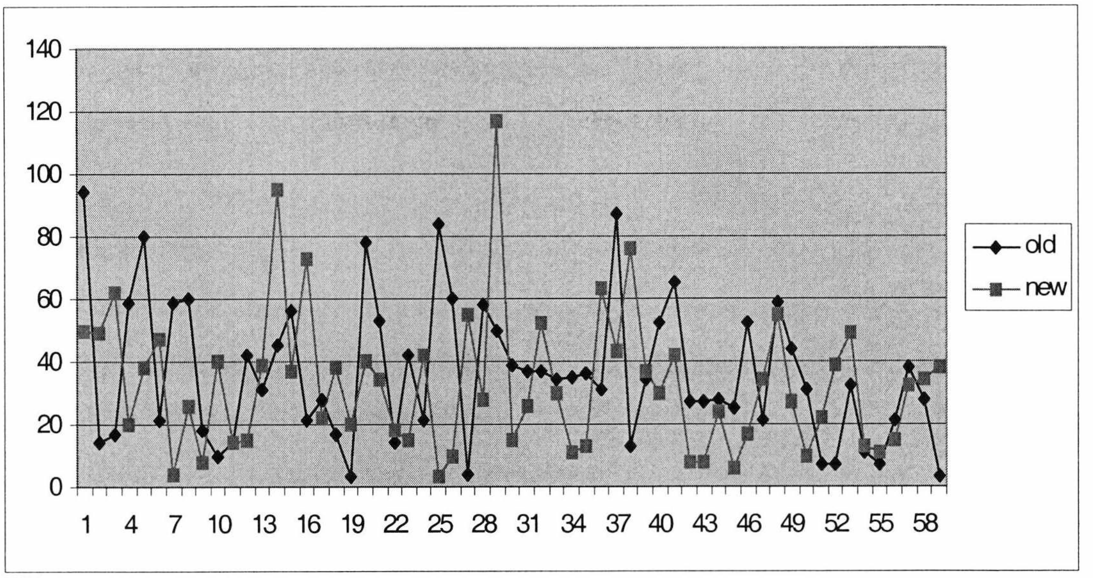
The Day Hospital data fitted the Negative Binomial Distribution best. The Day Hospital patients are expected to be around 53 over 5 months. The distribution generated a low 95% range of 48, an average of 53.4 and a high 95% range of 58.78. The generated Distribution has generated an average that is the same as the actual number of arrivals over five months. This means that the distribution behaves in a similar manner to the real life admission numbers. The graph comparing the actual arrivals with the ones generated shows that the generated on two occasions exceeds the actual data. However the generated data does have a similar trend to the actual data.



Graph comparing the actual Day Hospital inter-arrival days with the ones generated by the Negative Binomial distribution.

The LOS distribution chosen for Day Hospital was the Negative Binomial (3, 0.0778) because it gave the most realistic simulation results. The real LOS data (collected through assessment forms) when analysed with both Stat::Fit and SPSS gave a mean of 35.58, a median of 31.5 and a mode of 21. The generated distribution when put into simul8 and run (with a warm up time) for 5 months provided an average time in the system with a low 95% range of 28.92 an average result of 34.74 and a high 95% range of 40.56. The real data's mean and median are within the confidence interval and the generated distribution can therefore be deemed as appropriate. The low 95% range of maximum time in the Day Hospital system model was 66.50 the average was 89.40 and the high 95% range was 112.30. The real data used to model the distribution had a maximum value for LOS of 94 days, which is within the range.

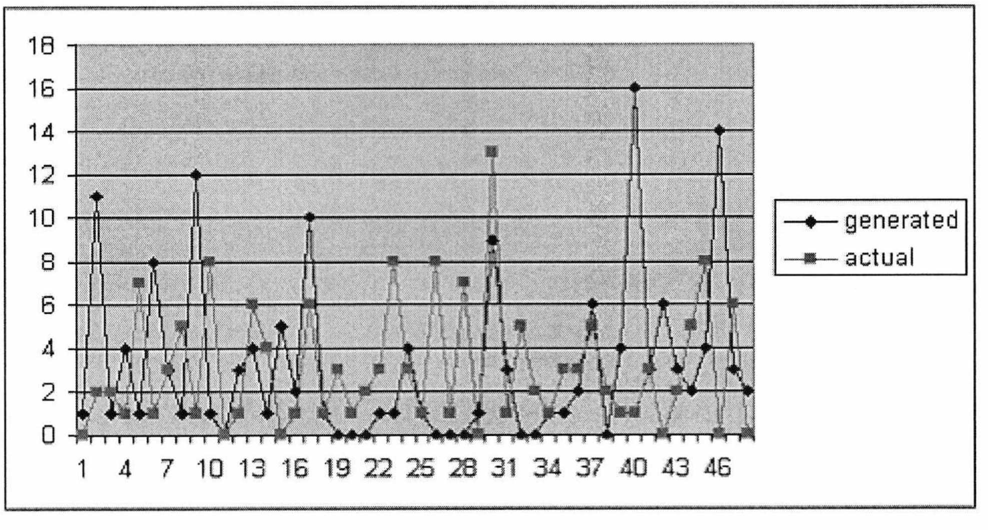
The Day Hospital manager indicated that the care, which is offered once or twice a week was offered for a max of 6-8 weeks. The simulation model showed that the low 95% range of the percentage of patients receiving treatment for less than 45 days (6 weeks= a max of 2*6 visits= 12 visits) is 61.83% of the patients. An average of72.38% and a high 95% of the range as in the system less than 45 days as 82.92% of the patients. The graph illustrates that the real data are similar to the generated data.



Graph comparing the actual Day Hospital LOS days with the ones generated by the Negative Binomial distribution.

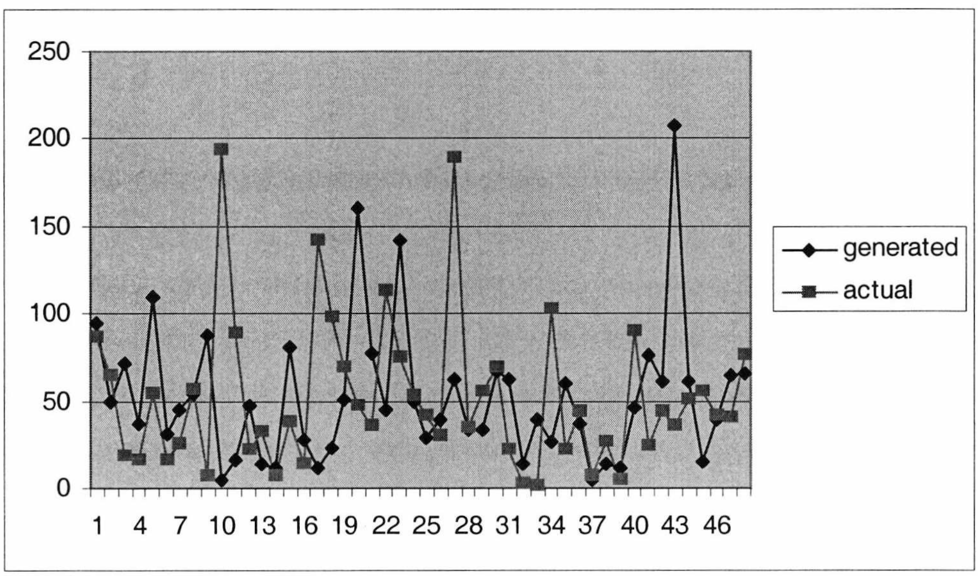
Validation and Verification of Fitton Orthopaedic rehabilitation ward

The orthopaedic ward data fitted the Geometric Distribution best. The wards patients are expected to be around 48 over 5 months. The distribution generated a low 95% range of 39.66, an average of 48.80 and a high 95% range of 57.94. This means that the inter-arrival distribution for this ward sends a realistic amount of patients into the model.



Graph comparing the actual Orthopaedic ward's days with the ones generated by the Geometric distribution.

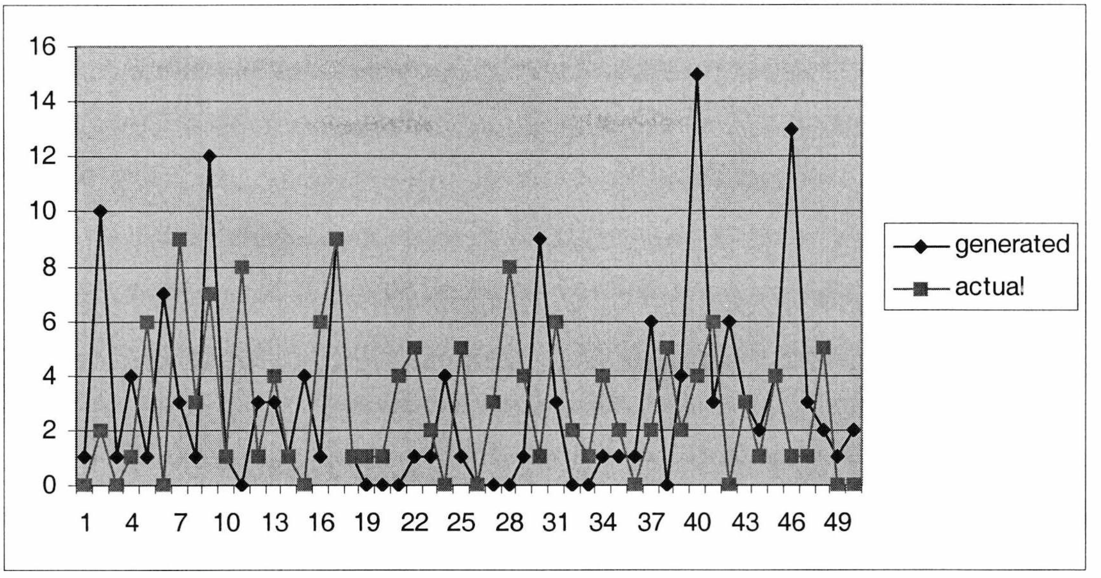
The LOS distribution chosen for this ward is the Negative Binomial (2, 0.0373). The real LOS data (collected through assessment forms) when analysed with both Stat::Fit and SPSS gave a mean of 51.625, a median of 41 and a mode of 7. The model was run with the generated distribution with a warm up time of at least 70 days over a 5-month period. The results showed a low 95% range in the system of 41.21 an average result of 54.77 and a high 95% range of 68.33. The real data's mean is within the confidence interval and the generated distribution can therefore be deemed as appropriate. The low 95% range of maximum time in the ward model was 102.05 the average was 129.80 and the high 95% range was 157.55. The real data used to model the distribution had a maximum value for LOS of 193 days, which is outside the range. However this is not of great concern as the vast majority of values are within the limit.



Graph comparing the actual Orthopaedic ward's LOS days with the ones generated by the Negative Binomial distribution.

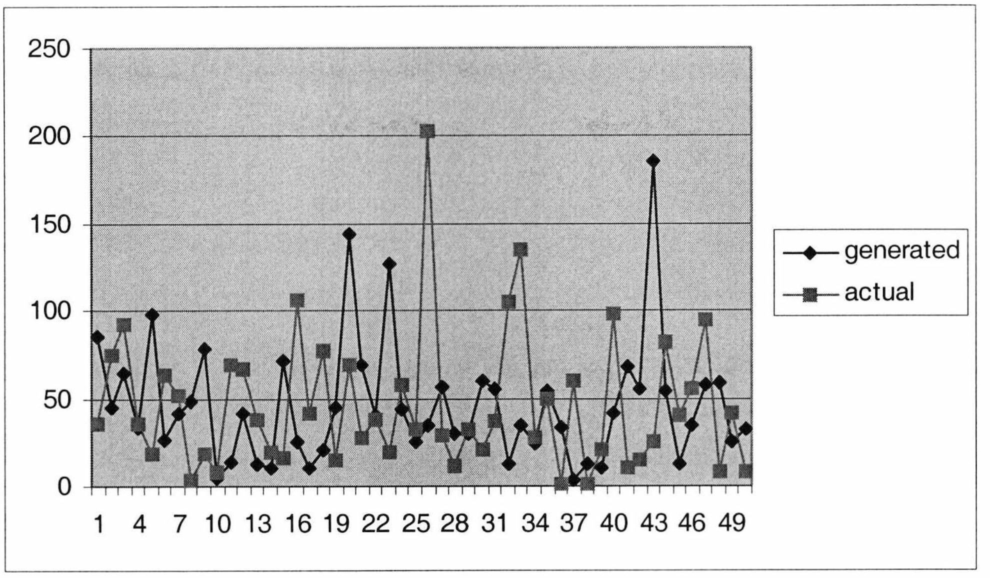
Validation and Verification of the Richard Steven stroke ward generated distribution

The stroke ward data fitted the Geometric Distribution best. The wards patients are expected to be around 50 over 5 months . The distribution generated a low 95% range of 47.22, an average of 52.60 and a high 95% range of 57.98. The generated Distribution provides similar arrivals to the real life arrivals.



Graph comparing the actual Stroke ward's inter-arrival days with the ones generated by the Geometric distribution.

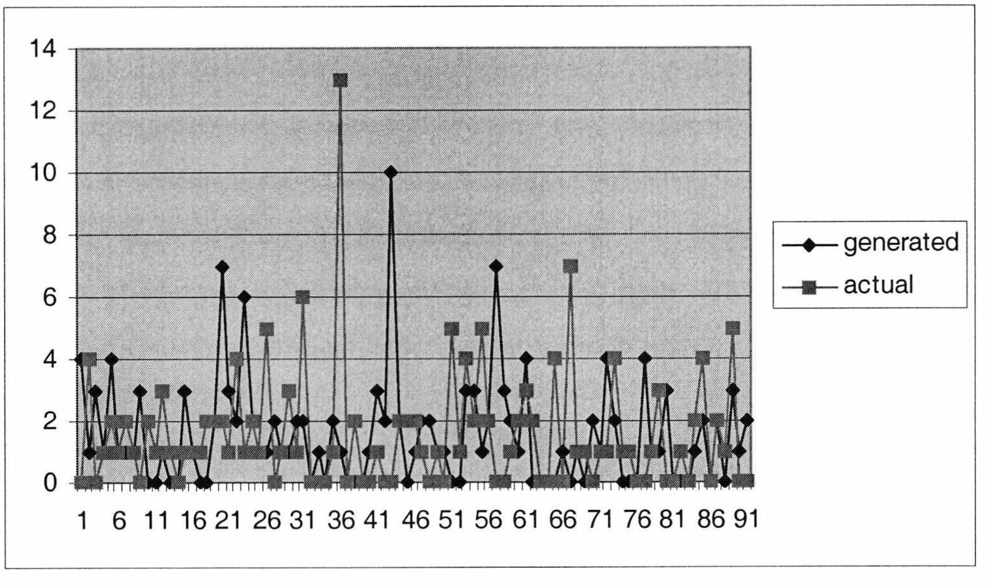
The LOS distribution chosen for the stroke ward was the Negative Binomial (2, 0.0415). The real LOS data (collected through assessment forms) when analysed with both Stat::Fit and SPSS gave a mean of 46.16, a median of 36.5 and a mode of 8. The generated distribution was entered into simul8 and the model was run with a warm up time of at least 90 days over a 5-month period. The range for the average time in the system has a low 95% range of 39.81. an average result of 46.30 and a high 95% range of 52.79. The real data's mean is within the range. The low 95% range of maximum time in the ward model was 101.68 the average was 136.40 and the high 95% range was 171.12. The real data used to model the distribution had a maximum value for LOS of 203 days, which is outside the range. However this is the only LOS's that are above high 95% range. In fact ward managers have suggested in discussions that there are a few long term bedblockers that should not be there and measures are being put in place that will eventually eradicate this problem. Therefore the generated distribution will be even closer matching as the measures are put in place.



Graph comparing the actual ward's inter-arrival days with the ones generated by the Geometric distribution.

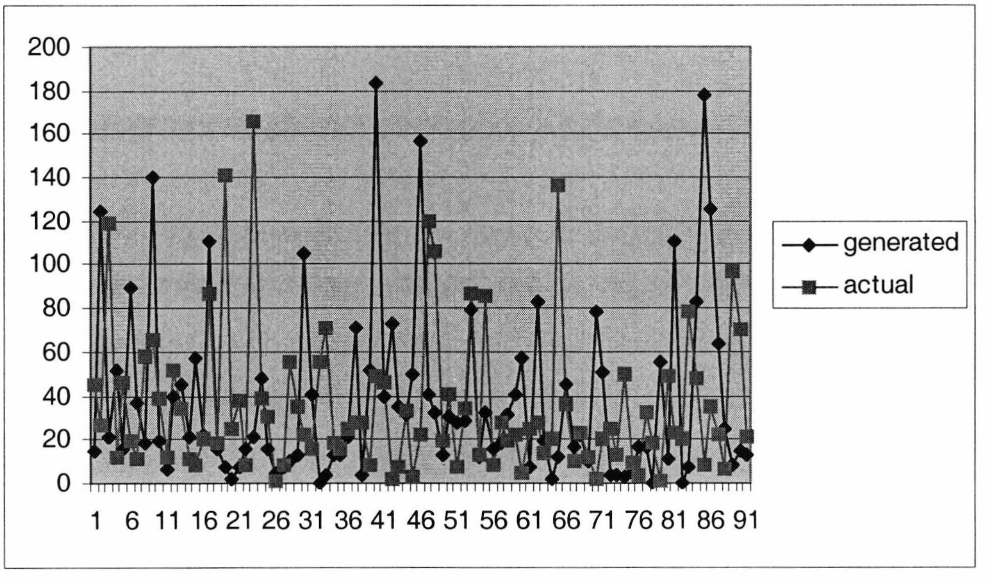
Validation and Verification of the Edinburgh rehabilitation ward

This ward data fitted the Negative Binomial Distribution best. The wards patients are expected to be around 91 over 5 months. The distribution generated a low 95% range of 75.21, an average of 87.20 and a high 95% range of 99.19. The graph comparing the actual data with the generated data is a clear indication of their close fit.



Graph comparing the actual ward's inter-arrival days with the ones generated by the Geometric distribution.

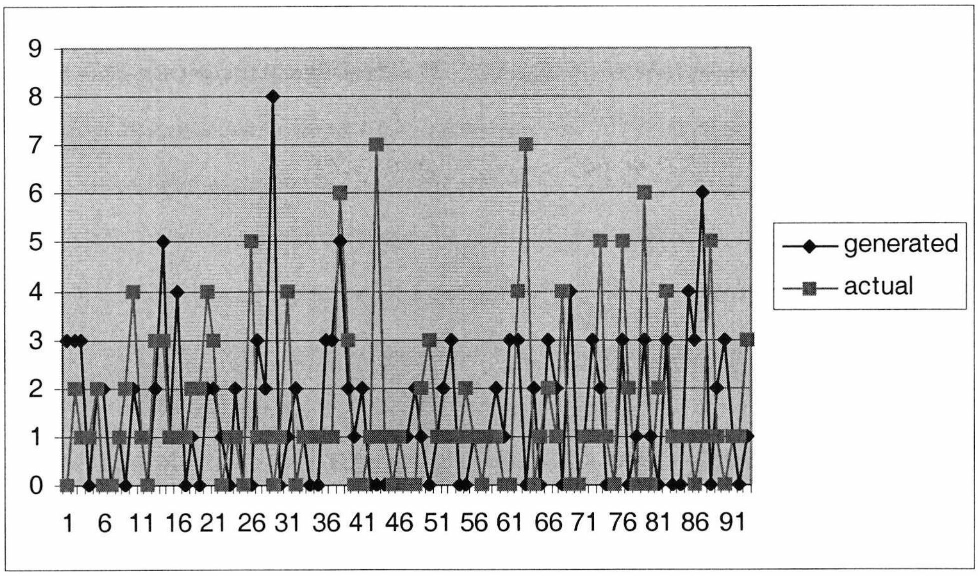
The LOS distribution chosen for this ward was the Negative Binomial (1, 0.0257). The real LOS data (collected through assessment forms) when analysed with both Stat::Fit and SPSS gave a mean of 37.94, a median of 27 and a mode of 8. The generated distribution was entered into simul8 and the model was run with a warm up time of 95 days over a 5-month period. The results provided an average time in the system for each run, which in turn was used to construct a range. The low 95% range in the system of 33.11. an average result of 37.52 and a high 95% range of 41.94. The real data's mean is within the range. The low 95% range of maximum time in the ward model was 122.9 the average was 156.40 and the high 95% range was 189.9. The real data used to model the distribution had a maximum value for LOS of 166 days, which is within the range.



Graph comparing the actual ward's LOS days with the ones generated by the Negative Binomial distribution.

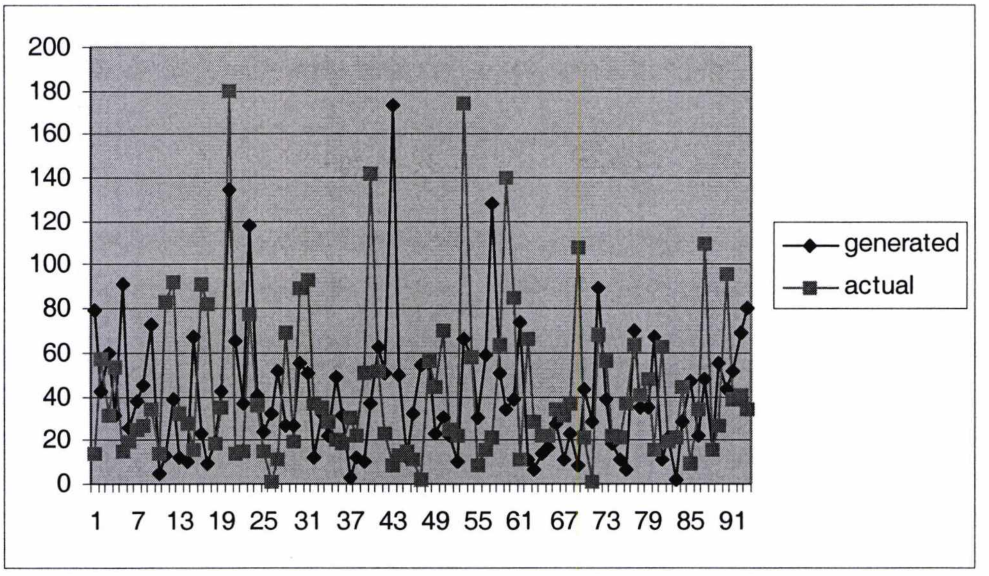
Validation and Verification of Bethersden rehabilitation ward in the acute hospital

This ward's data fitted the Negative Binomial Distribution best. The wards patients are expected to be around 93 over 5 months. The distribution generated a low 95% range of 83.74, an average of 92.8 and a high 95% range of 101.86. The generated Distribution adequately portrays the real life admission numbers.



Graph comparing the actual ward's inter-arrival days with the ones generated by the Negative Binomial distribution.

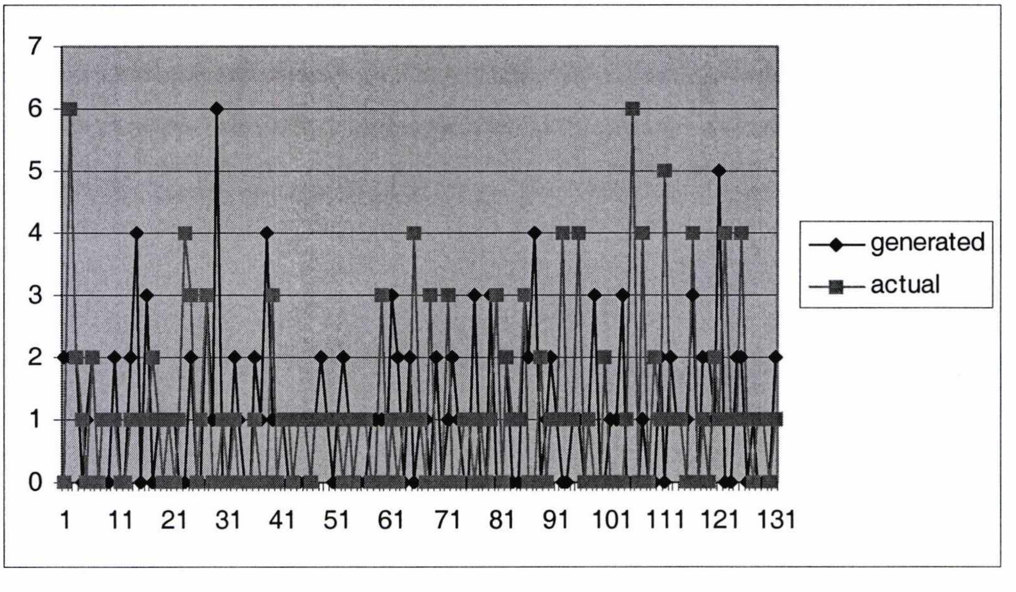
The LOS distribution chosen for this ward was the Negative Binomial (2,0.0445). The real LOS data (collected through assessment forms) when analysed with both statfit and SPSS gave a mean of 42.92, a median of 29.5 and a mode of 22. The generated distribution was entered into simul8 and the model was run with a warm up time of at least 60 days over a 5-month period. The results provided an average time in the system for each run, which in turn was used to construct a range. The low 95% range in the system of 34.94. an average result of 41.29 and a high 95% range of 47.63. The real data's mean is within the range. The low 95% range of maximum time in the ward model was 101.92 the average was 127.4 and the high 95% range was 152.88. The real data used to model the distribution had a maximum value for LOS of 180 days, which is outside the range. However like other IC wards there are patients that bedblock.



Graph comparing the actual ward's LOS days with the ones generated by the Negative Binomial distribution.

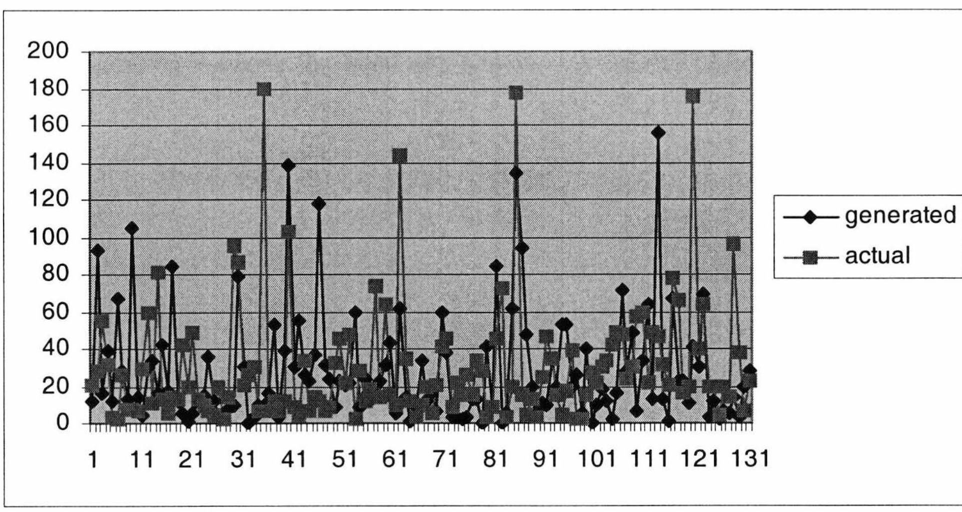
Validation and Verification of rehabilitation ward B in the acute hospital (Brook)

This ward data fitted the Distribution best. The wards patients are expected to be around 131 over 5 months. The distribution generated a low 95% range of 124.87, an average of 137 and a high 95% range of 149.13. The generated Distribution behaves in a similar manner to the real life admission numbers.



Graph comparing the actual ward's inter-arrival days with the ones generated by the Negative Binomial distribution.

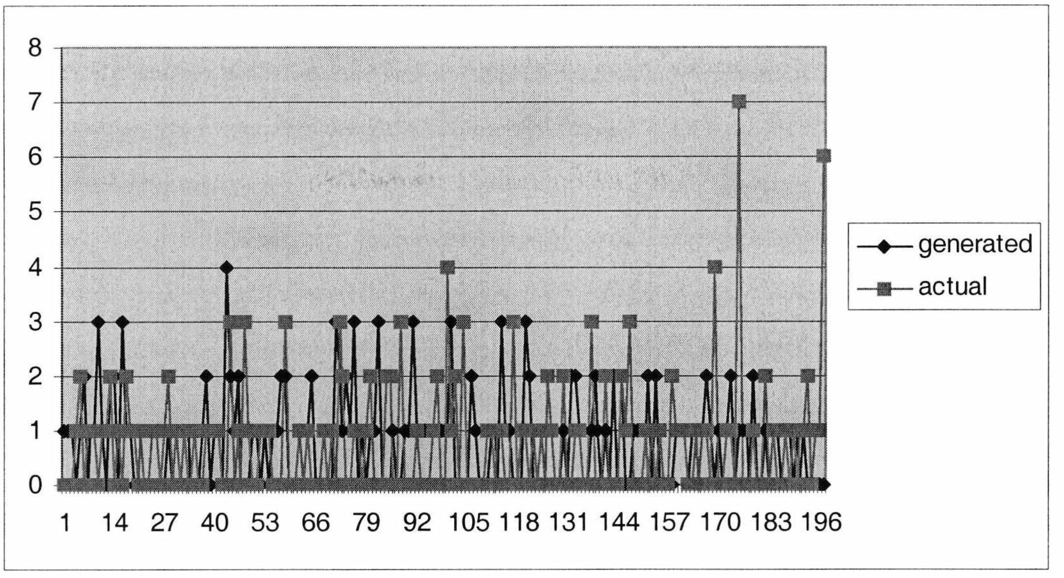
The LOS distribution chosen for this ward was the Negative Binomial (1, 0.034). The real LOS when analysed gave a mean of 28.44, a median of 20 and a mode of 15. The generated distribution was entered into simul8 and the model was run with a warm up time of at least 70 days over a 5-month period. The results provided an average time in the system with a low 95% range of 23.99 an average result of 28.74 and a high 95% range of 33.5. The real data's mean is within the range. The low 95% range of maximum time in the ward model was 94.47 the average was 126.8 and the high 95% range was 159.13. The real data used to model the distribution had a maximum value for LOS of 180 days, which is outside the range. However, like other IC wards there are isolated cases of patients that bedblock.



Graph comparing the actual ward's LOS days with the ones generated by the Negative Binomial distribution.

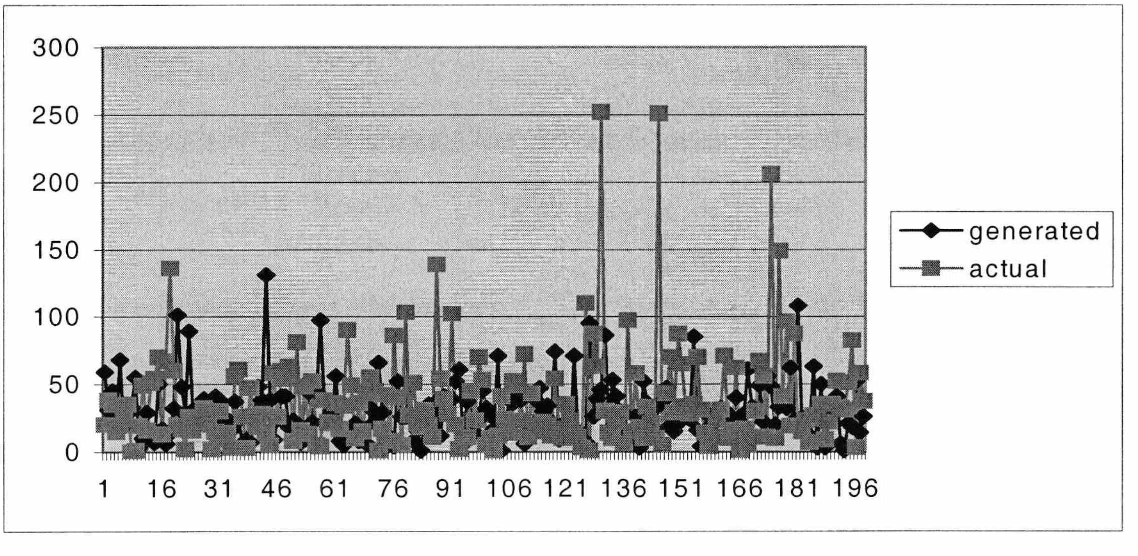
Validation and Verification of rehabilitation hospital wards (Montgomery & Ramsey)

These two wards data fitted the Poisson distribution best. The wards patients are expected to be around 198 over 5 months. The distribution generated a low 95% range of 191.22, an average of 207 and a high 95% range of 222.78. The generated Distribution is satisfactory for the purpose at hand.



Graph comparing the actual ward's LOS days with the ones generated by the Poisson distribution.

The LOS distribution chosen for this ward was the Negative Binomial (2, 0.0585). The real LOS data (collected through assessment forms) when analysed with both Stat::Fit and SPSS gave a mean of 32, a median of 23 and a mode of 20. The simulation results provided an average time with a low 95% range of 28.6 an average result of 31.9 and a high 95% range of 35.2. The real data's mean is within the range. The low 95% range of maximum time in the ward model was 96.52 the average was 111 and the high 95% range was 125.48. The real data used to model the distribution had a maximum value for LOS of 206 days, which is outside the range. The graph illustrates the few cases in which the actual distribution exceeds the generated.



Graph comparing the actual ward's LOS days with the ones generated by the Negative Binomial distribution.

Appendix L A supporting letter from am IC system manager

SENT BY EMAIL

Memorandum

To:	Kathy Kotiadis		
c.c.:			
From:	Janice Duff	**Ref:**	MK/KK /JD
Job Title:	District Manager (Hospitals), Mid Kent		
Dept:	Adult services	**Date:**	4 December 2003

Subject: **Supporting statement – ICON project**

I am able to confirm that I was part of the team which worked with Iain Carpenter and Kathy Kotiadis on the ICON project.

At the time of the initial project a lot was happening with intermediate care within East Kent , the pace was such that the project findings could not be utilised as one would have hoped. However, as the services developed , the opportunity arose to revisit the project and review it along side service evaluation. Working with Kathy enabled us (as in the whole health and social care economy, represented through the joint planning board for older people) to review the current service framework through the simulation model , proceeding to test out our future assumptions through the model as well. The opportunity to do this has added a validation aspect to the review document and one which Kathy was able to support us with at a stakeholder conference. The model has been of benefit to the service and offers continued potential in defining services for older people within East Kent.

Janice Duff
District Manager (Hospitals)
MID KENT

References:

Adams Andrew L, Chick Steven E, Koopman James S, Yu Peter J, (1999). Germs: An Epidemiologic Simulation Tool for Studying Geographic and Social Effects on Infection Transmission. Proceedings of the 1999 Winter Simulation Conference.

Alvarez Adriana M., Centeno Martha A. (1999). Enhancing Simulation Models for Emergency Rooms Using Vba. Proceedings of the 1999 Winter Simulation Conference.

Armstrong D., Baker A. (1995). *An Evaluation of the Lambeth Community Care Centre.* Lambeth Southwark and Lewisham Health Commission.

Bagust Adrian, Place Michael, Posnett John W.,, (1999). Dynamics of Bed Use in Accommodating Emergency Admissions: Stochastic Simulation Model. *British Medical Journal* 318: 155-8.

Bailey, N.T, (1952). A Study of Queues and Appointment Systems in Hospital Outpatient Departments, with Special Reference to Waiting Times. *Journal of the royal statistical society* A14: 185-199.

Baldwin Lynne P, Eldabi Tillal A, Paul Ray J. (1999). Simulation Modelling as an Aid to Decision-Making in Healthcare Management: The Adjuvant Breast Cancer Trial (Abc). Proceedings of the 1999 Winter Simulation Conference.

Bellinger, Gene; Modelling and Simulation; www.outsights.com/systems/modsim/modsim.htm, 2000

Brocklesby John (1997). Becoming Multimethodology Literate: an Assessment of the Cognitive Difficulties of Working Across Paradigms. In: *The Theory and Practice of Combining Management Science Methodologies – Multimethodology*, Mingers J. and Gill A. (eds). Chichester, UK: John Wiley and Sons Ltd

Brooks Roger, Robinson Stewart, Lewis Colin, (2001). *Simulation and Inventory Control*, Palgrave Macmillan

Brunk H. D. (1960). *An Introduction to Mathematical Statistics*, Ginn&Co.

Butler T., Karwan K., Sweigart J.,, (1992a). Multi-Level Strategic Evaluation of Hospital Plans Decisions. *Journal of the Operational Research Society* 43: 665-675.

Butler T., Reeves G., Karwan K., Sweigart J.,, (1992b). Assessing the Impact of Patient Care Policies Using Simulation Analysis. *Journal of the Society of Health Systems* 3: 38-53.

Cacciabue, Pietro Carlo (1998). *Modelling and Simulation of Human Behaviour in System Control*, Springer.(first),

Campbell Helen, Karnon Jonathan, Dowie Robin,, (2001). Cost Analysis of a Hospital at Home Initiatiave Using Discrete Event Simulation. *Journal of Health Services*

Research and Policy 6(1): 14-22.

Carpenter G.I., Challis D. (1999). United Kingdom. In: Care of Older People - a Comparison of Systems in North America, Europe and Japan. G.I. Carpenter, D. C., J. Hirdes, G. Ljunggren, R. Bernabei. London, Ferrand Press.

Carpenter Iain, (1997a). Addressing the Problems of Care Services for the Elderly with a Database of Primary Clinical Data. *The British Journal of Healthcare Computing & Information Management* 14(10): 16-18.

Carpenter Iain, Calnan Michael, (1997b). Grey Matters. *Health Service Journal.*

Carr W., Kemmis S. (1986). *Becoming Critical: Education, Knowledge and Action Research*, London: The Falmer Press

Checkland, P.B (1993). *Systems Thinking Systems Practice*, Chichester: John Wiley

Checkland P.B., Scholes J. (1990). *Soft Systems Methodology in Action*, Chichester: John Wiley and Sons

Checkland, Peter (1998). *Systems Thinking Systems Practice*, Chichester: John Wiley & Sons

Checkland, Peter (1999). Soft Systems Methodology: A 30 - Year Retrospective. In: Systems Thinking, Systems Practice. Chichester, John Wiley & Sons.

Christodoulou Georgina, Taylor Gordon J., (2001). Using Continuous Time Hidden Markov Process, with Covariates, to Model Bed Occupancy of People Aged over 65 Years. *Health Care Management Science* 4: 21-24.

Cohen M.A., Hershey J.C. , Weiss E.N., (1980). Analysis of Capacity Decisions for Progressive Patient Care Hospital Facilities. *Health Services Res* 15: 145-160.

Connell NAD, (2001). Evaluating Soft Or: Some Reflexions on an Apparent 'Unsuccesful' Implementation Using a Soft Systems Methodology (Ssm) Based Approach. *Journal of the Operational Research Society* 52: 150-160.

Cromwell David A., Priddis Donna, Hindle Don,, (1998). Using Simulation to Educate Hospital Staff About Casemix. *Health Care Management Science* 1: 87-93.

Davies Huw T.O, Davies Ruth, (1995). Simulating Health Systems: Modelling Problems and Software Solutions. *European Journal of Operational Research* 87: 35-44.

Davies R., Davies H.T.O., (1994). Modelling Patient Flows and Resource Provision in Health Systems, *Omega*, 22(2): p.123-131.

Davies R., Brailsford S., Roderick P., Canning C., Crabbe D.,, (2000). Using Simulation Modelling for Evaluating Screening Services for Diabetic Retinopathy. *Journal of the Operational Research Society* 51: 476-484.

Davies Ruth, Roderick Paul, (1998). Planning Resources for Renal Services Throughout Uk Using Simulation. *European Journal of Operational Research* 105: 285-295.

De Vries Theo, Beekman Reno E., (1998). Applying Simple Dynamic Modelling for Decision Support in Planning Regional Health Care. *European Journal of Operational Research* 105: 277-284.

Department of Health; Single Assessment Process: Assessment Tools and Scales; http://www.doh.gov.uk/scg/sap/toolsandscales/index.htm; March 28, 2002a

Department of Health (1997). *Better Services for Vulnerable People.* Inspector, C. CI (97)24. London.

Department of Health (1998a). *Modernising Health and Social Services: National Priorities Guidance.* Local Authority Circular. LAC (98)22. London.

Department of Health (1998b). *Modernising Social Services Promoting Independence, Improving Protection, Raising Standards.* London. The Stationery Office.

Department of Health (2000). *Shaping the Future NHS: Long Term Planning for Hospitals and Related Services: Consultation Document on the Findings of the National Beds Inquiry.* London. Department of Health.

Department of Health (2001a). *Intermediate Care.* London. Department of Health,.

Department of Health; The Single Assessment Process: Consultation Papers and Process; http://www.doh.gov.uk/scg/sap/index.htm, 2001

Department of Health (2001c). *Intermediate Care.* HSC 2001/01:LAC (2001). London.

Department of Health; Single Assessment Process: Assessment Tools and Scales; http://www.doh.gov.uk/scg/sap/toolsandscales/index.htm, 2002b

Department of Health; Single Assessment Process: Key Implications, Guidance for Local Implementation and Annexes to the Guidance; http://www.doh.gov.uk/scg/sap/index.htm, 2002

Department of Health (2002c). *NSF for Older People Supporting Implementation, Intermediate Care: Moving Forward.*

Department of Health (2003). *Changes to Local Authorities Charging Regime for Community Equipment and Intermediate Care Services.* Local Authority Circular. LAC (2003)14, London, Department of Health,.

DeTombe Dorien J., (2001). Introduction to the Field of Methodology for Handling Complex Societal Problems. *European Journal of Operational Research* 128: 231-232.

Dimopoulou Stathi (1982). *Monotoniko Ermineftiko Lexiko Tis Dimotikis Glossas*, Athens, Greece: Angyra

Dumas, M.B., (1984). Simulation Modelling for Hospital Bed Planning. *Simulation* 43: 69-78.

Dumas, M.B., (1985). Hospital Bed Utilisation: An Implemented Simulation Approach to Adjusting and Maintaining Appropriate Levels. *Health Services Res* 20: 43-61.

Edwards Margaret (2001). *Primary Care Organisations and Older People.* London.

Kings Fund.

Eldabi Tillal, Paul Ray, Taylor Simon, (1999). Computer Simulation in Health Care Decision Making. *Computers & Industrial Engineering* 37: 235-238.

England W., Roberts S. (1978). Application of Computer Simulation in Health Care. Proceedings of the 1978 Winter Simulation Conference.

Fishman G.S. (1973). *Consepts and Methods of Discrete Event Digital Simulation*, New York: Wiley

Flood Robert L., Jackson Michael C. (1991). *Creative Problem Solving - Total Systems Intervention*, Chichester: John Wiley & Sons

Forte Paul, Bowen Tom (1997). Improving the Balance of Elderly Care Services. In: Enhancing Health Service Management. Cropper S, F. P. Milton Keynes, Open University Press.

Gallivan Steve, Utley Martin, Treasure Tom, Valencia Oswaldo, (2002). Booked Inpatient Admissions and Hospital Capacity: Mathematical Modelling Study. *British Medical Journal* 324: 280-2.

Garcia-Navarro J.A., Thomson W.A., (2001). Analysis of Bed Usage and Occupancy Following the Introduction of Geriatric Rehabilitative Care in a Hospital in Huesca, Spain. *Health Care Management Science* 4: 63-66.

Geer Mountain Software Corporation (2001). *Stat::Fit*. South Kent.

Gleser Leon Jay, (1985). Exact Power of Goodness-of-Fit of Kolmogorov Type for Discontinuous Distributions. *J.Am.Stat.Assoc.* 80: 954.

Guilbert Nigel, Troitzsch Klaus G. (1999). *Simulation for the Social Scientist*, Philadelphia: Buckingham: Open University Press.(first),

Hanford L., Easterbrook L., Stevenson J., (1999). *Rehabilitation for Older People: The Emerging Policy Agenda*. London. Kings Fund.

Harper P. R., Shahani A.K., (2002). Modelling for the Planning and Management of Bed Capacities in Hospitals. *Journal of the Operational Research Society* 53: 11-18.

Hart E., Bond M. (1995). *Action Research for Health and Social Care: A Guide to Practice*, Buckingham: Open University Press

Henderson Shane G., Mason Andrew J. (1999). Estimating Ambulance Requirements in Auckland, New Zealand. Proceedings of the 1999 Winter Simulation Conference.

Huxham Chris, (2003). Action Research as a Methodology for Theory Development. *Policy & Politics* 31(2): 239-48.

InterRAI; www.Interrai.Org, 2003

Isken Mark W, Ward Timothy J, McKee Timothy C, (1999). Simulating Outpatient Obstetrical Clinics. Proceedings of the 1999 Winter Simulation Conference.

Jackson Mike C. (1997). Pluralism in Systems Thinking and Practice. In: *The Theory and Practice of Combining Management Science Methodologies – Multimethodology*, Mingers J. and Gill A. (eds). Chichester, UK: John Wiley and Sons Ltd

Jackson M.C. (1999). Towards Coherent pluralism in management science, *Journal of the Operational Research Society*, 50: p.12-13.

Jackson M.C., Keys P., (1984). Towards a system of systems methodologies, Journal of the Operational Research Society, 35: p. 473-486.

Jenkins Roger, Deshpande Yogesh, Graydon Davison (1998). Verification and Validation and Complex Environments: A Study in Service Sector. Proceedings of the 1998 Winter Simulation Conference.

Johnson Norman L., Kotz Samuel, Kemp Adrienne W., (1992). Univariate Discrete Distributions. In., John Wiley & Sons. p.223.

Jun J.B, Jacobson S.H, and Swisher J.R, (1999). Application of Discrete-Event Simulation in Health Care Clinics: A Survey. *Journal of the Operational Reseearch Society* 50: 109-123.

Kho James W., Johnson Miles G. (1976). Computer Simulation of a Hospital Health-Care Delivery System. Proceeding of the 1976 Winter Simulation Conference.

Kim Seung-Chun, Horowitz Ira, Young Karl K., Buckley Thomas A., (1999). Analysis of Capacity Mangement of the Intensive Care Unit in a Hospital. *European Journal of Operational Research* 115: 36-46.

Kings Fund (2000). *Briefing: Rehabilitation and Intermediate Care.*

Klafehn Keith A (1987). Impact Points in Patient Flows through a Radiology Department Provided through Simulation. Proceeding of the 1987 Winter Simulation Conference.

Kleijnen J.P.C, (1995). Verification and Validation of Simulation Models. *European Journal of Operational Research* 82(1): 145-162.

Kleijnen Jack P.C., (1995). Statistical Validation of Simulation Models. *European Journal of Operational Research* 87(1): 21-34.

Klein Robert W., Dittus Robert S., Roberts Stephen D., Wilson James R.,, (1993). Simulation Modelling and Health-Care Decision Making. *Medical Decision Making* 13(4): 347-354.

Lagergren Marten, (1998). What Is the Role and Contribution of Models to Management and Research in the Health Services? A View from Europe. *European Journal of Operational Research* 105: 257-266.

Lange, Victor E (1999). The Benefits of Simulation Modelling in Medical Planning and Medical Design. Proceedings of the 1999 Winter Simulation Conference.

Law Averill M., Kelton David W. (1991). *Simulation Modeling & Analysis*, McGraw-Hill, Second Edition.

Lehaney B, Clarke S.A., Paul R.J.,, (1999). A Case of an Intervention in an Outpatients Department. *Journal of the Operational Research Society* 50: 877-891.

Lehaney Brian, Hlupic Vlatka, (1995). Simulation Modelling for Resource Allocation and Planning in the Health Sector. *J Roy Soc Health* 115(6): 382-385.

Lehaney Brian, Paul Ray J., (1996). The Use of Soft Systems Methodology in the Development of a Simulation of out-Patients Services at Watford General Hospital. *Journal of the Operational Research Society* 47: 864-870.

Lewin K., (1946). Action Research and Minority Problems. *Journal of Social Issues* 2: 34-46.

Lowery J.C. (1992a). Simulation of a Hospital Surgical Suite and Critical Care Area. Proceedings of the 1992 Winter Simulation Conference.

Lowery J.C. (1993). Multi-Hospital Validation of Critical Care Simulation Model. Proceedings of the 1993 Winter Simulation Conference.

Lowery J.C., Martin J.B., (1992b). Design and Validation of a Critical Care Simulation Model. *Journal of the Society of Health Systems* 3: 15-36.

Lowery Julie C. (1998). Getting Started in Simulation in Healthcare. Proceedings of the 1998 Winter Simulation Conference.

Lowery Julie C., Davis Jennifer A. (1999). Determination of Operating Room Requirements Using Simulation. Proceedings of the 1999 Winter Simulation Conference.

Mahacheck Arnold R., (1992). An Introduction to Patient Flow Simulation for Health Care Managers. *Journal of the Society of Health Systems* 3(3): 73-81.

Marshall A.H., McClean S.I., Shapcott C.M., I.R.Hastie, Millard P.H., (2001). Developing a Bayesian Belief Network for the Management of Geriatric Hospital Care. *Health Care Management Science* 4: 25-30.

Mason Jennifer (1996). *Qualitative Researching*, London: Sage Publications

McCornack, B., (1992). The Developing Role of Community Hospitals: An Essential Part of a Quality Service. *Quality in Health Care* 2: 253-258.

McCornack, B. (1996). *Community Hospitals Development Project - Final Report.* Oxfordshire Community Health NHS Trust.

Midgley Gerald (1990). Creative Methodology Design, *The Systemist*, 12: p.108-113.

Midgley Gerald (1997). Mixing Methods: Developing Systemic Intervention. In: *The Theory and Practice of Combining Management Science Methodologies – Multimethodology*, Mingers J. and Gill A. (eds). Chichester, UK: John Wiley and Sons Ltd.

Midgley Gerald (2000). Systemic Intervention: Philosophy, Methodology, and Practice – Contemporary Systems Thinking, New York: Kluwer Academic / Plenum Publishers.

Millard Peter H., Christodoulou Georgina, Jagger Carol, Harrison Gary W., McClean Sally, (2001). Modelling Hospital and Social Care Bed Occupancy and Use by the Elderly People in an English Health District. *Health Care Management Science* 4: 57-62.

Mingers John, (2003). A Classification of the Philoshophical Assumptions of Management Science Methods. *Journal of the Operational Research Society* 54: 559-570.

Mingers John (2001). Multimethodology - Mixing and Matching Methods. In: *Rational Analysis for a Problematic World Revisited.* Rosenhead Jonathan, M. J. Chichester, John Wiley and Sons.

Mingers John (1997a). Multi-paradigm Multimethodology. In: *The Theory and Practice of Combining Management Science Methodologies – Multimethodology*, Mingers J. and Gill A. (eds). Chichester, UK: John Wiley and Sons Ltd

Mingers John (1997b). Towards Critical Pluralism. In: *The Theory and Practice of Combining Management Science Methodologies – Multimethodology*, Mingers J. and Gill A. (eds). Chichester, UK: John Wiley and Sons Ltd

Mingers, John, (2000). Variety Is the Spice of Life: Combining Soft and Hard or/Ms Methods. *International Transactions in Operational Research* 7: 673-691.

Mingers John, Brocklesby John, (1997). Multimethodology: Towards a Framework for Mixing Methodologies. *Omega* 25(5): 489-509.

Moreno L, Aguilar R.M, Pineiro J.D, Estevez J.I, Sigut J.F, Gonzalez C, (2001). Using Kads Methodology in a Simulation Assistedknowledge Based System: Application to Hospital Management. *Expert Systems With Applications* 20: 235-249.

Oakshot Les (1997). *Business Modelling and Simulation*, London: Pitman Publishing

Ormerod Richard (1997). Mixing Methods in Practice: a Transformation-Competence Perspective. In: *The Theory and Practice of Combining Management Science Methodologies – Multimethodology*, Mingers J. and Gill A. (eds). Chichester, UK: John Wiley and Sons Ltd

Pala O, Vennix J.A.M, Mullekom T. van,, (2003). Validity in Ssm: Negelcted Areas. *Journal of the Operational Research Society* 54: 706-712.

Pearson A., Punton S., Durant I., (1992). *Nursing Beds: An Evaluation of the Effects of Theraputic Nursing*. Royal College of Nursing Research Series. Harrow, Scutari Press.

Pidd, Michael (1996). *Tools for Thinking: Modelling in Management Science*, Chichester: John Wiley & Sons

Pidd, Michael (1998). *Computer Simulation in Management Science*, Chichester: Wiley. (Fourth edition).

Pidd Michael (2004). Bringing it all together. In: *Systems Modelling – Theory and Practice*, Pidd Michael (eds). Chichester, UK: John Wiley and Sons Ltd.

Pidd Michael (2004). Complementarity in systems modelling. In: *Systems Modelling –*

Theory and Practice, Pidd Michael (eds). Chichester, UK: John Wiley and Sons Ltd

Pollack-Johnson Bruce (1987). Simulation of a Hospital Patient Trasportation System. proceedings of the 1987 Winter Simulation Conference.

Ridge J.C., Jones S.K., Nielsen M.S., Shahani A.K.,, (1998). Capacity Planning for Intensive Care Units. *European Journal of Operational Research* 105: 346-355.

Robinson S. (1999). Three Sources of Simulation Inaccuracy and How to Overcome Them. Proceedings of the1999 Winter Simulation Conference.

Robinson S., (2001). Soft with a Hard Centre: A Discrete Event Simulation in Facilitation. *Journal of the Operational Research Society* 52: 905-915.

Robinson S., (2002). General Concepts of Quality for Discrete Event Simulation. *European Journal of Operational Research* 138: 103-117.

Robinson Stewart, Edwards John S., Yongfa Wu, (1998). An Expert Systems Approach to Simulating the Human Decision Maker. Proceedings of the 1998 Winter Simulation Conference.

Rose Jeremy, Haynes Mike, (1999). A Soft Systems Approach to the Evaluation of Complex Interventions in the Public Sector. *Journal of Applied Management Studies* 8(2): 199-216.

Rosenhead, Jonathan (1999). *Rational Analysis for a Problematic World*, Chichester: John Wiley & Sons

Rosseti Manuel D., Trzcinski Gregory F., Syverud Scott A., (1999). Emergency Department Simulation and Determination of Optimal Attending Physician Staffing Schedules. Proceedings of the 1999 Winter Simulation Conference.

Royston Geoff, (1998). Shifting the Balance of Health Care into the 21st Century. *European Journal of Operational Research* 105: 267-276.

Sargent Robert G. (1987). An Overview of Verification and Validation of Simulation Models. Proceedings of the 1987 winter simulaton confernce.

Sargent Robert G. (1998). Verification and Validation of Simulation Models. Proceedings of the 1998 Winter Simulation Conference.

Seymour D.G., (2001). Health Care Modelling and Clinical Practise. Theoretical Exercise or Practical Tool? *Health Care Management Science* 4: 7-12.

Shuman L.J., Speas R.D., Young J.P, (1975). *Operations Research in Health Care - a Critical Analysis*, The John Hopkins University Press

Simul8 Corporation (1993-2001). *Simul8 V7.*

The Single Assessment Process: Consultation Papers and Process; http://www.doh.gov.uk/scg/sap/index.htm, 2001

Smith-Daniels Vicki L., Schweikhart Sharon B., Smith-Daniels Dwight E., (1988). Capacity Management in Health Care Services: Review and Future Research

Directions. *Decision Sciences* 19: 889-919.

Stafford Edward F. (1976). *A General Simulation Model for Multifacility Outpatient Clinics*. Department of Management Science and Organisational Behaviour. The Pennsylvania State University.

Steiner, A (1997). *Intermediate Care. A Conceptual Framework and Review of the Literature*. London. King's Fund.

Steiner, A and Vaughan, B (1997). *Intermediate Care: A Discussion Paper Arising from the King's Fund Seminar Held on 30th October 1996*. London. Kings Fund.

Stevenson Jan (2001). *Mapping Local Rehabilitation and Intermediate Care Services: A Whole Systems Approach to Understanding Service Capacity and Planning Change*. Kings Fund.

Stringer E. (1996). *Action Research: A Handbook for Practitioners*, Thousand Oaks: Sage Publications

Stuart Alan, Ord J. Keith (1991). *Kendall's Advanced Theory of Statistics*, Oxford University Press

Sturdy Deborah, Carpenter Iain, (1997). Benefits of Standardised Assessment. *Nursing Times* 93(13): 53-55.

Swisher James R., Jacobson Sheldon H., Jun Brian J., Balci Osman,, (2001). Modeling and Analyzing a Physician Clinic Environment Using Discrete-Event (Visual) Simulation. *Computers & Operational Research* 28: 105-125.

Taylor S.J.E., Eldabi T., Macredie R.D., Paul R.J., Brown J., Karnon J., (1998). Economic Evaluation of Adjucant Breast Cancer Treatment Using Simulation Modelling. Proceedings of the 1998 Medical Sciences Simulation Conference, San Diego, California, The Society for Computer Simulation International.

Taylor Simon, Kuljis Jasna; Simulation in Health Care Management: Modelling an Outpatient Clinic; 2000

Tunnicliffe-Wilson J.C., (1980). A Review of Population Health Care Problems Tackled by Computer Simulation. *Publ. Hlth* 94: 174-182.

Valinsky, D. (1975). Simulation. In: Operational Research in Healthcare: A Critical Analysis. L.T Shuman, R. D. S., J.P Young. The John Hopkins University Press.

Varela F., Thompson E., and Rosch E., (1991). The Embodied Mind – Cognitive Science and Human Experience, Cambridge, MA: MIT Press

Vasilakis C., El-Darzi E., (2001). A Simulation Study of the Winter Bed Crisis. *Health Care Management Science* 4: 31-36.

Weng M. L., Houshmand A.A. (1999). Healthcare Simulation:A Case Study at a Local Clinic. Proceedings of the 1999 Winter simulation conference.

White L., Taket A., (1997). Critiquing Multimethodology as Metamethodology: Working Towards Pragmatic Pluralism. In: *The Theory and Practice of Combining*

Management Science Methodologies – Multimethodology, Mingers J. and Gill A. (eds). Chichester, UK: John Wiley and Sons Ltd

Wilson Keith, Stevenson Jan (2001). *Intermediate Care Co-Ordination - the Function.* Kings Fund.

World Health Organisation; Http://www.who.int/en/, 1999