UNIVERSITY OF SOUTHAMPTON

FACULTY OF BUSINESS AND LAW

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The Development of a Combined Simulation Approach in a Sexual Health Context: Combining Discrete Event and System Dynamics Simulation to Form a Composite Model

by

Joe Viana

Thesis for the degree of Doctor of Philosophy

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ABSTRACT

FACULTY OF BUSINESS AND LAW
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THE DEVELOPMENT OF A COMBINED SIMULATION APPROACH IN A SEXUAL HEALTH CONTEXT: COMBINING DISCRETE EVENT AND SYSTEM DYNAMICS SIMULATION TO FORM A COMPOSITE MODEL

by Joe Viana

Sexually Transmitted Infections (STIs) are a priority of many health services. *Chlamydia Trachomatis* (Chlamydia) is one of the most common STIs in the world. Chlamydia can have serious consequences for men and women in the form of infertility and particularly in women has been associated with Pelvic Inflammatory Disease (PID). A System Dynamics (SD) model of Chlamydia prevalence has been constructed to evaluate different screening strategies. The SD model incorporates risk groups, ageing, gender, heterosexual and homosexual relationships and migration in and out of the area of interest. A Discrete Event Simulation (DES) model has been constructed of the Genito-urinary Medicine (GUM) department at St Mary's Hospital, Portsmouth, the department that treats patients presenting with STIs to enable healthcare professionals evaluate different GUM configurations. A composite model has been developed in which the SD model provides the demand (number of patients) to be treated in the GUM DES model each month. The DES model transforms the demand generated by the SD model into patient arrival patterns based on historically recorded data. The DES model processes the demand based on its current configuration and provides the number of treated patients back to the SD model. The DES model and the SD model can be run independently as stand-alone models or in the composite state through a simple Excel user interface. Results from each model are presented and model development discussed. The simulation models were developed in close collaboration with healthcare professionals. The models were informed by other methodologies including: regression analysis of socioeconomic data, geographical referencing of infection data and a behavioural survey to identify behaviours associated with STI infection.

Contents

List of figures

List of tables

DECLARATION OF AUTHORSHIP

I, Joe Viana

declare that the thesis entitled

The Development of a Combined Simulation Approach in a Sexual Health Context: Combining Discrete Event and System Dynamics Simulation to Form a Composite Model

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
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    - Brailsford, S.C., Desai, S.M. and Viana, J. (2010) Towards the Holy Grail: Combining System Dynamics and Discrete-Event Simulation in Healthcare, In *Proceedings of 2010 Winter Simulation Conference*, eds. B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan and E, Yucesan, 2293-2303. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Signed: ………………………………………………………………………..

Date:……………………………………………………………………………….

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It has been emotional.

Definitions and abbreviations

A&E	– Accident and Emergency Department
ABC	– Adjuvant Breast Cancer
ABM	– Agent Based Modelling
ACD	– Activity Cycle Diagram
AIDS	– Acquired Immune Deficiency Syndrome
ANC	– Ante-Natal Clinic
ANOVA	– Analysis of Variance
ART	– Acuity Ratio Triage
CABG	– Coronary Artery Bypass Graft
CASWEB	– Census Area Statistics on the Web
CDC	– Centre for Disease Control
CHAART	– Centre for Health Applications of Aerospace Related Technology
CHAID	– Chi-squared Automated Interaction Detector
CI	– Confidence Interval
CMO	– Chief Medical Officer
CRT	– Classification and Regression Trees
CTPNI	– Chlamydia Testing Programme Northern Ireland
DES	– Discrete Event Simulation
df	– Degrees of Freedom
DH	– Department of Health
DOB	– Date of Birth
DQA	– Discrete Quantity Approach
DSAR	– Differential, Switched Algebraic and state-Reset equations
DT	– Delta Time
ECDC	– European Centre for Disease Control
ED	– Emergency Department
EDINA	– Edinburgh Data and Information Access
EDSIM	– Emergency Department SIMulation
EGU	– Ella Gordon Unit
ENAADS	– European Non-Aggregate AIDS Data Set
ENT	– Ear, Nose and Throat outpatient department
EPSRC	– Engineering and Physical Sciences Research Council
EU	– European Union
FPA	– Family Planning Association
FTE	– Full Time Equivalent
GERMS	– Geographic-Environmental Re-infection Modelling Simulator
GIS	– Geographical Information Systems
GP	– General Practitioner

GPE – General Practitioner, East Hampshire
GPF – General Practitioner, Fareham
GPG – General Practitioner, Gosport
GPP – General Practitioner, Portsmouth
GPS – Global Positioning System
GUM – Genito Urinary Medicine
GUMCAD – Genitourinary Medicine Clinic Activity Dataset (replaced KC60)
GYN_ALL – Gynaecology, Coloscopy, Hosptial and Infertility Clinics
Hants – Hampshire
HeCaSe – Health Care Services multi-agent system
HepB – Hepatitis B
HepC – Hepatitis C
HIG – High Income Group
HIV – Human Immunodeficiency Virus
HPA – Health Protection Agency
HPP – Hierarchical Production Planning
HPV – Human Papilloma Virus
HR – High Risk Group
HSV – Herpes Simplex Virus
ICER – Incremental Cost-Effectiveness Ratio
IDU – Injecting Drug User/Injected Drug User
KC60 – DH uses to record information on services provided by GUM
LA – Local Authority
LCSP – Location Set Covering Problem
LIG – Low Income Group
LoS – Length of Stay
LR – Low Risk Group
LSD – Least Squared Deviation
MCLP – Maximal Covering Location Model
MIMAS – Manchester Information and Associated Services
MSc – Master of Science
MSM – Men who have sex with men
NATSAL – National Survey of Sexual Attitudes and Lifestyles
NCSP – National Chlamydia Screening Programme
NGO – Non Government Organisation
NGU – Non Gonococcal Urethritis
NHS – National Health Service
NICE – National Institute for Clinical Excellence
NS – Patients Not Seen
NSC – National Screening Committee

NSGI	– Non-specific Genital Infection
NSPD	– National Statistics Postcode Directory
NSSEC	– National Statistics Socio-economic Classification
NSU	– Non Specific Urethritis
ONS	– Office of National Statistics
OR	– Operational Research/Operations Research
OT	– Operating Theatres
PCT	– Primary Care Trust
PhD	– Doctor of Philosophy
PICU	– Paediatric Intensive Care Unit
PID	– Pelvic Inflammatory Disease
PO	– Portsmouth Postcode Area
POST	– Patient Oriented Simulation Technique
QALY	– Quality Adjusted Life Years
QSS	– Quasi Steady State approximation
QUEST	– Quick, Unbiased and Efficient Statistical Tree
R&D	– Research and Development
RCT	– Randomised Controlled Trial
REC	– Research Ethics Committee
RGO	– Research Governance Office
RPT	– Retrospective Partner Trial
S	– Patients Seen
SASHU	– Small Area Health Statistics Unit
SD	– System Dynamics Simulation
SHHAPT	– Sexual Health and HIV Activity Property Type (replaced GUMCAD)
SIS	– Susceptible-Infection-Susceptible model
SPSS	– Statistical Package for the Social Sciences
SSM	– Soft Systems Methodology
STD	– Sexually Transmitted Disease(s)
STI	– Sexually Transmitted Infection(s)
SXS	– Sex Sense
SW	– Sex Workers
TOP	– Termination of Pregnancy
UK	– United Kingdom
UKCRN	– UK Clinical Research Network
UNICEF	– United Nations Children’s Fund
US	– United States of America
USA	– United States of America
V&V	– Validation and Verification
VBA	– Visual Basic for Applications

VL – Visual Logic

WHO – World Health Organisation

WSW – Women who have sex with women

1 Introduction

1.1 Chapter Introduction

This thesis aimed to investigate primarily how Operational Research (OR) can help aid in the reduction of the spread of Sexually Transmitted Infections (STIs), with a particular focus on Chlamydia. This research, builds upon previous research conducted at the University of Southampton, applying OR methods to Chlamydia including: the work carried out by Evenden et al (2003), which applied System Dynamics (SD) simulation in the evaluation of screening strategies; and the application of a Discrete Event Simulation (DES) model created by Gove (1997) of Chlamydia.

This chapter provides: an introduction to Genito-urinary Medicine (GUM) (section 1.2) and to the increasing burden of STIs (section 1.3); the research questions the thesis addresses (section 1.4); the ethical implications of this research and approval (section R2); the multiple methodologies approach adopted in approaching this topic from multiple perspective (section 1.6); and, an overview of the structure of thesis (section 1.7).

1.2 Genito-Urinary Medicine

Genito Urinary Medicine (GUM) departments provide sexual health services to the population. They are commonly known as sexual health departments. The capacity of GUM departments in the UK has been and continues to be stretched due to the high demand for services, due to increases in the prevalence of many STIs. This research was undertaken in collaboration with Dr Veerakathy Harindra and staff from the department of GUM at St Mary's Hospital, Portsmouth. Portsmouth was one of the two pilot sites, along with the Wirral, Merseyside, chosen for the National Chlamydia Screening Programme (NSCP) conducted in England in 2003. The city of Portsmouth is an island, see point A in figure 1-1; it is an established commercial and military port with a dense population. St Mary's hospital serves Portsmouth and the surrounding area broadly highlighted by the dotted red circle equating to 500,000 people. Point B in figure 1-1 displays the location of the University of Southampton approximately 20 miles west from Portsmouth.

Figure 1-1: Research location

1.3 The Problem

There are 38 STIs and conditions and variations there of that GUM departments diagnose and provide where available treatment for; and 25 tests that they offer. These have been derived from the Sexual Health and HIV Activity Property Type (SHHAPT) codes which are used to report information to the Health Protection Agency (HPA). These codes compliment the GUMCAD codes, and replace the KC60 codes. During the course of this research data has been utilised from all three coding systems. The change in coding structure was a result of consultation with the British Association for Sexual Health and HIV (BASHH). The incidence and prevalence of many of the STIs has increased leading to, the 198 GUM departments in England being overstretched with the burden of this ever increasing demand. The background to the problem is elaborated in chapter 2.

1.4 Research Objective and Questions

The objective of this research was to improve the sexual health of the UK population. Two main research questions arose from this objective:

R1. How to reduce the prevalence of STIs?

R2. How to organise sexual health services to operate more effectively and efficiently?

1.5 Ethical Approval

Ethical approval for this research was obtained from the School of Management and the Research Governance Office (RGO) at the University of Southampton and also from the National Health Service (NHS) Research Ethics Committee (REC). This was necessary as the research recruited patients from the GUM department and students from the University of Southampton to complete a questionnaire about their sexual behaviour, knowledge and attitudes. Permission was also sought to be able to work with unidentifiable patient records from the GUM department. Obtaining ethical approval from all the relevant parties delayed the project by some 18 months. A condensed version of the research protocol which received approval from the Berkshire NHS research committee, ref. 08/H0505/71, can be found in appendix A.

1.6 Multiple Methodologies

This research utilised multiple methods. The unique combinations of methods provided the healthcare stakeholders with information capable of contributing to more informed decisions with respect to: treatment and screening strategies, the evaluation of department design and providing specific behavioural and attitudinal information about the local population. The methods utilised in this research were: questionnaires; logistic regression and decision tree analysis; geographical information systems (GIS) particularly geographical referencing; and, DES and SD computer modelling. The methods used in this research are discussed and justified in chapter 5.

1.7 Thesis Structure

The thesis has been broken into 13 chapters which are encapsulated in 5 parts. Chapter 1, the introduction and chapter 2, the background constitute part I. Part II is formed of chapters 3, 4 and 5 the: behavioural and geographical referencing (the non-OR review); STI modelling and hybrid simulation (OR review); and, the choice of methods. Part III focuses on the data analysis which is useful in its own right and used to inform the simulation models. Part III consists of four chapters: chapter 6 screening data; chapter 7 geographical referencing; chapter 8 socioeconomic analysis; and, chapter 9 sexual behaviour survey. Part IV the development of new simulation models, consists of three chapters: chapter 10, DES GUM model; chapter 11, SD Chlamydia prevalence model; and, chapter 12, composite model. Part V, consists of chapter 13, limitations, contributions and future work, which draws together the key points of the thesis. A graphical representation of the thesis illustrating the interrelation of the parts and chapters is shown below in figure 1-2.

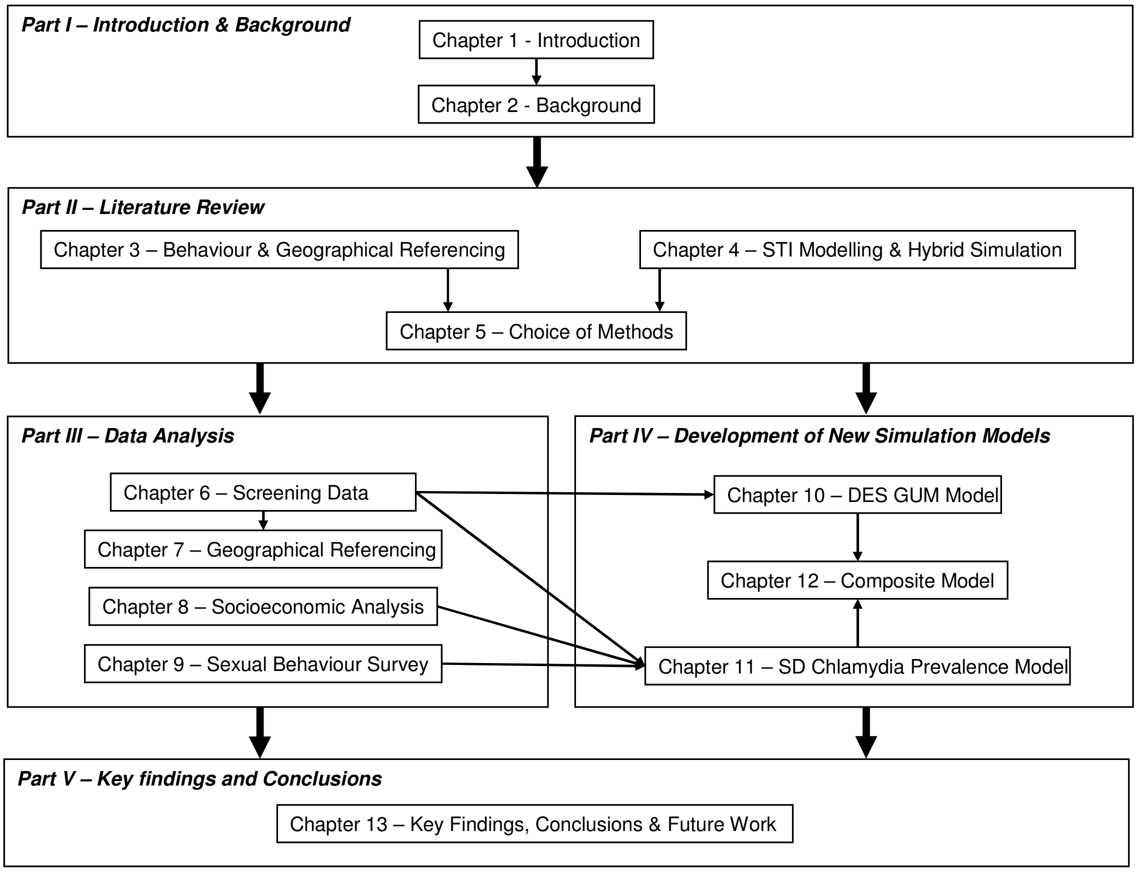

Figure 1-2: Thesis structure

The chapters are introduced in turn. A brief synopsis of each is provided and an indication of the interrelation with other chapter(s).

Chapter 2 provides an extended background to the problem of this thesis: the increasing levels of STIs. The major STIs are briefly discussed, but the chapter focuses on Chlamydia infection including a brief summary of the epidemiology and the prevalence both nationally and internationally. Treatments are briefly discussed as well as the consequences of not treating the infection. Policy and current screening practice including the NCSP are discussed. Chapter 2 loosely informs part II.

Chapter 3 builds on chapter 2, by examining the relevant research in relation to sexual behaviour and attitudes. This literature is large including: psychological, sociological, and biological research, therefore the review is highly selective. The chapter also provides a review of the GIS literature that relates to healthcare contexts. GIS has been used to monitor infection levels, identify sources of disease outbreaks and plan the location of both static and dynamic health services. This chapter informs chapter 5 and part III, particularly chapters 7, 8 and 9.

Chapter 4 builds on chapter 3, by focusing on reviewing the OR modelling techniques employed in healthcare with a particular focus on examples relating to Chlamydia, STIs or sexual health in general. The chapter reviews deterministic and stochastic models, such as: simulation (SD, DES), Markov models, Decision Trees, and other techniques. Hybrid simulation models are also reviewed; where different levels of model are combined in some way. The literature review of hybrid models is expanded to non-health contexts due to the limited number of published studies in this field. This chapter evaluates the appropriate modelling techniques and establishes the techniques that were used in this research. This review is used to inform the chapter 5 and part IV.

Chapter 5 provides a justification of the methods chosen to address the research questions stated in chapter 1. The research tasks which received ethical approval are provided. Clarification of how the research tasks address the research questions is provided.

Chapter 6 explains how the data was collected from the GUM department. The statistical analysis performed on this data is discussed, and how it was used to inform: the simulation models in part IV, the geographical referencing of chapter 7 and the socioeconomic analysis in chapter 8.

Chapter 7 illustrates how the data identified in chapter 6 was geographically referenced. This chapter highlighted the important steps and related issues that arose from mapping Chlamydia incidence and prevalence in the Portsmouth region.

Chapter 8 provides an explanation of the socioeconomic analysis which was undertaken, to ascertain factors associated with population level Chlamydia infection. Socioeconomic data were obtained from multiple sources including: the Office for National Statistics (ONS); Neighbourhood Statistics, Casweb and the 2001 Census. The socioeconomic data collected were converted to postcode sectors before being analysed. The analysis informs the identification of risk groups which are built into the SD model, in chapter 11.

Chapter 9 describes the design and content of the questionnaire developed to assess sexual behaviour, knowledge and attitudes. The results obtained are discussed, and like the socioeconomic data are used to define the risk groups incorporated into the SD model which is discussed in chapter 11.

Chapter 10 focuses on the development of a Discrete Event Simulation (DES) model of the GUM department. The chapter builds on the literature review conducted in chapter 4 and is informed also by the screening data analysis conducted in chapter 6. The GUM model is designed in the DES package Simul8 and its development, the experimentation and results are provided in this chapter. The developed DES model is one half of the developed composite model discussed in chapter 12.

Chapter 11 describes the System Dynamics (SD) model of the Chlamydia infection process. The chapter includes: the data requirements, the equations developed, the model design and processes involved in developing the model. The SD model is heavily informed by part III in particular chapters 6, 8 and 9. The developed SD model is one half of the developed composite model discussed in chapter 12.

Chapter 12 provides details on the development of a new composite model. This is the key contribution of this research. The chapter is informed directly or indirectly by the other chapters, but particularly by chapters 10 and 11. How and why the DES and SD models are combined is discussed.

Chapter 13 concludes the thesis by highlighting the limitations and contributions from parts III and IV, in relation to the stated research questions and the research tasks provided in chapter 5. Following the discussion further areas of research are identified.

1.8 Chapter Summary

This chapter has:

- Provided a rationale for the research.
- Identified the research questions.
- Touched upon the ethical approval.
- Noted that this research approaches the topic from multiple perspectives and is multi-methodological.
- Discussed the structure of this thesis.

2 Background

2.1 Chapter Introduction

This chapter provides a brief background to Sexually Transmitted Infections (STIs) also known as Sexually Transmitted Diseases (STD). There are many STIs, which have become a major health concern. The prevalence of each STI varies considerably as will be highlighted in this chapter. Co-infection is important to consider as many STIs increase the susceptibility of being infected with another. STIs have negative health consequences (sequelae), although some are more severe than others. This chapter will provide a brief background of the key STIs, highlighting those that have been included in this research. It is possible to classify STIs by cause: bacterial, viral or parasitic. The STIs are introduced and discussed under these headings.

2.2 Bacterial STIs

2.2.1 Chlamydia

Chlamydia is the most common bacterial STIs in the world caused by the bacterium *Chlamydia trachomatis*, and is the most common bacterial STI. It can be transmitted via sexual contact, and can be passed from a mother to baby during vaginal childbirth (NCSP, 2011).

Between 50-75% of all women who have a Chlamydia infection of the neck of the womb, have no symptoms (asymptomatic) and do not know that they are infected. Occasionally, the condition spreads to the upper genital tract in women causing Pelvic Inflammatory Disease (PID). Women infected with Chlamydia are up to five times more likely to become infected with HIV if exposed (FPA[a], 2006).

In men infection of the urethra is usually symptomatic (50%), causing a clear discharge from the penis with or without pain on urinating. Occasionally, the condition spreads to the upper genital causing epididymitis and epididymo-orchitis in men. Chlamydia conjunctivitis is a complication of Chlamydia Serotype transmitted sexually. Adults can get infected by autoinoculation or during sexual contact. Babies can get chlamydial conjunctivitis during birth with their eyes getting infected during vaginal delivery.

Chlamydia can be treated effectively with antibiotics. The issue is identifying those people who have the infection given the asymptomatic nature in the majority of cases. Cases are identified through screening: relating to health check, pregnancy test, gynaecological examination, family planning or opportunistic screening; those who present with symptoms and partners identified from those who have tested positive.

According to Health Protection Agency (HPA), (HPA, 2009) statistics a substantial proportions of chlamydia diagnoses are made outside the GUM department setting. This could be a result of the availability of Chlamydia testing in primary and community care. In 2008 in England and Wales, 82% of men were diagnosed in a GUM department as compared to 62% of women.

Figure 2-1 clearly illustrates that the rates of diagnoses of uncomplicated genital chlamydial infection have been increasing in the UK since 1999 for both genders. The rise in new diagnoses can be attributed to increases in testing, improved sensitivity of diagnostic tests, and changes in sexual behaviour. What is immediately clear from figure 2-1 is that the rate of chlamydial diagnoses has increased disproportionately among the younger age groups. Among men, the rate of diagnoses is highest in 20 to 24 year olds (1,163/100,000 in 2008), with lower rates seen among 16 to 19 and 25 to 34 year olds (602/100,000 and 492/100,000 respectively in 2008). Higher rates were observed among younger women (1,406/100,000 and 1,168/100,000) in 16-19 and 20-24 year olds, respectively in 2008 (HPA, 2009).

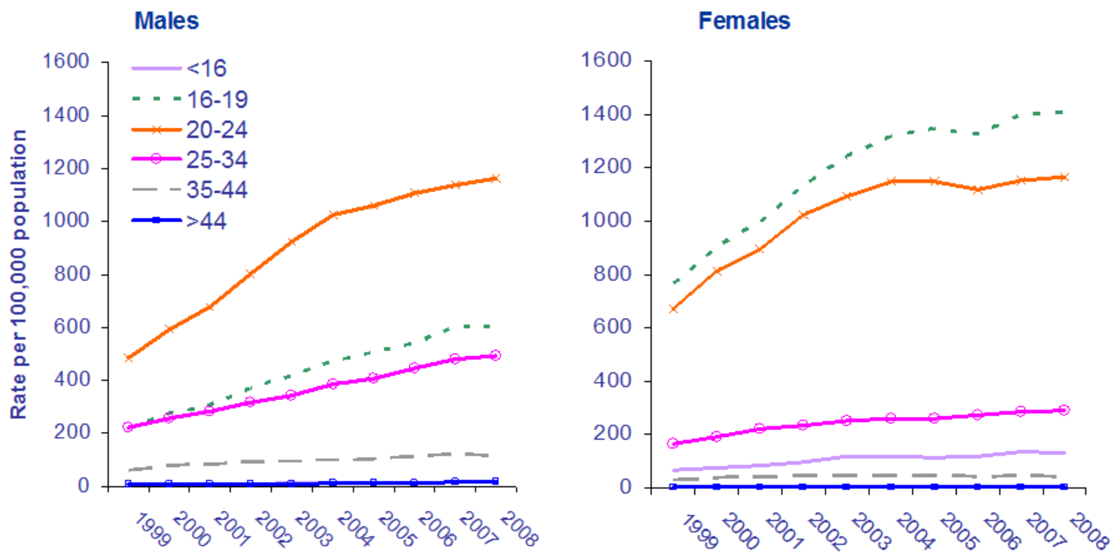

Figure 2-1: Rates of diagnoses of uncomplicated genital chlamydial infection by sex and age group, GUM departments, United Kingdom: 1999-2008 (HPA, 2009)

2.2.2 Gonorrhoea

Gonorrhoea is caused by the bacteria *Neisseria gonorrhoeae*. Like Chlamydia, Gonorrhoea can be transmitted via sexual contact, and can be passed from a mother to baby during vaginal childbirth. Gonorrhoea is asymptomatic in 30-60% of cases. In women Gonorrhoea can lead to PID, septic arthritis, septic pregnancy and infertility. Sequelae for men include: inflammation of the epididymis, testes, prostate gland and urethra. It can also cause conjunctivitis, which if not treated can lead to blindness (FPA[c], 2006).

Most diagnoses of gonorrhoea are still made in GUM departments. In 2008, men were more likely to be diagnosed in a GUM department than women: 92% of men were diagnosed in this setting as compared to 82% of women (HPA, 2009).

Figure 2-2 illustrates the Gonorrhoea rate for the period 1999-2008. The higher rates seen in men partly reflect infections acquired through sex between men and an increased likelihood of symptomatic infection in men. Since 1999, the number of men diagnosed with Gonorrhoea acquired homosexually has risen by 69%. During 2008, homosexually acquired Gonorrhoea accounted for nearly a third of diagnoses in men. Like other acute STIs, young people share a disproportionate burden of gonorrhoea. During 2008, in the UK, rates were highest in men aged 20 to 24 years (152/100,000 population) and women aged 16 to 19 years (135/100,000 population). Although the rates of Gonorrhoea have been declining in the last few years it is important to know that many strains of Gonorrhoea are becoming antibiotic resistant.

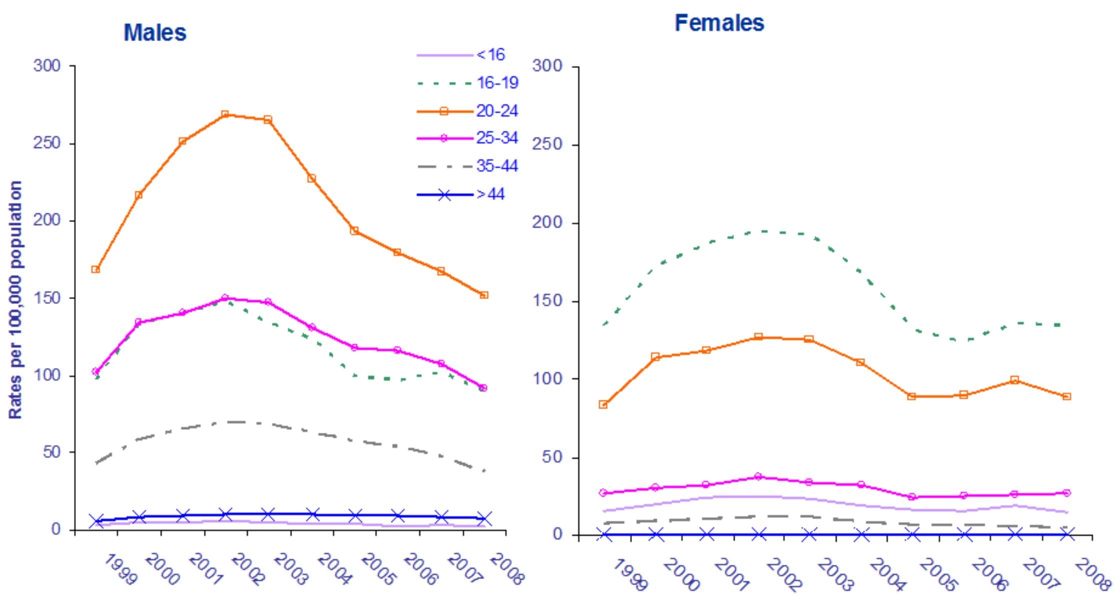

Figure 2-2: Rates of diagnosis of uncomplicated gonorrhoea by sex and age group, GUM departments: 1999-2009 (HPA, 2009)

2.2.3 Non-Gonococcal Urethritis

Non-Specific Urethritis (NSU) or non-gonococcal urethritis (NGU) is recorded by the HPA as Non Specific Genital Infection (NSGI). Treatment for mucopurulent cervicitis in females is now recorded as NSGI. It is possible for men and women to have NSU, but it is more difficult to diagnose in women. There are many different causes, some but not all are through sexual contact. Tests for STIs or possibly urinary tract infections are conducted to determine the cause of the inflammation of the urethra. Causes of NSU include: STIs, other organisms, damage to the urethra, antibacterial liquids, sensitivity or irritation (FPA[c], 2008).

The reported numbers of new episodes of NSGIs by gender and year are shown in table 2-1. The large increase in the number of female cases from 2003 onwards results from the previously mentioned change of coding structure.

Uncomplicated non-gonococcal/non-specific urethritis in males, or treatment of mucopurulent cervicitis in females										
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Male (all)	59,770	63,163	66,008	71,202	74,589	74,901	73,989	72,102	67,688	63,932
-of which MSM	3,995	4,727	4,736	5,172	5,325	5,433	5,943	5,490	5,433	5,484
Female	160	129	134	6,923	7,768	7,865	7,385	7,250	6,874	6,509
Total	**59,930**	**63,292**	**66,142**	**78,125**	**82,357**	**82,766**	**81,374**	**79,352**	**74,562**	**70,507**

Table 2-1: Number of New Episodes of Non Specific Genital Infection seen at GUM departments by gender 2000-2009 (HPA, 2009)

2.2.4 Syphilis

Syphilis is a sexually transmitted disease caused by the spirochetal bacterium *Treponema pallidum*. The route of transmission of syphilis is almost always through sexual contact, though there are examples of transmission from mother to child during pregnancy. There are different stages of syphilis, primary, secondary, tertiary, latent and neurosyphilis. The signs and symptoms of syphilis are numerous which had made diagnosis very difficult. The disease was dubbed the “Great Imitator” as it was often confused with other diseases. Syphilis can be treated with penicillin. Left untreated, syphilis can damage the heart, aorta, brain, eyes, and bones. In some cases these effects can be fatal.

Since 1999, the number of homosexually and heterosexually acquired infectious syphilis in men has increased sharply (26 and 8 fold respectively) see figure 2-3. During 2008, homosexually acquired syphilis accounted for 62% of diagnoses in men; in 1999 this figure was 47%. Although syphilis is still a relatively rare condition, since 1999 there has been a substantial increase in the number of diagnoses mainly due to localised outbreaks, particularly in Bristol, London, Brighton and Manchester. Many of the cases have been among Men who have Sex with Men (MSM); however heterosexual men and women have also been affected. Investigations into the outbreaks have shown some common behavioural features including high rates of partner change and anonymous contacts, unprotected oral sex, recreational drug use during sexual intercourse, and concomitant HIV infection (FPA[a], 2009).

Unlike most other acute STIs, the burden of syphilis does not fall solely upon young people, again see figure 2-3. Since 1999, rates have increased sharply in men aged 45 and older (22 fold), 35 to 44 years (16 fold), and those aged 20 to 24 years (12 fold). The increase in women occurred across all age groups, but was markedly smaller (HPA, 2009).

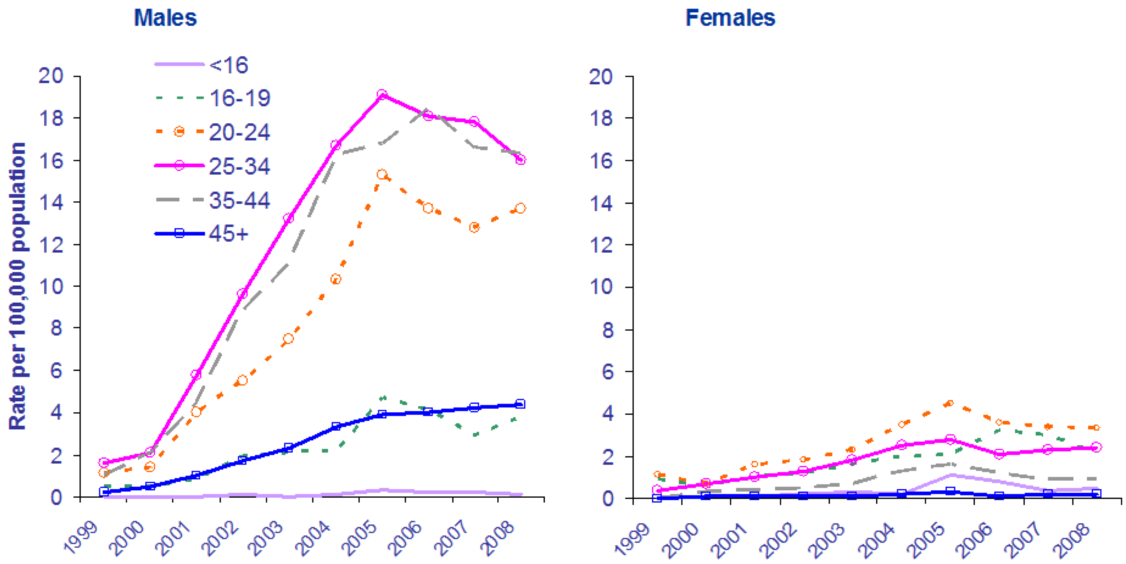

Figure 2-3: Rates of diagnoses of infectious syphilis (primary & secondary) by sex and age group, GUM departments, United Kingdom: 1999 – 2008 (HPA, 2009)

2.3 Viral STIs

2.3.1 Human Immunodeficiency Virus (HIV)

HIV can be transmitted through sexual contact, and in a number of other ways including needle sharing (FPA[b], 2008). HIV is considered a viral pandemic, with 33.3 million people infected worldwide (WHO, 2011). HIV affects the body's immune system so that it cannot fight off infections. HIV progresses to Acquired Immunodeficiency Syndrome (AIDS) once tests show the immune system cannot cope and particular illnesses start to develop, including: pulmonary infections, gastrointestinal infections, neurological and psychiatric involvement and tumours. The term AIDS is not used very often now. Late stage or advanced HIV infection is used instead (FPA[b], 2008).

By the end of 2007 there were an estimated 73,000 people living with HIV in the UK of whom about a third had not had their infections diagnosed. The number of new HIV/AIDS diagnoses and the new diagnoses is highlighted in figure 2-4 (HPA, 2009). Highly active antiretroviral therapies have resulted in substantial reductions in AIDS incidence and deaths in the UK, which, in turn, has led to an increase in the number of people needing long-term treatment (FPA[b], 2008).

The average lifetime treatment costs for an HIV positive individual is calculated to be between £135,000 and £181,000, and the monetary value of preventing a single onward transmission is estimated to be somewhere between £1/2 and 1 million in terms of individual health benefits and treatment costs (DH, 2001).

Until the 1990s there was little reliable information on the sexual behaviour of the general population in Great Britain. The emergence of AIDS in the 1980s provided the impetus for the first National Survey of Sexual Attitudes and Lifestyles (NATSAL), which was carried out in 1990 and the subsequent Natsal 2000 enables us to assess how reported sexual behaviour has changed. NATSAL will be discussed in more detail in part 3.2.3.

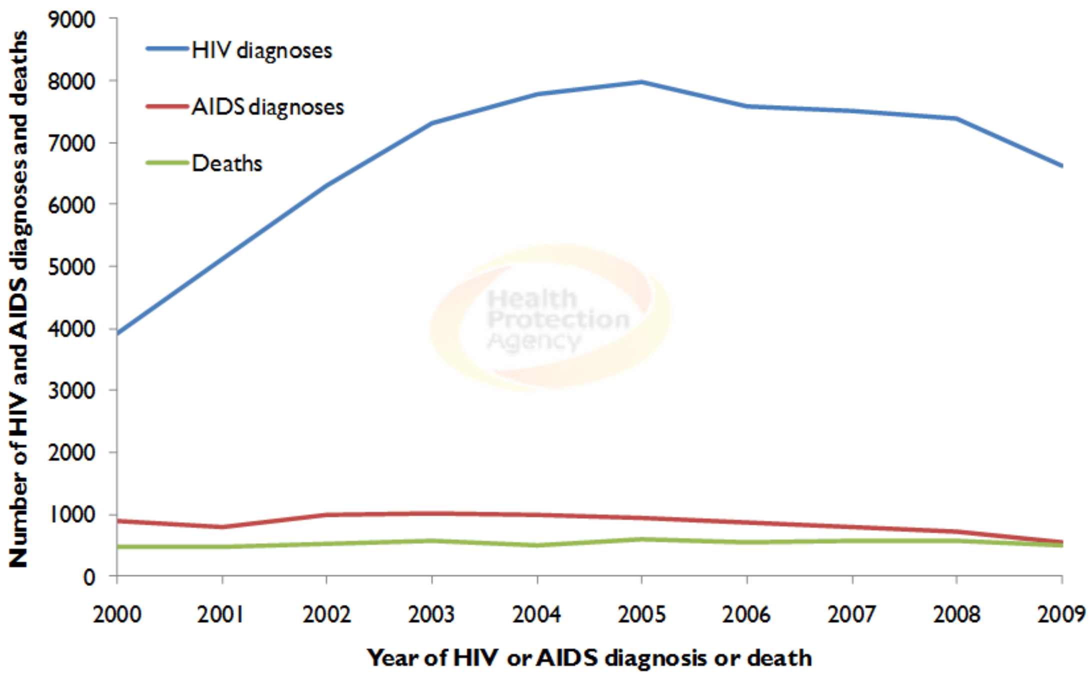

Figure 2-4: New HIV and AIDS diagnoses in the UK, and deaths among HIV infected individuals: 2000-2009 (HPA, 2009)

2.3.2 Genital Warts

Genital warts are a highly contagious sexually transmitted infection caused by some sub-types of human papillomavirus (HPV). It is spread through direct skin to skin contact during sexual contact with infected individuals (FPA[a], 2008). Once cells are invaded a latency period of months to years may occur. HPV can last for several years without a symptom. Having sex with a partner whose HPV infection is latent and demonstrates no outward symptoms still leaves one vulnerable to becoming infected. Although treatments can remove warts, they do not remove the HPV, so warts can recur after treatment. It has been presumed that the virus remains in the body for a lifetime.

Between 1972 and 2008, the number of all genital warts diagnoses increased by 8 and 11 fold in men and women respectively. The rises may be due to increased incidence of infection, greater public awareness and/or improved detection rates. Figure 2-5 provides the Genital Wart rate by gender between 1999 and 2008 (HPA, 2009).

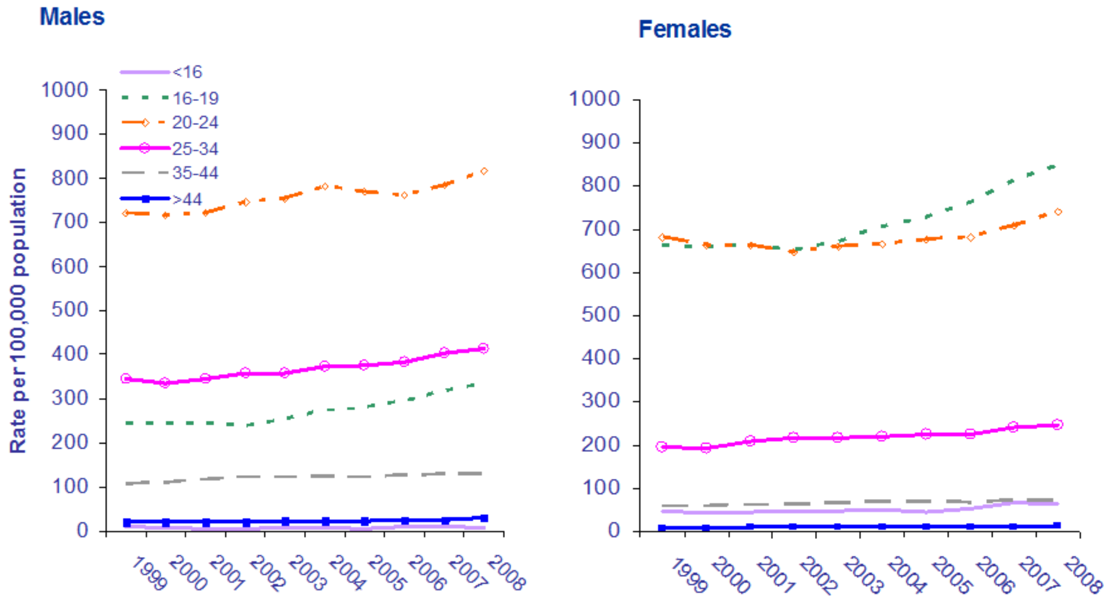

Figure 2-5: Rates of diagnoses of genital warts (first attack) by sex and age group, GUM departments, United Kingdom: 1999 – 2008 (HPA, 2009)

2.3.3 Genital Herpes

Herpes simplex virus 1 and 2 are two species of the herpes virus family. Herpes variations cause cold sores and chicken pox to brain inflammation. All viruses in the herpes family produce lifelong infections. An infection by a herpes simplex virus is marked by watery blisters in the skin or mucous membranes of the mouth, lips or genitals. HSV is spread during close contact with an infected person who is shedding virus from the skin, in saliva or secretions from the genitals. Vertical transmission can occur between mother and child during childbirth, which can be fatal to the infant (FPA[b], 2006).

Figure 2-6 illustrates the rate of diagnoses of genital herpes (first attack) by age group and gender. The number of diagnoses has risen sharply in the last few years due to increasing use of highly sensitive diagnostic tests. During 2008, in the UK, the highest rates of genital HSV diagnoses were in those aged 20 to 24 years, for both men and women (133/100,000 population and 251/100,000 population respectively) (HPA, 2009).

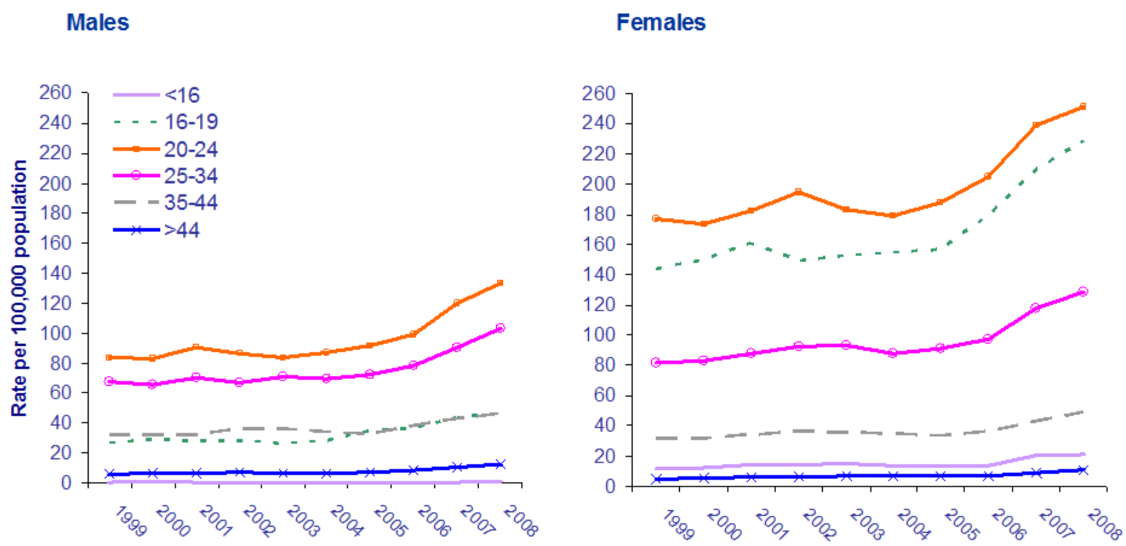

Figure 2-6: Rates of diagnoses of genital herpes (first attack) by sex and age group, GUM department, United Kingdom: 1999 – 2008 (HPA, 2009)

2.4 Parasitic STIs

The STIs caused by parasites include: Trichomoniasis, Pubic lice and Scabies. Trichomoniasis is a parasitic infection of the vagina and urethra of women and the urethra of men (FPA[e], 2008). The parasites are usually passed through sexual contact. It is asymptomatic in 50% of cases for both genders. Reported new episodes of Trichomoniasis have been generally declining.

Pubic lice and scabies are tiny parasitic insects and mite respectively that live in coarse body hair (FPA[d], 2008). Both can be passed through close body or sexual contact. Pubic lice and scabies can live for up to 24 and 72 hours off the body respectively. Therefore it may be possible for them to spread by sharing clothing, bedding or towels. Both can be treated by use of special cream, lotion or shampoo. As they can survive off the body, cleaning of clothes and bedding on a 50°C or higher wash is advised.

2.5 Research Focus

The focus of this research was the development and combination of two simulation models: a Discrete Event Simulation (DES) model of the GUM department and a screening System Dynamics (SD) model. The STIs included in the DES GUM model are provided in part 2.5.1. The SD screening model focussed on Chlamydia. Parts 2.5.2 through 2.5.4 provide the justification for the construction of a Chlamydia only screening model.

2.5.1 Genito-Urinary Medicine Department Discrete Event Simulation Model

A Discrete Event Simulation (DES) model of the GUM department was constructed to capture the key processes of the walk in clinics that the department provides. Following discussion with colleagues at the St Mary's, GUM the GUM model focussed on the following "key" STIs:

- Chlamydia
- Gonorrhoea
- Syphilis
- HIV
- Herpes
- Genital Warts
- Non-specific Urethritis (NSU)

The key STIs above represent the majority of the conditions that the department encounters. In 2007 22.67% (6428/28348) of the patients who visited the department tested positive for one or more of the key STIs. The key STIs were selected as they are the most infectious and potentially have the most severe consequences. Many of them as previously stated are asymptomatic and therefore people are unaware that they may have these conditions. The development of the DES GUM department model is discussed in chapter 10.

2.5.2 Cost and Consequences of Chlamydia

Chlamydia was chosen as the key condition of this research as:

- It is the most prevalent STI in the UK
- The negative consequences (sequelae) of untreated Chlamydia can be severe for both genders
- It is asymptomatic in the majority of cases.
- Many of those infected with Chlamydia are more likely to have co-infections.

- It can be effectively treated with antibiotics

The sequelae for women include: Infection of the reproductive system, Pain in the abdomen, Reiter's syndrome (which can cause Urethritis, Conjunctivitis and a form of arthritis) and Pelvic Inflammatory Disease (PID), which can lead to Infertility and Ectopic Pregnancy, which can potentially be life threatening. Chlamydia is implicated in more than 50 per cent of cases of PID (Moss T.R. ed 2006). Although PID infection itself can be cured, effects of the infection may be permanent. The sequelae for men include: inflammation of the testicles, possibly infertility and Reiter's syndrome (previously mentioned and is most common in men). It is estimated that the costs that result from the development of these sequelae cost the NHS at least £100 million per year.

This makes early identification and prevention vital in maintaining viable reproductive capabilities. Prevention of PID and the protection of fertility were key factors in the development of the government's sexual health strategy.

The UK government was aware of the impact of Chlamydia and aware that measures had to be taken to reduce its prevalence. Sexual health in general became a hot topic for the government and was a key component of many white papers: Choosing Health: Our Health, Our Care, Our Say (2006) and Choosing Health: Making healthy choices easier (2004). These papers recommended the use of screening for Chlamydia with a particular focus on the young (those under 25) who carried a burden of the infection. Screening has been shown to be effective elsewhere and will be discussed in part 2.5.3.

2.5.3 Chlamydia Screening

The white papers above were influenced by the Department of Health's (2001) National strategy for sexual health and HIV in which the recommendation for Chlamydia screening pilot sites was put forward. The pilot sites were Portsmouth and the Wirral. Following these initial pilots the National Chlamydia Screening Programme (NCSP) was rolled out in phases to cover the rest of England. Autonomy was given to the Primary Care Trusts (PCTs) to deliver the programme as they deemed appropriate.

The impetus for the development of a screening programme for the England came from successful screening programmes implemented in Scandinavia (Ostergaard et al, 2000; Hillis et al, 1995) and the United States of America (USA) (Scholes et al, 1996; Egger et al, 1998). These studies showed that the likelihood of developing PID reduced as a result of screening.

England is the only country in the United Kingdom (UK) to have an established national control programme for Chlamydia (NCSP, 2011). There are no formal screening programmes for Chlamydia in Scotland, Northern Ireland or Wales. Scottish guideline states that for asymptomatic individuals attending healthcare settings other than genitourinary medicine (GUM) departments, testing should be most strongly advised for those with two or more partners in the past 12 months (Scottish Executive, 2005). In Northern Ireland, the Department of Health, Social Services and Public Safety are currently putting in place plans for the introduction of a Chlamydia Testing Programme (CTPNI) similar to the NCSP (Northern Ireland Department of Health, 2008). In Wales individuals can request confidential screening for Chlamydia and other sexually transmitted infections, either from their general practitioner (GP) or from a GUM department (National Assembly for Wales, 2000).

Chlamydia is one of the most common bacterial sexually transmitted infections in Europe. Rates in sexually active young people are commonly between 5 per cent and 10 per cent. The number of diagnosed cases is increasing in many European countries, in part due to increased testing and the use of more sensitive tests. The European Centre for Disease Control (ECDC) report 'Review of Chlamydia control activities in the EU countries' presents a systematic survey of Chlamydia control activities in 29 countries, including 24 EU Member States.

In the 2006 edition of the Canadian Guidelines on Sexually Transmitted Infections, emphasis is given to the importance of screening all sexually active females under 25 years of age and all people who have risk factors for Chlamydia infection. Chlamydia screening is among the top ten high value clinical preventive services ranked by the National Commission on Prevention Priorities in the USA. In January 2008 the CDC in partnership with a series of non-profit organisations formed a US Chlamydia Coalition. The Coalition, includes the NCSP, aims to increase awareness of the importance of screening via: public education, encouraging health care providers to increase screening rates, advocate for policy changes to increase access to Chlamydia screening and treatment and to encourage research to enhance the prevention of Chlamydia and its medical and social consequences.

Chlamydia trachomatis is the most commonly diagnosed bacterial STI in Australia. In its first National Sexually Transmissible Infections Strategy release in 2005 the federal government stated that a Chlamydia screening pilot program targeting sexually active young people under 25 years of age should be a priority action.

2.5.4 System Dynamics Simulation Chlamydia Screening Model

A SD screening model for Chlamydia was developed, see chapter 11, to further evaluate the effectiveness of the current NCSP guidelines and future scenarios. Chlamydia was chosen as the infection of interest due to the reasons discussed in section 2.5.2. If other conditions were modelled in the SD model they would result in a large model which may be difficult for non-technical people to understand. The principles that underlie the development of this single condition could then be replicated for the other conditions. A key feature in the developed model, rarely captured in other models, is the possibility of treatment influenced behavioural change of the population.

2.6 Chapter Summary

This chapter:

- Clearly illustrated that STIs are a key health concern and in general are increasing year on year.
- Provided an introduction to the main STIs by type: bacterial, viral, parasitic and other. Focused in particular on those that will be included in the computer model.
- Rationalised why Chlamydia has been made the focus of this research.

3 Behavioural and Geographical Factors Impacting on Sexual Health

3.1 Chapter introduction

This chapter focuses on the literature which informs the non-OR methodologies used in this research, namely: the socioeconomic analysis, the sexual health survey and the geographical referencing. As these methods are primarily used to inform the construction of the OR simulation models in part IV, this review will be selective. The behaviour section 3.2 provides key literature investigating a person's behaviour and probability of acquiring an STI. Particular attention is paid to behaviours that place people at greater risk. How these behaviours change naturally and can be changed through various interventions. This literature is used to inform the socioeconomic (8) and sexual health (9) chapters. The geographical information systems (GIS) section 3.3 relates to the application of GIS as they pertain to sexual health services or STIs. Particular focus is paid to the development of screening programmes through the identification of clusters of infection. The chapter concludes with a summary of the key aspects of the literature, and how they relate to this research 3.4.

3.2 Behaviour

In general observations, questionnaires or interviews have been used to record and explain why people exhibit certain behaviours. The subject of this thesis was particularly sensitive. Therefore additional steps were required to ensure all appropriate measures were taken, when developing the methods used to collect the necessary data. This section examined the literature as it pertained to: sexual behaviour, risk taking behaviour (part 3.2.1) and treatment seeking behaviour (part 3.2.2) as this information would be incorporated in the developed computer models; the National Survey of Sexual Attitudes and Lifestyles (NASTAL) is discussed (part 3.2.3) as an example of good practice; core group theory (part 3.2.4) and its importance in sexual health, behaviours and screening programmes; behavioural models (part 3.2.5) in terms of statistical and computer models of sexual behaviour; and behavioural change studies (part 3.2.6).

3.2.1 Sexual behaviour and risk taking behaviour

The key behaviours and factors that influence behaviour were informed by literature searches from online databases including: web of knowledge, MEDLINE and psychinfo. The key behaviours and factors that influence sexual behaviour were identified as:

contraception, sexual partnerships, age and temporal changes, gender, unplanned pregnancy and fertility, HIV, marriage, sexual acts, sexuality, age of sexual debut, ethnic and cultural factors, rural or urban, education, holiday, alcohol and drugs, sexual worker population, sexual assault, and self-perception and vulnerability. The factors identified above are discussed in this section in turn. It should be noted that most research investigates combinations of these factors, and rarely look at a single factor in isolation. Trying to quantify and understand any behaviour is often complicated. It is often difficult to disentangle multiple influences and reasons, for the exhibited or self-reported behaviour (Aral, 2004).

Contraception

Contraceptive use is one of the primary behavioural factors that have been investigated. There are many contraceptives, but the one which is most effective in terms of reducing the spread of STIs is the male latex condom. Many studies explore whether a condom was used with the last sexual partner or if condoms are used as the main method of contraception. They however don't ask questions about how the condom is used, i.e. when the condom was put on and when it was removed. Abel and Brunton (2005) conducted a survey to examine if young people (16-18) in New Zealand used condoms consistently. Of those who were sexually active, 25% didn't use a condom as they believed that they or their partner did not have an STI, and 25% did not use a condom as they reported using another contraceptive method. The main reason for not using a condom was reported as being the reduction in sexual pleasure. This study did not investigate the types of relationship. Contraceptive use has been found to be dependent upon relationship status (Connell et al, 2004; Warner et al, 2006; Pinkerton et al, 2003). A randomised study in which participants were assigned to use or not use condoms with their prospective sex partners would generally be considered unethical (Warner et al, 2006).

Warner et al, 2006 conducted a systematic review of condom use and risk of gonorrhoea and Chlamydia. They found that in their review of 45 studies that most found reduced risk of infection associated with condom use. They evaluated the studies by 4 measures: 1. Distinguished consistent from inconsistent condom use; 2. Measured correct use and/or condom use problems; 3. Distinguished incidents (new) infections from prevalent (pre-existing) infection; and, 4. Selected population had documented exposure to Chlamydia and gonorrhoea.

Johnson et al (2001) compared the results from the NATSAL 2000 study with NATSAL 1990 NATSAL. NATSAL will be discussed in greater detail in part 3.2.3. Greater condom use was found between the 1990 and 2000 surveys. This greater use was attributed to HIV awareness programmes. The increase in condom use is offset by increased numbers of sexual partners. An increase was found from the NATSAL 1990 to NATSAL 2000 in consistent condom use in the past 4 weeks. The observed increase in condom use was found to coincide with increases in condom sales nationally during the same period.

Respondents from a small study conducted with 38 people, mostly African American men, conducted by Newman (2002) suggested that condoms were rarely used as they simply did not like them and with their main partner there was assumed fidelity. Condoms were found to be selectively used with partners they perceived to be risky (Warner et al, 2006).

Pinkerton et al (2003) created a mathematical model where one of the key behaviour variables that could be changed was condom use. The model was originally developed in reference to HIV but was adapted for other STIs. Condom use was found to be more effective at reducing the cumulative transmission risk for HIV than for other infectious STIs. The protection provided by condoms for multiple acts of intercourse depends on the infectiousness of the STI. Verhoeven et al (2003) produced a logistic regression model to determine the risk factors associated with Chlamydia and to estimate the prevalence in Antwerp, Belgium. One of the determinants identified was not using contraceptives in particular, condoms. Gotz et al (2005) found that Chlamydia infection was associated with no condom use at last sexual intercourse. This view was supported by van Bergen et al (2005) who found that no condom use at last sexual contact was an independent factor prevalence of Chlamydia. Radcliffe et al (2001) conducted a questionnaire used to assess the demographic and behavioural parameters which are associated with Chlamydia in adults, in Birmingham in the UK. They found that higher reported use of condoms were associated with a lower risk of infection. Weinstock et al (1992) carried out a logistic regression on data from 4 family planning clinics in San Francisco. This analysis identified 5 factors associated with infection one being the lack of barrier contraception.

Sexual Partnerships

Aral and Wasserheit (1998) conducted a literature review exploring the social and behavioural correlates of PID. Multiple sex partners, new sex partners and high risk sex partners were found to be correlated with exposure to gonorrhoea and Chlamydia infection through intercourse with infected partners. The numbers of sex partners indicate that the majority of people have a few sex partners while a small minority report very large numbers (Aral, 2004). Johnson et al (2001) found that 81.9% of men and 76.4% of women reported more than one lifetime partner whereas 34.6% of men and 19.4% of women reported at least ten lifetime partners. Pinkerton et al (2003) created a mathematical model where one of the key behaviour variables that could be targeted was the number of partnerships. The results of the model indicated that a decrease in the number of sexual partners is a more effective strategy for reducing STI risk than HIV risk.

Concurrent partnerships occur where individuals are engaged in more than one sexual partnership during the same time period. Concurrent partnerships were independently associated with Chlamydia (Fenton et al, 2001) and it was estimated that 14.6% of men and 9.0% of women had such partnerships (Johnson et al, 2001). Pinkerton et al (2003) suggested that partnership concurrency tends to amplify STI epidemics by facilitating rapid transmission through sexual networks.

Chlamydia infection was associated with multiple lifetime partners, a new contact in the previous two months (Gotz et al, 2005). Studies suggested that Chlamydia risk was most strongly associated with having a new sexual partner in the past year, rather than the total number of partners (Macleod et al, 2005; Verhoeven et al, 2003). Radcliffe et al (2001) conducted a questionnaire to assess the demographic and behavioural parameters which are independently associated with Chlamydia in adults. They found that reporting fewer partners was associated with a lower risk of infection, although perhaps counter intuitively an increased number of casual sexual partners where a single sexual act was reported did not increase the risk of being infected. A simulation model developed by Turner et al (2006) contained people aged 16-44. The preference of new partnership was adjusted annually and was primarily informed by the NATSAL surveys.

Age and Temporal Changes

Aral (2004) measured temporal changes in sexual behaviour and the relationship between timing of sexual behaviour measurement and STI prevalence and incidence in 1998. Aral and Wasserheit (1998) found that young age correlated with exposure to gonorrhoea and Chlamydia infection. They also suggested that early sexual debut correlated with exposure to Gonorrhoea and Chlamydia infection through intercourse with infected partners. Fenton et al (2001) also found that age was associated with Chlamydia infection, with young age being likely to be associated with infection (Gotz et al, 2005). Johnson et al (2001) found by analysing the NATSAL survey that the proportion of people reporting a new partner in the last year declined with age in both genders. LaMontagne et al (2004) reviewed the implementation of the NCSP, and reported the positivity rates for the first year. Age for women 16-19 and men 20-24 were identified as risk factors. Weinstock et al (1992) suggested selective rather than universal screening for Chlamydia should be recommended due to the cost, with one of the discriminating factors being under 25. Monteiro et al (2005) showed that young age (15-24) was an independent risk factor for all STIs. Radcliffe et al (2001) conducted a survey to assess the demographic and behavioural parameters which were independently associated with Chlamydia. Increasing age was associated with a lower risk of infection. This conflicts with many Chlamydia screening programmes in Europe. Verhoeven et al (2003) found age 18-27 was one of determinants of Chlamydia infections. This finding conflicts with current screening strategies with the age range being higher than currently screened.

Aral and Wasserheit (1998) have suggested that US teenagers may know more about STIs than adults. They found that neither group has much knowledge about PID. 57% of adults and 45% of teenagers dramatically underestimated the prevalence of STIs. Abel and Brunton (2005) suggested that young people believed they were invulnerable to STIs. They suggested that as people get older they may get involved in more stable relationships involving more trust with their partner and less concern over STIs.

Gender

Through focus group discussions with young people living in an area with known high prevalence of gonorrhoea and Chlamydia in the London, Connell et al (2004) noted a clear differences across ethnic groups between women's and men's: attitudes towards sexual health priorities, relationships, and risk reduction strategies. Participants engaged in discussions that blamed the other gender for spreading sexually transmitted infections. As previously mention there are reported gender differences between the numbers of reported partners (Johnson et al, 2001)

LaMontagne et al (2004) noted that the risk factors in the development of Chlamydia varied by sex. Radcliffe et al (2001) reported that male sex was associated with an increased risk of Chlamydia infection; Abel and Brunton (2005) suggested that males thought themselves less likely to become infected with an STI. Females were found to be less likely than males to use condoms on every occasion of sexual intercourse. This was possibly due to some women believing that to use a condom was a sign of distrust of your partner (Pavlin et al, 2006). Novak et al (2003) found that internet screening was more effective for males outside the high risk group in Sweden. The internet screening was part of a new Chlamydia screening method based on a home sampling strategy. The internet was used to obtain their test results.

Unplanned Pregnancy and Fertility

The protection of fertility and reduction of unplanned pregnancy, have been identified as being more significant in the use of contraception and the type of sexual behaviour exhibited than the risk of contracting an STI. Abel & Brunton (2005) suggested that young people are more concerned about preventing pregnancy than STIs. This may be due to the recognition of peers who become pregnant and the result of having to leave school coupled with the associated consequences of early and unexpected parenthood. They may not notice a peer who has an STI. Connell et al (2004) supported this view that women unanimously identified unplanned pregnancy as their main fear to a wider age range. Protection of fertility was identified by Pimenta et al (2003[a]) as one of the most important factors in a person's decision to accept screening.

HIV

Johnson et al (2001) compared the NATSAL 2000 and 1990 surveys. They found that the proportion of the population regarding themselves as at risk of HIV/AIDS remained low but had increased when compared with NATSAL 1990. Fethers et al (2000) conducted a retrospective cross sectional of women who have sex with women (WSW). The study demonstrated that WSW are more likely than non-WSW to engage in recognised HIV risk behaviours such as IDU, sex work, sex with a bisexual man and sex with a man who injects drugs. Connell et al (2004) found that sexually transmitted infections were viewed as being less serious than HIV because they were curable and not fatal. This is a fragile point of view when combined with the misperception as highlighted by Abel and Brunton (2005) study that only 23% of the young people felt vulnerable to acquiring an STI.

Marriage

Non-marriage was independently associated with infection with C trachomatis. (Fenton et al, 2001). This could be due to the number of potential new partnerships that could be formed when an individual is single. A strong association between age and new partnerships may in part be explained by the higher proportion of unmarried respondents at younger ages (Johnson et al, 2001). Being unmarried was found to be an independent risk factor in Chlamydia development (Radcliffe et al, 2001; Weinstock et al, 1992).

Sexual Acts

Certain sexual acts place individuals at greater risk of acquiring STIs. Unprotected virginal or anal intercourse was associated with an increased likelihood of Chlamydia infection (Fenton et al, 2001). Johnson et al, (2001) identified an increase from the NATSAL 1990 to NATSAL 2000 in oral-genital contact and heterosexual anal sex in the past year.

Sexuality

Fethers et al (2000) noted the sexual health risks of WSW are poorly understood. Possible misconceptions held by healthcare providers could have an impact on the health status of WSW. The study found that 93% of WSW reported previous sexual contact with a man and that they were significantly more likely to report more than 50 lifetime male sexual partners. Research into STI transmission dynamics and behavioural research of WSW is required as it is an area poorly explored. There have been many studies of examining the sexual behaviour of men who have sex with men (MSM) and NATSAL 1990 was a reaction to the HIV epidemic which sought to elicit such information from MSM.

Age of Sexual Debut

A younger age of sexual debut has been associated with risk behaviours which have been linked to STIs. Abel and Brunton (2005) study identified an association between early sexual debut and condom non-use. Ross and Radcliffe (2006) associated earlier sexual debut with greater drug use. Drug use and its association with STIs are discussed later in this part.

Ethnic and Cultural Factors

The influence of ethnicity and cultural factors on the acquisition of STIs has been extensively investigated. Connell et al (2004) stressed that the one size fits all approach in the understanding of risk behaviours may not feasible, given cultural diversity. Interestingly over 97% of women in the UK's pilot Chlamydia screening programme were of white ethnicity (Pimenta et al, 2003[b]). This most likely reflected the resident populations of the pilot sites.

Belonging to an ethnic minority correlated with exposure to Gonorrhoea and Chlamydia infection through intercourse with infected partners (Aral and Wasserheit, 1998; LaMontange et al, 2004; Radcliffe et al, 2001; Connell et al, 2004). Monteiro et al (2005) examined the interrelation between demographic and geospatial risk factors for four STIs. Regression analysis showed that ethnicity (gradient black, white, asian) was an independent risk factor for all STIs. Turner et al (2004) developed a simple mathematical model to investigate ethnic difference in rates of gonorrhoea. Interventions to reduce duration of infection were most effective when targeted at black Caribbean's. Postal screening coverage was found to be lower in areas with a higher proportion of non-white residents (Macleod et al, 2005).

Connell et al (2004) found ethnic differences in terminology, awareness of sexually transmitted infections, non-exclusive sexual relationships, and experience of sexual health services. Young black people were more aware of gonorrhoea and Chlamydia than their white peers but these infections were not a serious concern for any ethnic group. Pavlin et al (2006) suggested that women from various countries and ethnic backgrounds shared similar views regarding Chlamydia screening, testing and diagnosis. Newman (2002) found within Black African American men the primary prevention strategy was partner selection based on: familiarity, appearance and reputation.

Rural or Urban

Gotz et al (2005) found that Chlamydia infection was associated with high level of urbanisation. This view was supported by (Verhoeven et al, 2003 and Aral and Wasserheit, 1998). van Bergen et al (2005) investigated the prevalence of Chlamydia in 15-29 year old women and men in rural and urban areas in Netherlands. Chlamydia prevalence was significantly lower in rural areas compared with very highly urbanised areas.

Education

van Bergen et al (2005) found an association between low educational level and Chlamydia incidence. Awareness and knowledge about STIs has been found to be low 74.3% of sexually active participants agreed that people their age could get an STI yet 23% felt it was likely that they would get one (Abel and Brunton, 2005).

Holiday

Rogstad (2004) conducted a review of the literature focussed on the implications of international mixing on the risk of acquiring sexually transmitted infections. The paper focused on the implications of sexual partnerships whilst on holiday. A key risk factor identified was that of the sex tourist, where men and women travel long distances with the intention of having sex. Sexual encounters on holiday have the potential to be a major cause of morbidity and the risk is likely to be greatest in younger people and sex tourists. Sexual encounters abroad can impact on nationally organised screening programmes.

Alcohol and Drugs

Aral & Wasserheit (1998) found a correlation between drug use and exposure to Gonorrhoea and Chlamydia infection. Johnson et al (2001) reported an increase from the NATSAL 1990 to NATSAL 2000 in those reporting ever use of injecting non-prescribed drugs. Fethers et al (2000) demonstrated that WSW were more likely than non-WSW to engage in risk behaviours such as IDU, and sex with a man who injects drugs. Ross and Radclife, (2006) assessed the association between drug use and Gonorrhoea in a UK setting. They developed a multivariate model which took into consideration demographic and behavioural factors. Many reported use of non-injected drugs and only one case reported the use of intravenous drugs. This study explored the type of drug use which previous studies lacked. An increase in the number of sexual partners and in unprotected sex may result from the exchange of sex for drugs or money to buy drugs, especially for women. Drug users may have a faulty perception of risk. The use of low-dose cocaine resulted in decreased inhibition and increased sexual desire, which may result in an increased number of partners and reduced use of condoms. Chronic use however was found to decrease sexual function and promote sexual disinterest. A surprising finding from this study was that 44% of cases and 30% of controls admitted to using illicit drugs in the previous 12 months. This study therefore suggests that health education aimed at STI clinic attendees should address this issue as well as the prevention of infection.

Sexual Worker Population

Aral (2004) suggested that the size of the sex worker (SW) population relative to the total population was most important in determining the overall prevalence of infection, with larger populations of SWs resulting in a higher overall prevalence. SWs also are a key member of the core groups - see part 3.2.4. Aral & Wasserheit, (1998) suggest exchange of sex for money correlated with exposure to Gonorrhoea and Chlamydia infection through intercourse with infected partners. This is supported by Johnson et al (2001) who compared the NATSAL 1990 to NATSAL 2000 and found an increase in men paying for sex in the last 5 years. Fethers et al (2000) Study also suggested that WSW were more likely than non-WSW to engage in SW.

Aral (2004) makes a very important point, being: "The risk of acquiring an STI depends on whether the partner is infected. Regardless of behaviour, infection cannot be acquired from uninfected partners. Moreover, behaviours are related to the infection status of the partner: people are more likely to have safe sex with risky partners and risky sex with safe partners".

Sexual Assault

Determining the transmission probability of STIs following a sexual assault is complicated as it is difficult to differentiate between a pre-existing STI(s) and those transmitted by the assault. Schwarcz and Whittington (1990) conducted a literature review which ascertained that the rates of Gonorrhoea of adult victims of sexual assault ranged from 6% to 12%. Reynolds et al (2000) conducted a literature review with the objective of determining the prevalence rates of STDs in victims of sexual assault found that the range for Gonorrhoea to be 0.0% to 26.3%. This difference could be due to a change of prevalence over time and also the number of studies included in each review, and the source of the studies included. Reynolds et al (2000) also found in relation to this research that the prevalence range for Chlamydia was 3.9% to 17.0%. These studies suggest that those individuals who are sexually assaulted are exposed to a higher underlying prevalence of these conditions.

Stoner et al (2000) conducted face to face interviews with two groups of patients, those who had tested positive for Gonorrhoea and those who had tested positive for Chlamydia. They found a significant difference in the two groups when considering a past history of sexual assault, with the Gonorrhoea group more likely than the Chlamydia group to report a past history of abuse (19.6% compared to 13.0%)

Victims of sexual assault are often reluctant to report being abused for many reasons including for example fear of not being believed, or a need to not acknowledge the event. Sensitive, expedient non-judgement care is crucial for the mental and physical health of the individual (Mein et al, 2003; Reynolds et al, 2000; and Schwarcz and Whittington, 1990).

Self-Perception and Vulnerability

Typically self-perception and vulnerability in relation to STIs focussed on contraception use and likelihood given an individual's sexual behaviour their risk generally to HIV/AIDS (Johnson et al, 2001). Due to the nature of STIs the individual's perception of their partner(s) is also assessed, when considering their own risk. Abel and Brunton (2005) found that young people in New Zealand were unlikely to perceive a personal susceptibility to STIs, and that many young people exhibited a sense of invulnerability especially among males which they suggest should be addressed. Pavlin et al (2006) found that women who were waiting for Chlamydia test results did not view themselves as being at risk. Self-perception changes once a STI is acquired with people tending to feel: angry, dirty or embarrassed (Connell et al, 2004).

Contraception use has been found to be dependent upon an individual's perception of their partner and the type of relationship they are in (Abel et al, 2005; Newman, 2002; Pavlin et al, 2006; Pinkerton et al, 2003). Other factors previous discussed such as alcohol and drugs have been shown to affect a person's perception. Ross et al (2006) highlighted that drug users may have a faulty perception of risk, e.g. deciding that a partner is STI free without discussing the risk with them.

3.2.2 Treatment Seeking Behaviour

Treatment seeking behaviour was broken down in line with the literature into: screening and targeted interventions, partner notification, treatment delay, location of treatment, worried well, confidentiality concerns and compliance with treatment.

Screening and Targeted Interventions

Pimenta et al (2003[b]) investigated the acceptability of opportunistic screening of Chlamydia. In depth interviews and self-completed questionnaires were used to evaluate the screening programme in which urine samples were found to be universally accepted. It is important to note in this study that clinics and GPs were financially remunerated, and even with this remuneration, some people who were eligible for screening were not offered it because of high staff workload and time constraints. They also found at the time of this study that in the absence of symptoms, people would not have sought screening and that the majority of respondents said they would not have accepted screening if it had entailed having a swab.

Campbell et al (2006) investigated postal screening found that home screening was associated with reduced anxiety. The home nature of the tests resulted in a higher response rate amongst women. They conclude that postal screening does not appear to have a negative impact. A possible negative impact however is the contact time with healthcare professionals that the non-infected individuals may have had. The contact time with health professionals discussing sexual behaviour and practice may have led to behavioural changes; this opportunity is missed if individuals do not need to attend at a health provider location. Macleod et al (2005) measured the coverage and uptake of systematic postal screening for Chlamydia. Finding that postal Chlamydia screening was feasible but coverage was incomplete and uptake was modest. Salisbury et al (2006) compared an opportunistic screening approach with a systematic postal approach for Chlamydia. They commented on the lack of evidence about young people's access to primary health care to make opportunistic screening effective compared to a systematic population-based approach. Opportunistic and population based approaches to Chlamydia screening would both fail to contact a substantial minority of the target group if used alone. A pragmatic approach combining both strategies potentially could achieve higher coverage. This study highlighted the pressing need to improve the accuracy of registers maintained by GP. The registers held by GP are used by the NHS in the cervical and breast cancer screening programmes.

Pimenta et al (2003[b]) evaluated participant's attitudes and views towards Chlamydia screening. They found that: improving awareness and education about STIs is required to alleviate negative reactions associated with testing positive for infection and; offering screening outside GUM likely to detect those who don't consider themselves at risk of infection, or are asymptomatic. Interestingly women were unaware that referral to GUM for treatment led to a full sexual health screen and partner notification which resulted in anxiety. Pimenta et al (2003[b]) also stressed that GUM departments are already overstretched and that a screening programme will exacerbate the situation. Pavlin et al (2006) compiled from literature reviews the attitudes and opinions of women about being screened, tested and diagnosed with Chlamydia. The themes identified from the literature were: need for knowledge and information, choice and support concerns about confidentiality, costs, fear, anxiety and stigma.

Hart et al (2002) draw attention to the screening of men, as initially when Chlamydia screening programmes were rolled out, women were the focus, with men identified through contact tracing. They argue for the inclusion of men, and this has been included in the NCSP as men are also screened although there is variation by PCT. As men are likely to be symptomatic perhaps the focus should be on screening men and identifying women through contact tracing? Menon-Johansson et al (2006) assessed the use of a text message result service within an inner London sexual health clinic. Patients with Chlamydia were found to be diagnosed and receive treatment sooner as a result of the text message service, and the service has resulted in a significant saving in staff time. Novak et al (2003) investigated the use of internet screening which was found to be more effective in the contact of males in particular outside the high risk group. The combination of internet and home sampling strategy gave a male answer response of 38.5%, at the time assumed that it was the highest ever participation rate yet for Chlamydia based screening using home obtained urine samples. Novak et al (2003) makes a key point echoing that of Hart et al (2003) that by restricting male participation in screening to that of traceable contacts makes successful eradication of Chlamydia unlikely. Salisbury et al (2006) found that offering Chlamydia screening to men in primary care would be beneficial, as Chlamydia prevalence in men is as high as in women. They estimated that 60% of men in the 16 to 24 year age group visited their GP each year.

Partner Notification

Partner notification is essential to prevent re-infection of index patients, decrease the pool of infectious people, and prevent the transmission of STIs (Mathews, 2007; Aral and Wasserheit, 1998). Until recently under Swedish law, sexual partners could not be anonymous (Novak et al, 2003). Tyden and Ramstedt (2000) investigated how patients in Sweden perceived the legal enforcement of partner notification and sought their view regarding legislation which affected their own sexual behaviour. They found that 18% admitted having disclosed the name of their partner(s), and 90% considered it beneficial that Chlamydia infection was regulated and that a named partner could be forced to undergo STD testing. Partly based on this research the Swedish government removed the use of police enforcement as a tool for contact tracing.

Matthews et al (2001) reviewed RCT of partnership notification strategies. They found that provider referral alone or the choice between patient and provider referral when compared with patient referral among patients with HIV or any STD, increases the rate of partners presenting for medical evaluation, this was supported by 11 RCTs. LaMontage et al (2004) investigated partner notification primarily when index partners were offered the choice of notifying their own partners or supplying information to health care professionals to notify the partner, without the patient's name being given. Trelle et al (2007) examined the effectiveness of methods to improve partner notification by patient referral (index patient has responsibility for informing sex partners) They conducted a systematic review, 14 of the trials included which examined various STIs suggested that involving index patients in shared responsibility for the management of sexual partners improves outcomes. The literature on partner notification contact tracing already mention all agree that the stigma attached to an STI makes partner notification difficult. Low et al (2006) conducted RCT of partner notification, a nurse led strategy, to improve the notification and treatment of partners of people with Chlamydia infection. GP partner notification by trained practice nurses compared to specialist health advisers at GUM clinic. 65.3% of participants receiving practice nurse led partner notification had at least one partner treated compared with 52.9% of those referred to a GUM clinic. They suggest as GUM clinics are failing to cope with the increasing workload the nurse led notification could lead to improvements. In the NCSP 44% of all contacts identified were treated. Practice nurse led partners notification could be introduced into the NCSP which currently suggests referral to a GUM clinic. This could be viewed as just transferring the pressure, could GPs cope with it?

Kiss et al (2005) found the efficacy of contact tracing is difficult to evaluate without precise knowledge of the underlying contact structure. The length of the latency period influences the effectiveness of tracing; longer latency periods allow more time for tracing, thus making it more effective. If infected nodes quickly become infectious then the time for tracing is very short and the value of tracing less. Pimenta et al (2003[a]) found that women created a distinction between current and past partners, and expressed reluctance to contact former partners themselves. Common responses to a positive test result included feeling dirty, ashamed at passing on the infection and suspicion about where the infection originated. For some it led to tension within relationships. Most said their partner had been understanding and rational. In fact the under-representation of men in opportunistic Chlamydia screening in Sweden is thought to be one reason why Chlamydia transmission has not been controlled (Tyden et al 2000).

Treatment Delay

Connell et al (2004) emphasised the need to challenge the wide spread beliefs that people with sexually transmitted infections always have symptoms or can be identified through visual and behavioural cues, which is likely to result in people delaying seeking for treatment . Aral and Wasserheit (1998) observed critical delays in detection and treatment of cervical infection, which were amenable to interventions contributed towards development of PID. Delay was identified as being particularly long among women living with a permanent partner possibly reflecting their perception of low STI risk associated with monogamous sexual behaviour. Another key factor in the delay of treatment seeking is that the taboo concerning STIs may act as a barrier. The average total care seeking interval (from presumed infection to seeking care) was 9.6 days for symptomatic women, 5.8 days for asymptomatic women, 6.3 days for symptomatic men, and 7.3 days for asymptomatic men. Aral and Wasserheit (1998) attribute this somewhat counterintuitive behaviour in treatment delay to the role of healthcare providers conducting contact tracing, identifying the asymptomatic patients more rapidly, but also to the time that a patient may spend evaluating their own symptoms in respect to the symptomatic patients before presenting to a health care service. Patients expect to be examined in a timely fashion and excessive waiting times or early clinic closures frustrate and distance patients from the health service delivery system.

Location of Treatment

Aral and Wasserheit, (1998) found that most American men and women seek STI care at non-STI faculties. This finding was reflected in the UK. Pimenta et al (2003[a]) indicated that during the Chlamydia pilot screening programme 90% of infections were diagnosed outside GUM in Portsmouth and this result was similar in the Wirral where 86% of infections were diagnosed outside GUM. Pimenta et al (2003[a]) analysed the potential impact of limiting screening to a single healthcare setting, such as GUM where prevalence is higher but utilisation is lower. When studies suggest that the GPs are a key site for screening although prevalence was lower here service utilisation is the highest. However, it should be noted that the reason why prevalence is higher in GUM is often people have been referred there from other healthcare services. LaMontagne et al (2004) support the view that screening should be offered at GPs as the service utilisation is higher. The screening in initial phases of the Chlamydia screening programme pilot were, conducted at GP surgeries which may have been more convenient acceptable to patients. This is not the norm now.

Worried Well

GUM departments main source of patients are from referrals from other healthcare organisations or through contact tracing. Also there are the “worried well” those who attend for assessment whose behaviour is unlikely to put them at risk of acquiring an STI (Jackson and Greenlick, 1974). Nicoll et al (2001) found that as a result of a national anti-HIV sexual health campaign that increases in attendance of the worried well increased for men and women.

Confidentiality Concerns

Confidentiality is a key concern in healthcare and particularly in relation to sensitive topics such as sexual health. Aral and Wasserheit (1998) found those adolescents seeking health care indicated that confidentiality was an important issue. 58–69% of adolescents indicated health concerns they wished to keep confidential and that they would not seek health services because of these concerns. Pavlin et al (2006) identified from the literature concerns about confidentiality. Concerns about: the confidentiality of attending a clinic and of results, wanting to keep STI screening private, not wanting anyone to know and thinking general practice is not confidential or private enough for Chlamydia.

Compliance with Treatment

There are two types of compliance: compliance with treatment and more importantly compliance with screening. There are different types of antibiotic treatment for Chlamydia, a single dose treatment which then involves seven days of abstinence, and a seven day course of antibiotics which also involves abstinence (Horner and Boag, 2006). Roberts et al (2006) reviewed 10 papers which modelled Chlamydia infection and they assumed that compliance with the single dose treatment was 100% and compliance with the seven day course was 75–87%. Non-compliance with the seven day course may exceed 65%, and also asymptomatic patients are less likely to comply (Aral and Wasserheit, 1998). Compliance with therapy is improved if there is a positive therapeutic relationship between the patient and healthcare professional (Horner and Boag, 2006).

3.2.3 National Survey of Sexual Attitudes and Lifestyles

The National Survey of Sexual Attitudes and Lifestyles (NATSAL) is one of the largest scientific studies of sexual behaviour in the world. It originated from an urgent need to gather more information about sexual behaviour following the HIV epidemic. There have been three waves of the NATSAL survey 1990, 2000 and 2010. The 1990 survey was conducted as a traditional paper based questionnaire and also face to face interviews. This led to confidentiality concerns. The 2000, and presumably the 2010 surveys are a combination of face-to-face computer assisted personal interviews and computer assisted self-interview. The computer assisted interviews were for the respondents to fill in alone and related to the more sensitive questions. They obtained higher response rate with the computer based questionnaires compared to the 1990 survey (Johnson et al, 2001). The 2010 NATSAL results are scheduled to be available in 2013.

The topics included in NATSAL are: age at first intercourse, no. of homosexual partners, no. of heterosexual partners, no. of partners in different time periods, sexual practices and sexual attitudes. New questions were introduced to NATSAL 2000 relating to patterns of partnership formation, sexual mixing and STI acquisition (Johnson et al 2001).

3.2.4 Core Group Theory

The role of core groups in STD transmission dynamics and their implications for the measurement of sexual behaviour was investigated by (Aral, 2004). Core group theory in an STI context proposes that: “Small proportions of persons with an STD who are frequently infected with and transmit the disease, and who sustain the endemic and epidemic transmission of STD” (Aral, 2004). Monitoring of the core group(s) is vital in the control of any infectious disease. An outbreak of primary and secondary syphilis in Vancouver, Canada, led to mass treatment intervention to be implemented. This mass treatment resulted in increased incidence of syphilis by returning infected people to susceptible status and thereby increasing the pool of susceptible individuals who subsequently reacquired the infection. Data on number of sex partners indicate that the majority of people in a population have a few sex partners while a small minority report very large numbers (Aral, 2004; Zenlimen et al, 1999). Zenlimen et al (1999) found that although the distances between residences of core group members and their partners were short, there was substantial contact between core group members and partners outside the core. Zenlimen et al (1999) and Aral (2004) research support the theory that the core group is maintaining the epidemic by acting as a reservoir for infecting others.

Ross and Radcliffe (2006) stated that prevention programmes need to identify the characteristics of individuals within core groups who have high rates of infection and exhibit rapid partner change, and who are therefore responsible for maintaining the infection within a community. Monteiro et al (2005) highlighted that 31% of four STIs occurred in core group areas identified as four inner city wards representing 15% of the population. Shahmanesh et al (2000) investigated whether the core group hypothesis was applicable to patients with Chlamydia in Birmingham. They found that in the large urban centre of the city there were key geographic areas which were associated with Chlamydia infection which also exhibited a considerable overlap with gonorrhoea.

Logistic regression models and GIS have been extensively used to identify core groups, see above. Harper and Winslett (2006) propose the use of classification trees to define risk groups. They used classification trees to identify risk groups in pregnant women. Classification trees analysis uses selected independent variables to group pregnant women according to dependent variables in a way that reduces variation. This technique could be used to identify core groups in sexual health (Evenden et al, 2006).

3.2.5 Behavioural Models

Gotz (2005) produced a multivariate logistic regression model used to identify risk factors associated with Chlamydia in the Netherlands. The prediction rule was intended to guide individuals in their choice of participation in Chlamydia screening when offered, and also to identify Chlamydia screening targets at the population level. Pinkerton et al (2003) developed a mathematical model which incorporated the effect of two behavioural change strategies: reducing the number of sexual partners and increasing condom use. Brandeau et al (1993) created a dynamic compartmental model to assess programs for HIV screening in the US state of California. The model demonstrated that screening all women potentially could be beneficial if they showed relatively modest levels of behavioural change. Behavioural change was captured in the model by allowing movement between high and low risk groups. The changing of behaviour was assumed to result from education and counselling and was modelled by decreasing the rate of transition to the later stages. Behavioural change took place during screening and was assumed then to be permanent. This is a limitation of the study a point which was conceded by the authors, as they state that some individuals may revert to riskier behaviour. Turner et al (2006) developed a stochastic individual based dynamic sexual network model of Chlamydia transmission. Estimating the parameters for the models of sexual behaviour and transmission was complex. Data used to populate the model related to partnership formation and behavioural parameters came primarily from NATSAL. A gap was built in the model between partnerships during which time no new partnerships can be formed, plus a gap to prevent the original partnership reforming immediately. For many parameters in the model few data are available including: the proportion of individuals desiring short partnerships, the proportion of individuals changing from wanting short partnerships to long partnerships each year, the average duration of long partnerships, the annual increase in preferred partnership duration and the duration of average gap between partnerships. Model outputs were grouped by age, sex and sexual activity and were compared to NATSAL 2000.

3.2.6 Behavioural Change

Pimenta et al (2003[a]) who evaluated the Pilot Chlamydia Screening Programme, state that it would be difficult to judge the impact that screening may have on long term behaviour. Several women who were interviewed said that the experience had highlighted the need to practice safer sex and raised awareness of Chlamydia. They understood that it may be beneficial to be screened following a change in sexual partner. Improvements in public awareness and greater education on STIs are necessary to help alleviate perceived stigma and distress associated with positive results (Pimenta et al, 2003[b]; Pavlin et al, 2006). Increased publicity generated by the screening programme aided normalisation of the topic of infection in the target group;

this should be actively promoted. Radcliffe et al (2001) suggested that young adults are the group most at risk from Chlamydia and that these individuals are an important target for health education interventions to encourage behavioural change. They go on to suggest that interventions should therefore be appropriately targeted at members of the core group with the aim of reducing high-risk behaviour. Pinkerton et al (2003) support this view and suggested that behavioural change interventions should be carefully tailored to address specific STI related behavioural risks.

The model developed by Pinkerton et al (2003) suggested that condoms are more effective at reducing the cumulative transmission risk for HIV than for other infectious STIs. However caution is required in extrapolating from one STI to another and from one behaviour risk reduction strategy to another and indeed from one model to another. The underlying premise is that if participants increase their condom use or take other steps to reduce their HIV risk then these same behavioural changes will also reduce their risk of STI infection. All STDs are not created equal and neither are all behavioural risk reduction strategies.

3.3 Geographical Information Systems

This section provides an overview of what Geographical Information Systems (GIS) are and how they are used, focusing on healthcare contexts. This section is structured as follows: provides a definition of GIS; GIS use in evaluating access to and location of health services (part 3.3.1); GIS use to monitor and report on disease and infection outbreaks (part 3.3.2); GIS role in identifying partnership formation (part 3.3.3); and how GIS has been combined with other methodologies (part 3.3.4).

Kamel Bolous, Roudsari and Carson (2001) produced a methodological review of geomatics which incorporates: GIS, Global Positioning Systems and other remote sensing methodologies. This paper provides an excellent introduction to the field. They begin the paper with an interesting quote:

> *"Space is an essential framework of all modes of thought. From physics to aesthetics, from myth and magic to common everyday life, space, in conjunction with time provide a fundamental ordering system for interlacing every facet of though…In short, things occur or exist in relation to space and time" (R.Sack, 1980 taken from Kamel Bolous et al, 2001)*

The 1854, Cholera outbreak in London, Dr John Snow using a hand drawn map discovered that the source of the disease was a contaminated water pump. Dr Snow plotted the cases on a street map and found that they clustered around a Bond Street water pump. The pump drew water from a supply contaminated by sewage. Snow proved his theory that Cholera was transmitted through contaminated drinking water. Snow was actually performing what is now referred to as spatial analysis, commonly used in GIS (Kamel Bolous et al, 2001; Moore and Carpenter, 1999)

GISs in terms of modern day technology are an integrated set of computer hardware and software tools to capture, store, edit, organise, analyse and display spatially referenced data (Moore, 1999; Kamel Bolous et al, 2001). The data can exist in multiple dimensions of time and space usually up to four dimensions. GIS systems allow data mining to take place which can be layered onto maps of an area of interest.

Analysis using GIS needs to follow good cartographic principles (Quinn, 1999) if the results are not to be misleading. This is because one of the main advantages of GIS is the available graphical output; an effective method of communication, if used incorrectly could be misleading (Kamel Boulus et al, 2001; Moore et al, 1999)

In terms of health related GIS, Moore et al (1999) split down the application of GIS into three categories: i) the spatial properties of delivery systems and their accessibility; ii) the associated utilisation and planning of health care services and iii) the spatial structure of disease patterns in both static and dynamic forms. The remaining parts of section 3.3 follow a similar structure, part 3.3.1 examines the accessibility and utilisation of proposed and existing health services; part 3.3.2 explores the application of GIS to the monitoring and analysis of disease

3.3.1 Access to Health Services

Access to health service has been broken into two categories: i) the distance between demand and supply and ii) the planning of suitable sites for new fixed or movable facilities constrained by a number of factors. The above will be discussed following a brief explanation of the common geographical approaches applied.

The most popular geographic problems that are applicable in the health care context include: i) Location Set Covering Problem (LCSP), which seeks to supply all demand points from centres located within a given distance; ii) p-median, minimises average distance travelled by the customers on their way to the service; iii) p-centre, minimises the maximum distance between a centre and a furthest assigned demand point; and, iv) Maximal Covering Location Model (MCLP), a limited number of centres is deployed so as to include as much demand as possible within the coverage distance (Marianov and Taborga, 2001).

Wang and Luo (2005) assessed the spatial and non-spatial factors associated with accessibility to primary healthcare in Illinois. A two-step floating catchment area method was implemented in a GIS to measure accessibility based on travel time. The spatial and non-spatial factors were integrated. They found that population subgroups differ in terms of healthcare needs and accessibility according to their age, sex, social class, ethnicity and other non-spatial characteristics. West Midlands GIS Service looked at catchment areas of breast cancer screening sites and at the relative distances patients must travel for gynaecology and obstetrics services (Kamel Boulos et al, 2001).

Accessibility to HIV care services in Toronto was investigated using GIS by (Fulcher et al, 2005), with the aim of identifying any disparities. The distance measure used in the evaluation of the services was based on the shortest distance between two points. The GIS was adapted to enable "what if" scenarios to be evaluated to aid decision makers i.e. suggestions for location of services. The main finding was that highly served neighbourhoods were the more urban/densely populated areas of Toronto. They noted that the distance measure used may not be appropriate, and perhaps the public transport system should be used as the measure. Bendall et al (2007) used mapping to assess access to GUM clinics in Cornwall among 16-25 year olds. The data related to the first year of Cornwall's screening programme. Proximity to a testing centre seemed to be the main determinant of uptake. Langford and Higgs (2006) investigated the implications of adopting differing spatial representations of population on healthcare accessibility modelling outcomes. Results suggest that the degree of disadvantage experienced in rural areas may be greater than has previously been recognised.

Marianov and Taborga (2001) constructed a model and heuristic to ascertain the most effective location of public health centres providing non-vital services in competition with existing private health centres. The aim was to find the solution of this problem, the equilibrium between maximum coverage of low-income population and an adequate capture of high-income population between the private and public facilities. A 30 node network, not an actual map of the area was used to construct a conceptual model of the city of Santiago, Chile. It was use to assess "what if" scenarios, the proposed locations of new hospitals. The model did not consider the capacity of the centres however the authors identified this as a potentially limiting factor. Fulcher et al (2005) previously discussed, in relation to the accessibility to HIV services, provided graphical representation of current service locations and planned to map locations for potential outreach programmes. Through the analysis conducted by Bendall et al (2007) the PCT responsible for TR14 and T27 postcode districts in Cornwall, UK, commissioned enhanced sexual health services for these areas.

Not all access models involve the location of fixed facilities such as hospitals, clinics and dentists. Mobile health units can also benefit through the use of GIS systems and analysis to determine better locations for units based on demand or time. A good example of this is: an ambulance location decision support tool developed in Sweden (Andersson and Varbrand, 2007), in which the level of preparedness was included in a GIS system to enable ambulance dispatchers to reposition ambulances during the day. This model assumes that ambulance relocations are instant as the simulation does not have a way to keep track of travel times, which is unrealistic.

3.3.2 Identification of infection levels

The most common methods in the identification of disease/infection include: disease mapping, clustering techniques, diffusion studies, identification of risk factors etc. Mapping diseases includes mapping point locations of cases, incidence rates by area and standardised rates. Moore et al (1999) stated that:

> *"Person, place, time: these are the basic elements of outbreak investigations and epidemiology. Historically, however, the focus in epidemiologic research has been on person and time, with little regard for the implications of place or space even though disease mapping has been done for over a hundred years"*

The extensive literature review conducted by Kamel Boulos et al (2001), identified several examples where GIS had been used in identifying infections/disease rates: i) Spatial patterns of filariasis in the Nile Delta, Egypt, and prediction of villages at risk for filiariasis transmission was conducted by the Centre for Health Applications of Aerospace Related Technology (CHAART); ii) CHAART investigated Lyme disease in Westchester County, New York, leading to the development of satellite remote sensing. This informed public health workers leading to reduction in the disease incidence; iii) HealthMap a joint WHO/UNICEF programme intended to monitor the Guinea Worm Eradication Programme. It has also been used in the control prevention and eradication of: Guinea worm, onchocerciasis, lymphatic filariasis, malaria, schistosomiasis, intestinal parasites, blinding trachoma and HIV; iv) WHO using GIS in its Leprosy Elimination Programme; v) MARA – Mapping Malaria Risk funded by several international bodies including the UK Welcome Trust, aimed to produce an atlas of malaria risk for Africa. Through mapping the continent appropriate control measures could be tailored for each region utilising available resources more efficiently; vi) the Small Area Health Statistics Unit (SASHU), in London, set up following the identification of a cluster of childhood leukaemia near the Sellafield nuclear plant in 1983. SASHU use GIS to investigate unusual clusters of disease particularly around industrial installations.

Core groups in relation to sexual health have been identified using GIS. The identification of dense core groups using GIS has been carried out, in Baltimore, USA, relating to the spread of STIs (Zenliman, 1999). Core groups were identified utilising GIS by Monterio et al (2005) who examined the incidence of four STIs. The STIs were found to be spatially correlated around the inner city areas of deprivation. The key finding was that 31% of all STIs occurred in four inner city wards, keeping with the core theory. Shahmanesh et al (2000) identified similar geographical clustering of Gonorrhoea and Chlamydia in Birmingham. Overlapping of the areas of Gonnorhoea and Chlamydia infections were identified, which could facilitate locally targeted sex education. Zenliman (2002) used GIS to assess gonorrhoea and Chlamydia levels at Fort Bragg the US Military base in North Carolina. The geographical epidemiology of infectious diseases can help identify the source of outbreaks, and give directions to control strategies. Evenden et al (2006) utilised GIS to geographically referencing to map the prevalence of Chlamydia, leading to the identification of "hot spot" postcode clusters. Screening could then be focussed rather than screening everyone in a region under the age of 25 as the NCSP recommends. Bendall et al (2007) also assessed the prevalence of genital Chlamydia with GIS in Cornwall and found highest rates of infection were noted in two areas with poor access to GUM clinics.

3.3.3 Partnership formation

Zenliman (1999) found that sexual partners tended to reside closer to one another than would be expected. Indeed the partners of patients in core areas in Baltimore live remarkably close to one another, and the partner selection patterns in general indicated a non-random distribution. Through GIS the distance between residence of core residents and their partners were identified as being short, there was substantial contact between core residents and those outside the core. This supported the view that the core areas are important in maintaining a community wide epidemic, by functioning as a reservoir for infecting other areas. This view was supported by Shahmanesh et al (2000) who reported that spatial distance between partners in core gonorrhoea areas is shorter than those in non-core zones. It is important to note that partnership formation tends to be with a partner from a similar group; however, spatial bridging can occur, which is the formation of partners from different locations. Aral (2004) points out that although spatial bridging is not in itself a high risk activity, sexual mixing with residents of areas where incidence of STI is higher may constitute high risk activity.

3.3.4 GIS and Simulation

Harper et al (2005) used a simulation location-allocation approach to determine the optimal location of an outpatient department within a city, and the provision of hospital-based specialist services for cardiac and dental surgery respectively. These case studies took into account the service capacities, distribution of patients and ease of access. The location of Oral and Maxillofacial Surgery, Plastic Surgery and ENT facilities in London was examined and the model was used to evaluate various scenarios which were used as the basis for complex provision of dental services across London. The number of Coronary Artery Bypass Graft (CABG) procedures were to increase as part of the government plan to expand revascularisation services on the NHS in England and Wales. New locations were to be developed for the site of a cardiac centre, with the issue being the importance of centre locations for patient access whilst assuring a critical mass at each centre. Simulation was used to test 43 scenarios, before a several locations were recommended.

The ambulance location decision support tool developed by (Andersson, 2007) allowed the dispatcher to manually assess the level of preparedness based on the ambulance locations. A simulation model was developed which suggested to the dispatcher potential locations where ambulances could be relocated following the dispatch of an ambulance. The urgency of the calls were included, so that if an ambulance is on route to a call and a higher priority call came in then the ambulance could be re-routed. De Silva and Eglese (2000) developed a prototype spatial decision support system (SDSS) for contingency planning for emergency evacuations. The focus of this paper was on the integration of the packages; essentially the linking of an object oriented simulation model to a GIS. The simulation was capable of incorporating the behaviour of evacuees on road networks within the danger zone, the GIS was primarily used for storing the information and providing the visual display. GISs are capable of successfully analysing and managing static data, they are limited in their functions to deal with dynamic data associated with an external model. This paper aids the field by demonstrating that it is possible to enhance GIS by linking it to an external model.

3.4 Chapter Summary

In terms of the behavioural literature that has been discussed it is clear that it is difficult to treat the individual factors identified in isolation. The factors interrelate and weave together to influence an individual's sexual behaviour. Key factors were identified from the literature and broad agreement was found between the various studies but the results were affected by the culture, geography and time period of the studies.

The discussed behavioural factors were used to inform the development of a questionnaire to assess the sexual behaviour and attitudes, of those people in the research area, namely the Portsmouth and surrounding area. Interestingly many studies stressed the need to better educate the public about STIs. In addition to assessing the sexual behaviours and attitudes of the Portsmouth area an opportunity presented itself to assess the educational level a person reaches and their level of awareness of STIs. The development of the questionnaire will be discussed in chapter 9.

The use of GISs has been showed in the focused literature review on health care applications to be a useful tool in the planning and implementation of interventions and programmes. Previous work had already been carried out in the Portsmouth area to plot Chlamydia infection rates onto maps to identify potential screening targets (Evenden et al, 2006). Similarly to the behavioural research GIS has a temporal facet which needs to be taken into consideration. In chapter 7, the Chlamydia incidence levels for the Portsmouth and surrounding areas are geographically referenced, to show how Chlamydia infection rates have changed over time.

4 Sexually Transmitted Infection Modelling and Hybrid Simulation

4.1 Chapter Introduction

This chapter explores and reviews the simulation literature related to sexual health and to hybrid simulation. The review itself is split into three broad sections: modelling in sexual health (sections 4.2 to 4.5); other related modelling in healthcare (sections 4.6 to 4.8); and, hybrid simulation modelling (section 4.9). The modelling sections are split into deterministic, stochastic and other models. The aim of the chapter is to identify potential areas in the literature that have not been previously explored or investigated to their full potential; and to suggest appropriate methods and techniques to address these areas.

There are many modelling techniques. This chapter focuses primarily on computer simulation and mathematical models. The choice of model should be dependent on the system being modelled, however many modellers are influenced by personal preference and their ability (Brennan, Chick and Davies, 2006). Taxonomies of modelling in healthcare have been proposed by Barton, Bryan and Robinson (2004); Brennan et al (2006); Davies, Roderick and Raftery (2003); and, Karnon (2003), to provide guidance on which models are appropriate in what situations; their advantages and drawbacks. Welte, Postma, Leidl and Kretzschmar (2005) assessed the impact of model choice when evaluating Chlamydia screening programs. If incorrect assumptions or structures are used then the model findings and suggestions may be flawed and subsequent decision may be incorrect (Brennan et al, 2006). These taxonomies focussed on differentiating techniques into when and where they should be used, giving little consideration of the combination or integration of the approaches, which may widen the scope of existing methodologies and address the situations which do not fall neatly into the existing taxonomies.

The National Institute for Clinical Excellence (NICE) requires commissioned economic analysis of new technologies or drugs (Barton et al, 2004). NICE are interested in mean cost per Quality Adjusted Life Years (QALY) gained and Probabilistic Sensitivity Analysis (PSA). Cooper et al (2007) provide an explanation of QALYs and the incremental cost-effectiveness ratio (ICER) and why the costs and effectiveness measures are often subject to discounting over time. NICE's requirements may influence the researchers chosen methodology, but modellers need to choose the approach which best fits the situation being modelled (Brennan et al 2006).

Decision trees, Markov models (Barton et al, 2004), Discrete Event Simulation (DES) and System Dynamics simulation (SD) (Brennan et al, 2006) are the main modelling techniques used in healthcare evaluation. The advantages and drawbacks of each approach have been well established and the taxonomies previously discussed provide these.

When modelling a system the simplest model that adequately reflects the system should be chosen. However, Davies et al (2003) argue that the choice of a simplest model should not lead to the omission of those factors that substantially influence the results and conclusions. Cooper et al (2007) though suggested that population-based models, which tend to complicate model construction, be used in order to evaluate healthcare interventions as they can provide the costs, health benefits and the cost effectiveness of the interventions, as they capture individual differences between people and can track history. The choice of what to include and what to exclude when model building can be thought of as a combination of science and art.

4.2 Sexual Health Modelling

Mathematical modelling was introduced to the STI field in the 1980s (Aral and Roegner, 2000). As the subsequent sections will demonstrate, other modelling approaches have been utilised, but primarily STI modelling has focused on the spread of infections rather than the provision of services. Over and Aral (2006) suggest that it is not an accident that mathematical simulation models play a larger role in understanding STIs than they do for many other diseases. The models illuminate the complex dynamics of STI interventions and the effects of policy interventions. The determination of variable values is crucial and can drastically affect models. van Valkengoed, Moore, van den Brule, Meijer, Bouter and Boeke (2004) stressed that existing Chlamydia screening studies may have made incorrect assumptions regarding variable values which may lead to under or overestimation of the effectiveness screening.

4.3 Deterministic Sexual Health Models

The use of deterministic models to model the spread of infectious diseases, such as STIs has been questioned. Many have argued that they presume a constant force of infection and ignore the impact of re-infection (Roberts, Robinson, Barton, Bryan et al, 2006; Roberts, Robinson, Barton, Bryan et al, 2004), thus ignoring a change in prevalence over time. These models tend to also fail to account for uncertainty regarding many of the key variables, e.g. the probability of developing PID (Valkengoed et al, 2004). Different forms of deterministic model applied to sexual health are evaluated in the remaining parts of this section.

4.3.1 Decision Trees Models in Sexual Health

A decision tree methodology was used by Adams, LaMontagne, Johnston, et al (2004) to estimate the average cost in terms of screening and treatment, per Chlamydia positive episode for an opportunistic screening programme. They found that varying the proportion that accepted a test had the largest effect on the cost per offer, since the participants largely drive the overall costs of the screening programme. Identifying cases through screening with the aim to reduce transmission and prevent sequelae may save money in the longer term. Screening focused on identifying female cases with male partners assumed to be identified through partner notification. They assumed that partner notification is effective. Ginocchio, Veenstra, Connell and Marrazzo (2003) used a decision tree to evaluate three screening strategies specifically focused on asymptomatic men. The decision tree models discussed have several limitations such as: the accuracy of the probabilities used; the costs values assigned to treatment, the structure of the models ignores changing Chlamydia prevalence level over time and the impact of re-infection. These factors can be addressed in population approaches such as DES and SD.

4.3.2 System Dynamics/Compartmental Models in Sexual Health

The AIDS epidemic of the 80s and 90s acted as a catalyst for the development of STI modelling including SD and compartmental models. Dangerfield (1999) conducted a review of SD models in the UK and Europe noted their contribution in epidemiological studies particularly the analysis of the AIDS. Homer and Hirsch (2006) argued that SD modelling of chronic disease prevention should seek to incorporate all the basic elements of a modern ecological approach, including disease outcomes, health and risk behaviours, environmental factors, and health related resources and delivery systems. SD and compartmental models tend to represent homogeneous groups, as they represent entities such as people at an aggregate level. SD models attempt to capture heterogeneity by disaggregating the susceptible population into separate strata. They are not truly heterogeneous which can be captured in ABM and DES models. The underlying mathematical principles of the SD approach were highlighted as lending themselves to the modelling of infectious diseases.

Roberts and Dangerfield (1990) developed an SD model of the spread of AIDS in the UK to assess the efficacy of various intervention strategies. They identified a high risk subset of the male homosexual group who reported large partner-change rates and often high-risk sexual practices, as a high risk group that should be the focus of targeted interventions. Brandeau, Owens, Sox and Wachter (1993) developed a dynamic compartmental model of the HIV epidemic, incorporated behavioural change. The model enabled evaluation of HIV screening and intervention policies over time, and the effects on the entire population, rather than limited to the screened group. A criticism of this model is the assumption that the behavioural change from higher risk groups to lower risk groups continues over the time horizon of the model and there is no movement in the other direction. Griffiths, Lowrie and Williams (2000) developed a compartmental model of HIV/AIDS identified the age groups that need to be targeted for an intervention campaign to be most effective. They argue that behaviour governs infection rates and these rates are indirectly related to age, since behaviour is age dependent. Behavioural change was again identified as key factor in a compartmental model of HIV/AIDS model (Griffiths, Lawson and Williams, 2006). The parameters of the model were determined by estimation techniques by comparing model outputs with the observed incidence data from the European Non-Aggregate AIDS Data Set (ENAADS). This method of estimation assumed that parameters remain static, though many of the parameters are not. Pinkerton, Layde, DiFranceisco and Chesson's (2003) mathematical model of HIV/STD, modelled the effects of: reducing the number of sex partners and increasing condom use. The model suggested the same behavioural strategies have different effects on different STDs. Limitation of the model, include the omission of: non-random mixing patterns, selective condom use, sexual contact network characteristics, and concurrent partnerships.

Townshend and Turner (2000) developed an SD model to evaluate the cost-effectiveness of Chlamydia screening. Heterogeneity was captured in this population by disaggregation along two dimensions: age and sexual activity levels. The model suggested that screening would prevent significant numbers of infertility cases. The model highlighted that treating people who remain high risk increases the pool of people with a high potential for becoming infected and the incidence of re-infection. The model assumes that immediate partners of those found to be infective are themselves screened. The work was presented to the National Screening Committee (NSC) as part of the CMO's expert group's report, which contributed towards the implementation of the NCSP. Evenden, Harper, Brailsford and Harindra (2005) and Evenden, Harper, Brailsford and Harindra (2006) developed a SD model which captured the Chlamydia infection dynamics within a population. The model demonstrated like HIV and other STIs that high risk groups are key, in determining the overall infection dynamics of the system, as it provides a key source of new infection into the low-risk groups. Of particular importance was that the repeated re-infection mechanism was captured, along with the increased risk of sequelae this creates. The model demonstrated the immediate benefit of a screening and that greater cost benefit can be achieved by targeting high-risk groups. The identification of the high risk group is acknowledged as not being easy, Turner, Garnett, Ghani, Sterne and Low (2004) developed a compartmental model, used to investigate ethnic differences in rates of gonorrhoea. The reported sexual behaviours and mixing patterns generated major differences in the rates of gonorrhoea experienced by each subpopulation. They assumed a closed population to simplify the development of equations and estimation of parameters. The model outputs gave prevalence values close to the limit of persistence, such that small changes in behaviour would reduce the reproductive number to below one and the epidemic would be extinguished. The model did not take concurrent sexual partnerships into account, which have been shown to be important in the spread of STIs. A review of Chlamydia screening models suggested that all screening was cost effective (Honey, Augood, Templeton, Russell, Paavonen et al, 2002). The assumptions used in the models were questioned and more data particularly on the risk of complications in women with asymptomatic STIs is sought, as it has the greatest influence on the models results. The SD and compartmental models of Chlamydia and Gonorrhoea discussed incorporate various behavioural parameters, but unlike the HIV models, do not incorporate behavioural changes. The scenarios evaluated tend to focus on different screening rates. Partner or contact tracing is assumed to be effective in the models, which is unrealistic. It is important to note that the prevalence of a disease or infection is influenced by the combination of the natural dynamics of the epidemic and the influence of intervention programmes (Stover, 2000). Modelling has shown that a prevalence plateau may be the result of the natural dynamics of the epidemic, and not necessarily a planned intervention.

4.4 Stochastic Sexual Health Models

4.4.1 Markov Models in Sexual Health

Harper and Shahani (2003) demonstrated with a Markov model the provision of effective and efficient care to HIV/AIDS patients throughout Mumbai in India. The model incorporated: a high-income group (HIG), those who can afford tests and drugs; and a low-income group (LIG) those who are unable to afford all of the tests and drugs. The LIG group were found to pass through the disease states to death quicker than their HIG counterparts. They suggested that clinic managers could use the predicted numbers of patient in each clinical state to help plan for future health care needs and potentially obtain future Government or NGO (Non-Government Organisation) funding. Xu, Ding and Hu (2007) developed a Markov computer simulation, to forecast the proportion of the population infected with HIV against the total population in the transmission course of AIDS in China in next 20 years.

Oxman, Smolkowski and Noell (1996) developed a multi-compartmental iterative Markov computer simulation model of epidemic syphilis transmission based on empirical data. Endemic transmission resulted from adding a small core group of individuals with very high levels of partner exchange (300-400 partners per year) to a population with levels of partner exchange seen in the general population. Epidemic resolution could result from immunity or subtle changes in the size of partner exchange rate of the core group. Initial modelling results suggested that having a small subpopulation with a very high level of sexual activity was necessary for epidemic propagation. For control activities to be effective in preventing or interrupting transmission, they must be directed at those individuals and sub-communities that are involved in core transmission.

Kretzschmar, van Duynhoven and Severijnen (1996) used a discrete markov model implemented as a Monte Carlo simulation model describing pair formation and separation and disease transmission as stochastic processes. The underlying structure of the sexual contact pattern was used to study the spread of two STIs: gonorrhoea and Chlamydia. Spread of the STIs was modelled in an age-structured heterosexual population with a highly sexually active core group. Contact tracing strategies, screening of various subgroups, and the effect of condom use were compared. Contact tracing is very effective as a prevention strategy, and screening should be targeted to the highly active core group, and age is not sufficient as a determinant for high sexual activity to make screening of certain age groups useful, and, finally, that consistent condom use by a fraction of the population can contribute substantially to the prevention of STIs. If individuals are treated regardless of the status of their partner, infected partners will act as a reservoir and quickly re-infect their partners. Kretzschmar, Welte, van den Hoek and Postma (2001) produced an individual-based stochastic model implemented by Monte Carlo simulation of Chlamydia. Partner referral contributed substantially to prevalence reduction, and investigated by varying the percentages of partners treated in the baseline scenario. The model assumed that all infected individuals who develop symptoms visit the GP and are then effectively treated. The size of the core group was a strong influence on the prevalence in endemic equilibrium. Roberts, Robinson, Barton, Bryan et al (2007) used a transmission dynamic mathematical model to assess the cost effectiveness of screening for Chlamydia trachomatis. Proactive register base screening for Chlamydia is not effective if the uptake of screening and incidence of complications are based on contemporary empirical studies, which show lower rates than commonly assumed. No robust information exists for quality adjusted life years (QALY) relevant to the sequelae associated with Chlamydia; they are based on expert opinion. The assumptions surrounding the probability of developing PID had the biggest single impact on the incremental cost effectiveness ratio. Value for money of screening programmes crucially depends on the values attributed to the adverse outcomes averted by screening, and these should be the subject of explicit public debate. The paper demonstrated that population Chlamydia screening, probably does not represent good value for money.

4.4.2 Discrete Event Simulation Models in Sexual Health

Adams, Barth-Jones, Chick and Koopman (1998) developed, a DES (HIVSIM) of a closed population of homosexual males, developed for the purpose of quantifying differences between the Retrospective Partner Trial (RPT) HIV vaccine trial design and the standard vaccine trial design. Their model captured real world characteristics including: concurrent and monogamous partnership; partnerships with differing rates of sexual activity; individuals with different partnership-seeking propensities. During a partnership, episodes of sexual contact occur at random intervals and if one of the partners is infected each sexual contact presents the opportunity for disease transmission. Rauner, Brailsford and Flessa (2005) used DES to evaluate the relative benefits of two potentially affordable interventions aimed at preventing mother-to-child transmission of HIV, in Tanzania. Life histories of individuals are simulated as time progresses, individuals: grow older; the females conceive, give birth to, and breastfeed children; people die; children grow up and bear children thus perpetuating the process. They assumed the test sensitivity and specificity were both 100% and that all women were 100% compliant with bottle-feeding instructions. These assumptions are, of course, unrealistic but they enable clearer comparisons to be made since they show the maximum benefit achievable from a given policy.

Turner, Adams, LaMontagne, Emmett, Baster and Edmunds (2006) noted that screening for a STI has both direct individual and indirect population-wide effects. They developed an individual based, stochastic dynamic sexual network model of Chlamydia infection, which has an SIS structure, capturing these non-linear effects. The model results suggested that an opportunistic screening programme could reduce Chlamydia prevalence, providing that the healthcare settings offer screening to the entire eligible population when they attend, partner notification is maintained or improved, attendance rates to these healthcare settings remains high, and a significant proportion of those offered screening accept the invitation. Turner, Adams, Gay, Ghani, Mercer and Edmunds (2006) stressed that Chlamydia epidemiology remained poorly understood, resulting in the estimation of model parameter of sexual behaviour and transmission complex. The model was parameterised primarily by NATSAL 2000. Individuals are explicitly represented in the model by age, gender, preferred number of partners, preferred duration of partnerships, identity of current and past partners, infection status, and other clinical characteristics such as number of screens and results. Age is an important determinant of sexual behaviour and Chlamydia risk.

4.5 Other Sexual Health Models

Adams, Koopman, Chick and Yu (1999) developed the Geographic-Environmental Reinfection Modelling Simulator (GERMS) a SIS model of infectious disease transmission. The model is a network-valued stochastic process. Each node represents an individual in the population. Arcs may be added or removed through time as relationships between individuals are formed and dissolved. The model accounts for realistic infection transmission systems by explicitly modelling: i) heterogeneous populations of individuals with varying social and geographic characteristics ii) complex interaction between individuals to characterise opportunities for transmission, iii) infection characteristics such as transmission probabilities and infection duration, and iv) contact and infection histories. The work already allows for the modelling of a number of behavioural changes that may be a result of intervention programs. Chick, Adams and Koopman (2000) go on to suggest that the GERMS model helps to unify two approaches to infection modelling: deterministic differential equations and stochastic discrete individual simulations. Their model allows for partnership concurrency, as well as infection, recovery and re-infection. For simplicity the population is closed. They suggested that model exploration can proceed in stages, with deterministic models being used to explore some high-level issues. The general stochastic discrete individual model can then be used to refine or extend the analysis. These results help to bridge the gap between deterministic differential equation analysis and stochastic discrete individual simulation models for the study of infectious diseases.

Kretzschmar (2000) described network models, which include concurrent partnerships formation, are a natural extension of pair-formation models. Partnership duration and network structure should be taken into account when estimating the impact of STI prevention. Contact tracing can contribute significantly to reducing incidence and prevalence of STI, modelling has to be developed further to gain a better understanding of the relationship of network structure and the spread of specific STI. Neglecting those aspects of STI transmission dynamics may lead to false expectations about the impact of prevention and intervention program. Volz and Meyers (2007) developed a mathematical dynamic network model, to predicting disease transmission where each individual has a characteristic behaviour, but the identities of their contacts change in time. The existing mathematical methods assumed that contacts between individuals are fixed at least for the duration of an outbreak. Contact patterns may be quite fluid, with individuals frequently making and breaking social or sexual relationships. Dynamic contact patterns are shown to shape epidemiological dynamics in ways that cannot be adequately captured in static network models or mass-action models. Boily, Poulin and Masse (2000) evaluated and identified the most adequate sampling schemes to estimate the mixing matrix between sexual activity classes from large population networks with one or more components. Unbiased estimation of mixing patterns from large population networks is possible with a snowball sampling design in which the initial sample of index cases is drawn from the general population, all partners of the index case are recruited, and only one generation of partners are traced.

4.6 Other Relevant Health Models

Proudlove, Black and Fletcher (2007) sought to clarify why OR had been making relatively little contribution in improving patient flows in the NHS. They argue that large complex models may be unnecessary and even obstruct clear insight and guidance being gleaned from the model, for problem owners. They suggested that simple models can be of practical value in understanding and managing complex systems, changing mind-sets and driving collection and use of operationally valuable data. Baldwin, Eldabi and Paul (2004) found that simulation applications in healthcare are not as widely perceived for problem solving as it is in other application areas. Healthcare systems are often complex in that they involve multiple decision-makers and thus understanding and communication between the various stakeholders is potentially problematic. An iterative modelling approach based on the participation of stakeholders is proposed to enhance understanding and communication, is demonstrated through a case study and suggested that involving stakeholders throughout enables them to fully appreciate the findings. Harper and Pitt (2004) proposed a framework for successful OR model implementation following working with a number of participating health service organizations. Eldabi, Paul and Young (2006) went on to consider the future use of simulation as a problem solving technique in healthcare settings. A survey of experts including academics and industrialists, suggested that whole system approaches with more joined up modelling or mixed methods to tackle problems rather than single-solution-based practices were the future.

Kotiadis and Mingers (2006) explored the possibility of combining problem structuring methods with hard OR methodologies. They reflect on the barriers to such combinations that can be seen at the philosophical level, such as paradigm incommensurability, and cognitive level, type of personality and difficulty of switching paradigm. They presented their argument through the use of an intermediate care case study where Soft Systems Methodology (SSM) and DES are combined, that these problems are not insurmountable and that the result can be seen as interplay of the soft and hard paradigms. The idea of yin and yang is proposed as a metaphor for this process. This process is supported by Lehaney, Clarke and Paul (1999) who provided an account of soft system intervention, undertaken at a NHS hospital outpatients department. They noted that SSM was used to identify gaps between the customers' and providers' expectations. Simulation was used following the SSM work. A procedure to reduce unexpected non-attendance of patients has been implemented. Patient bookings are now scheduled according to simple rules, with the result that in clinic waiting times have been reduced. A model of the intervention process has been accepted by the key stakeholders as a sensible framework for continuing investigations. More widely, the participants increased their knowledge of their own systems. Sachdeva, Williams and Quigley (2007) noted that Healthcare OR has had limited success in achieving a sufficient level of stakeholder acceptance to lead to implementation of results. They combined OR methodologies to achieve greater acceptance of results for organizational change. Patient flow delays in the Paediatric intensive care unit (PICU) at Children's Hospital of Wisconsin (USA) were modelled using hard OR (simulation), with active stakeholder participation. Results from hard OR, particularly for politically sensitive issues, were persuasive but inadequate to result in change. Soft OR (cognitive mapping) was used to identify new issues and enhance results. After obtaining a holistic understanding of the system using hard and soft OR, stakeholders were willing to implement results from each independently, supporting the development of a common form of knowledge.

Soft OR approaches should not be overlooked as they play a vital role in healthcare modelling, as touched upon previously. Thunhurst (2007) utilised cognitive mapping to model 'upstream' problems in health sector planning. These address the underlying causes of ill health, and stand in contrast to 'downstream' health service planning which addresses the consequences of ill health. It argued for a fuller appreciation of the potential contribution of OR in this and in other areas of upstream health sector planning.

4.7 Deterministic Relevant Health Models

There are many forms of deterministic models, and to reflect the literature previously discussed in the sexual health section 4.3, the same structure is followed here.

4.7.1 System Dynamics/Compartmental Models in Relevant Health Settings

Wolstenholme (1993) proposed a revised framework for SD within a philosophy of modelling as learning using a SD model of community care as a case study. Systems' thinking combines knowledge acquisition and both qualitative and quantitative modelling, with the intention to assist the development of a shared understanding of how culture, power and politics combine to affect the behaviour of a process.

Royston, Dost, Townshend and Turner (1999) discussed how the OR department in the DH had used SD modelling in several areas of health care policy and programme development and implementation. It outlined applications in disease screening and in developing emergency care.

Lane, Monefeldt, and Husemann (2003) evaluated the collaborative process of building a SD model in order to understand patient waiting times in an A&E department. They explored the issues that arise when involving health care professionals, in model development. This paper was followed up by, Lane and Husemann (2008), who aimed to assess the usefulness of SD to elicit proposals concerning ways of improving patient experience. Initial interviews and hospital site visits generated a series of stock/flow maps. At workshops NHS staff were able to propose ideas for improving patient flows and the elicited data was subsequently employed to create a finalized suite of maps of a general acute hospital. The maps and ideas were communicated back to the DH and subsequently assisted the work of the NHS Modernization Agency.

Wolstenholme (1999) applied SD to the development of national policy guidelines for the NHS. A model of total patient flow through the NHS was developed to test major new structural initiatives for relieving pressure on health services and to complement health initiatives in "joint working" at the interface between health care sectors. The policies tested include the use of "intermediate care" facilities aimed at preventing patients needing hospital treatment or continuing and community care. Intermediate care, together with reductions in the overall length of stay of all patients in community care made possible by its use, was demonstrated to have a much more profound effect on total patient wait times than more obvious wait time solutions, such as increasing acute hospital bed capacity. The results provided a clear demonstration that adjustments to flow (throughput) variables in a system provide significantly more leverage than adjustments to stock (capacity) variables.

Lane, Monefeldt and Rosenhead (2000) described the formulation and calibration of a SD model of the interaction of demand pattern, A&E resource deployment, other hospital processes and bed numbers; and the outputs of policy analysis runs of the model which vary a number of the key parameters. An interesting result was that reductions in bed numbers do not increase waiting times for emergency admissions; instead they increase sharply the number of cancellations of admissions for elective surgery. They suggested that basing A&E policy solely on any single criterion will merely transfer the effects of a resource deficit to a different patient group.

Brailsford, Lattimer, Tarnaras and Turnbull (2004) and Lattimer, Brailsford, Turnbull, Tarnaras et al (2004) used SD as a central part of a whole-system review of emergency and on demand health care in Nottingham. An SD model was used to simulate patterns of demand, activity, contingencies, and system bottlenecks. A range of scenarios were tested to determine their likely effectiveness in meeting future objectives and targets. Without intervention, assuming current trends continue, Nottingham hospitals were unlikely to reach elective admission targets or achieve the government target of 82%

bed occupancy. Admissions from GPs had the greatest influence on occupancy rates. Modelling indicated considerable potential to intervene to alleviate these problems, in particular by increasing the care options available in the community.

4.8 Stochastic Relevant Health Models

There are many forms of stochastic models, and to reflect the literature previously discussed in the sexual health literature section 4.4, this section follows the same structure.

4.8.1 Markov Models in Relevant Health Settings

Akkerman and Knip (2004) analysed patients' length of stay (LoS) in hospital wards following cardiac surgery. Scenarios to evaluate LoS were evaluated using Markov chain theory and Monte Carlo simulation experiments. The scenarios centred on the examination of unused bed capacity in hospital wards, to attain a more efficient allocation of hospital beds. McClean and Millard (2007) used Markov models to describe movements of patients between hospital states. The average cost at any time was evaluated for two scenarios. The model suggested illustrated the idea that keeping acute patients longer in hospital to ensure fitness for discharge, may reduce costs by decreasing the number of patients that become long-stay. The model can be used to determine costs for the entire system thus facilitating a systems approach to the planning of healthcare and a holistic approach to costing.

4.8.2 Discrete Event Simulation Models in Relevant Health Settings

Robinson (2005) examined how DES became so established and possible future developments. DES has kept pace with developments in computing and Robinson questions whether this is desirable or that the methodology itself be developed. In addition to potential changes in model development: the domain of application for simulation and integration with other simulation approaches are considered as future possibilities.

Jun, Jacobson and Swisher (1999) conducted a literature review of the application of DES modelling to health care clinics and systems of clinics. Several examples of DES as effective tool for allocating scarce resources to improve patient flow, while minimising health care delivery costs and increasing patient satisfaction were identified. Fone et al (2003) reviewed the literature to evaluate the extent, quality and value of computer simulation modelling in population health and health care delivery. Simulation modelling has been undertaken in a wide range of health care topic areas, including hospital scheduling and organization, communicable disease, screening, costs of illness and economic evaluation. Both Jun et al (1999) and Fone et al (2003) note the lack of implementation.

Eldabi, Paul and Taylor (2000) observed that when conducting an experimental study in healthcare systems, two problems are faced, those of uncertainty and complexity. Uncertainty is related to identifying variables for data collection. Complexity is related to the existence of many interacting variables, each of a stochastic nature. They focus on the use of DES in supporting decision making in a randomised clinical trial (RCT) of Adjuvant Breast Cancer (ABC). With the aim of helping health economists identify the key factors active in the RCT through the development of a model of the healthcare related processes being studied by the RCT. Eldabi, Irani and Paul (2002) explored why DES is not as widely perceived as being useful for problem solving in the health-care arena. The problem they suggest may be a result of the complexity of health care systems in that they involve multiple decision-makers, making, understanding and communication between the stakeholders potentially problematic. They developed and demonstrated a modelling approach aimed at promoting problem understanding and efficient communication which they suggest would contribute to the solution. They concluded that involving stakeholders throughout not only helps them to understand their problem better, but also enables them to more fully appreciate the findings resulting from the model.

Gorunescu, McClean and Milard (2002) described the movement of patients through a hospital department using classical queuing theory and, presented a way of optimising the use of hospital resources in order to improve hospital care. A queuing model is used to determine the main characteristics of the access of patients to hospital, such as mean bed occupancy and the probability that a demand for hospital care is lost because all beds are occupied. The queuing model was capable of optimising the average cost per day by balancing costs of empty beds against costs of delayed patients. Ashton et al (2005) developed a DES model of an NHS walk in centre. The model developed of this multi-service facility was used identify existing and potential problems, and to investigate ideas for their 'solution'. The model enabled ideas for best practice borrowed from elsewhere to be quickly tested for suitability in the local situation.

Swisher, Jacobson, Jun and Balci (2001) provided details of the design and development of a DES model of a physician clinic environment within a physician network. DES model focussed on the operations of a family practice healthcare clinic, but also capture the operations of a centralized information centre. The simulation model provides a tool for risk-free evaluation of operating policies in the clinical environment.

van der Meer, Rymaszewski, Findlay and Curran (2005) discussed how an increasingly detailed and complex DES model was developed of orthopaedic medicine. The purpose of the model to help meet management challenges. The model focused on the reduction of waiting times for elective patients, both for a first outpatient appointment and for the subsequent commencement of in-patient treatment. The paper discussed the application of a modelling methodology based on the idea of requisite models evolving over time—that is participatory, iterative and focused on enhancing the clients' understanding of the main performance drivers of the service. Bowers and Mould (2004) noted that Orthopaedic care is affected by uncertainty. Given the variability and uncertainty in the demand much of the theatre time is not used. A DES model was used to explore the balance between maximising the utilisation of the theatre sessions, avoiding too many overruns and ensuring a reasonable quality of care in a typical hospital in the UK. Results suggested that if patients were willing to accept the possibility of their treatment being cancelled, substantially greater throughputs could be achieved. Vasilakis, Sobolev, Kuramoto and Levy (2007) used a DES model to compare two methods of scheduling outpatient clinic appointments, with the main measure being the number of patients waiting for appointments, and the times to appointment and to surgery. Their results suggested that pooling referrals, so that clinic appointments are scheduled with the first available surgeon, has a differential impact on different segments of patient flow and across surgical priority groups.

Connelly and Bair (2004) investigated the potential of DES models applied to investigation of emergency department (ED) operations. They developed an ED DES called: Emergency Department SIMulation (EDSIM). The EDSIM model was used to compare the fast-track triage approach with an alternative acuity ratio triage (ART) approach whereby patients were assigned to staff on an acuity ratio basis. The ART approach was found to reduce imaging bottlenecks and average treatment times for high acuity patients, but resulted in an overall increase in average service time for low-acuity patients. Ceglowski, Churilov and Wasserthiel (2007) argued that simulation models only model patient treatment implicitly, tracing the paths patients follow through the ED. They proposed that through data mining techniques core patient treatments could be identified from the ED and incorporated into a DES model. The essential characteristics of the presented model are used to indicate a generally applicable methodology for identifying bottlenecks in the interface between an ED and a hospital ward. Hay, Valentin and Bijlsma (2006) described their developed generic modelling environment in the healthcare domain that breaks away from the conventional entity driven request for resource. With their approach they created models of emergency care in four NHS hospitals that reflect more realistically the way emergency care is actually delivered. The model found paradoxically, that in simulating emergency care, it is best if the patient does not come first. Wullink, van Houdenhoven, Hans, van Oostrum et al (2007) used a DES model to investigate how long waiting times for emergency operations increased a patient's risk of postoperative complications and morbidity. In this study two approaches of reserving Operation Theatre (OT) capacity were compared: concentrating all reserved OT capacity in dedicated emergency OTs, and evenly reserving capacity in all elective OTs. Model demonstrated that emergency patients are operated upon more efficiently on elective OT instead of a dedicated Emergency OT. The results of this study led to closing of the Emergency OT.

Other uses of DES include: Groothuis, van Merode and Hasman (2001) demonstrated how to evaluate the use of catheterization capacity using DES. Katsaliaki and Brailsford (2007) developed a DES model to investigate policies for managing the blood inventory system in a UK hospital supplied by a regional blood centre. Harper and Shahani (2002) suggested that a model for the planning and management of bed capacities must be capable of incorporating uncertainty, variability and representing limited resources. They created a simulation model capable of incorporating: various types of patient flows, at the individual patient level, and resulting bed needs over time. The work has highlighted the need for evaluating hospital bed capacities in light of both bed occupancies and refused admission rates. The relationship between occupancy and refusals is complex and often overlooked by hospital managers, whose deterministic models do not take into account.

Traditional DES models have been adapted and improved through new innovations and the combination with methodologies from other fields. Davies, Brailsford, Roderick, Canning and Crabbe (2000) expanded on the traditional DES approach to develop a patient oriented simulation technique (POST) model to evaluate diabetes screening. The model described the progress of a population of diabetic patients, including new arrivals, over 25 years. The interval between screenings was found to be more important than screening sensitivity. Brailsford and Schmidt (2003) described a DES model of attendance for screening for diabetic retinopathy, a complication of diabetes, which took into account the physical states, emotions, cognitions and social status of the people modelled. The model also uses some ideas from the discipline of health psychology. We believe that this approach provides what is potentially a far more accurate method of modelling patients' attendance behaviour, compared with the standard approach of simple random sampling of patients. Brailsford, Sykes, Harper (2006) highlighted that outcomes from simulation models to improve patients' health have failed to take into account patient behaviour. E.g. patients may not complete a course of a prescribed medication because they find the side-effects unpleasant. A study designed to evaluate this medication which ignores such behavioural factors may give unreliable results. They discussed the incorporation of human factors in simulation models. Harper, Shahani, Gallagher and Bowie (2005) developed a discrete-event geographical location-allocation simulation model of evaluating various options for the provision of health services.

4.9 Hybrid Simulation

Hybrid simulation in the context of this research is defined as the combination and interaction of the simulation approaches previously discussed, i.e. SD and DES models; continuous and discrete; deterministic and stochastic. Current unpublished work into hybrid simulation that the author is aware of is be undertaking by: Sonia Vanderby (University of Toronto), Jennifer Morgan (University of Strathclyde) and Mitual Desai (University of Southampton). This section discusses: methodological papers addressing the proposed hybrid approaches; examples of hybrid models in fields such as power simulation and manufacturing are evaluated; the section concludes with the few examples of hybrid modelling related to healthcare.

4.9.1 Hybrid Simulation Methodological Papers

In the 1970s, Fahrland (1970) noted that system modelling had been classified as either discrete event or continuous. Fahrland posed the question: "Why limit the modelling to either discrete event or continuous when situations are evolving which require more interdisciplinary solutions?" A combined approached would provide a larger set of techniques for addressing problems. The combined approaches would bridge the gap between the automatic-control/physical-modelling people and the management-control/operations-research. The system being modelled must exhibit strong feedback or interaction between the discrete and continuous parts of the model; otherwise the system could be modelled as two separate models. Barton (2000) defined hybrid systems as systems that exhibit both discrete state and continuous state dynamics. In addition, these two aspects of system behaviour interact to such a significant extent that they cannot be decoupled and must be analysed simultaneously. We consider the modelling, simulation and sensitivity analysis of hybrid systems, with particular emphasis on the interactions between discrete and continuous subsystems. The discrete and continuous subsystems only interact at distinct points in time known as events, with the state of the discrete subsystems only changing at events. At events the discrete subsystems may alter the continuous subsystems in one of two ways: an alteration to the functional form of the embedded differential equations describing the continuous state evolution, and/or an impulsive forcing that causes the continuous state to be discontinuous or jump.

Remelhe (2001) examined a software environment which was dedicated to modelling and simulation of complex technological systems. Usually, these formalisms are based on different computational models and include continuous as well as discrete-event dynamics. They presented a hierarchical refinement concept which allows specification of new formalisms efficiently by deriving them from already defined formalisms. The basic formalism has to support continuous time integration of differential equations as well as discrete time simulation. Barton and Tobias (2000) demonstrated how continuous models may be simulated using a discrete executive: the discrete quantity approach (DQA). The method could also be used to allow a continuous part to be added to a discrete model without the need for a hybrid executive.

Chahal and Eldabi (2008) produced a meta-comparison of DES and SD. Classified under three main perspectives: systems perspectives, problems perspective and methodology perspective. Both SD and DES being established simulation techniques, one would have expected there to be a strong association between the two. However there seems to be little interaction between the two approaches. Tako and Robinson (2009) compared the use and perceptions of managers' use of DES and SD simulation approaches. They found no significant difference from the users' point of view between DES and SD in terms of model understanding and model usefulness. The study suggested that from the user's point of view the type of simulation approach used makes little difference. Users are likely to be more interested in what they can learn from a model than about how the model works, provided the model addresses the problem.

4.9.2 Hybrid Simulation of Power Systems

Power systems naturally lend themselves to hybrid simulation. Hiskens and Sokolowski (2001) noted that large disturbance behaviour of power systems often involves complex interactions between continuous dynamics and discrete events. Behaviour they suggest can be captured by a model that consists of differential, switched algebraic and state-reset (DSAR) equations. Power systems are characterised by: i) continuous and discrete states; ii) continuous dynamics; and, iii) discrete events, or triggers. Due to the size of the models they are most effectively constructed using a hierarchical or modular approach. Components are grouped together as subsystems, and the subsystems are combined to form the full system. This allows component and subsystem models to be developed and tested independently. Van Cutsem, Grenier and Lefebvre (2006) described a new method of dealing with simulation of long-term responses of power systems to large disturbances in the presence of discrete events. The power system was modelled under the quasi steady-state (QSS) approximation, a method combining detailed and QSS time simulations, the former being used for accuracy and the latter for efficiency reasons. Detailed time simulation is used to analyse the short-term period following a large disturbance and identify the discrete controls triggered. Next, QSS simulation is used to simulate the same time interval with the discrete controls imposed as external events, before letting the system evolve as usual in the long-term.

4.9.3 Hybrid Simulation of Industrial and Manufacturing Systems

Wolstenholme and Coyle (1980) and Coyle (1985) challenged the view that it was very hard to model discrete and random events in continuous simulation languages. A coal mining example was chosen, as it exhibits both continuous and event-based processes. They demonstrated that, one can produce events within continuous languages.

Lavoie, Kenne and Gharbi (2006) considered a production system consisting of multiple tandem machines subject to random failures. A combined discrete/continuous simulation model was used to obtain an estimate of the cost in a fraction of the time necessary for a discrete event simulation model, by reducing the number of events related to parts production. This is achieved by replacing the discrete dynamics of part production by a set of differential equations that describe this process. They proposed the combined discrete/continuous model and noted that discrete event only simulation is much more time consuming than the combined simulation.

Rabelo, Helal, Jones and Min (2005) argued that DES models alone are not enough to capture the impact of production decisions on enterprise level performance measures. They proposed an SD-DES hybrid simulation which followed a distributed simulation like approach. Production decisions at the shop floor were modelled using one or more DES models while the corporate and business levels of the enterprise were modelled using SD. The models shared data such that business decisions were made in the SD models. The outcomes of these decisions were then input to the DES models. The changes in performance in the DES models were fed back to the SD model for evaluating the impact of the business decisions and adjusted them as needed. As manufacturing systems become more integrated, DES capabilities will face serious challenges. One limitation of this study is that the data was exchanged between the DES and SD model manually, although they suggest that this would be the next step of the research. Venkateswaran, Son and Jones (2004) and Venkateswaran and Son (2005) explored how the concept of hierarchical production planning (HPP): provided a formal bridge between long-term plans and short-term schedules. A hybrid simulation-based production planning architecture consisting of SD components at the higher decision level and DES components at the lower decision level was developed. HPP was used to break the problem into smaller units, based on time of planning horizon. The DES model captures the detailed operational procedures of the shop. The production order release quantity from the SD model is translated into the release quantity of component parts whose flow through the shop is governed by queue rules or control policies. The daily update of work in process, inventory and average cycle time of products is fed back to the SD model from the DES model.

Greasley (2005) used system dynamics in a DES study of a production-planning facility in a gas cylinder manufacturing plant. This case showed how a traditional DES study incorporated an unplanned investigation using SD. He argued that the use of SD as a supplementary tool to incorporate organisational aspects has helped to generate a new methodology for DES so that human aspects can be taken into account to enhance the models relevance for decision making. The SD model was used to evaluate the sales department which was outside the scope of the manufacturing DES model.

4.9.4 Hybrid Simulation of Computer Simulation and Engineering Systems

Schwetman (1978) described the structure and operation of a hybrid simulation model in which both simulation and analytic techniques are combined to produce efficient yet accurate system models, of a hypothetical computer system. The accuracy and efficiency of the hybrid technique are demonstrated by comparing the result and computational costs of the hybrid model of the example with those of an equivalent simulation-only model. The simulation-only versions required from between 18 and 200 times as much CPU time as the equivalent hybrid model. Hybrid models can model systems which are not easily represented as a mathematical model. Hybrid models appear to be a cost-effective alternative to traditional DES models of computer systems.

Donzelli and Iazeolla (2001) proposed the combination of three traditional modelling methods (analytical, continuous and discrete-event), into a unique hybrid two-level modelling approach, to address software process simulation modelling issues. At the higher abstraction level, the process is modelled by a discrete-event queuing network, which represented the component activities, their interactions, and the exchanged artefacts. At the lower abstraction level, the analytical and continuous methods were used to describe the behaviour of the introduced activities. The hybrid approach was applied to a waterfall-based software process which studied the effects of instability on various process quality attributes. The software process is composed of the event-driven dynamics of the artefacts moving among different activities, and of the time driven dynamics of the tasks within particular activities. When in a system the continuous and discrete dynamics coexist and interact, however, the behaviour and the performance of the process can be fully understood only by developing models suitable to represent all dynamics together with their interactions. Martin and Raffo (2001) demonstrated how simulation models of the software development process can be used to evaluate potential process changes. While SD models have been used to model the project environment, DES models are more useful when modelling process activities. Hybrid models of the software development process can examine questions that cannot be answered by either SD models or DES models alone.

4.9.5 Hybrid Simulation of Health Systems

Chick et al (2000) previously discussed in section 4.5 combined a deterministic differential equation model with a stochastic discrete-individual infection model of STD transmission. The deterministic models can be used to explore high-level issues. The general stochastic discrete-individual model can then be used to refine or extend the analysis. Chahal and Eldabi (2008) proposed the combination of DES and SD to form a hybrid model in a healthcare context. They argued that integrated healthcare poses challenges to the use of DES and SD in isolation. Hybrid simulation is the deployment of SD and DES in an integrative way, where both paradigms symbiotically enhance each other's capabilities and mitigate limitations by sharing information. Hybrid models function by bouncing information between the SD and DES components. They propose 3 different types of hybrid model: i) mixed continuous and discrete format – some aspects represented by SD and some with DES without clear distinction; ii) Process – Environment – process is represented with DES and Environmental factors with SD; and, iii) Hierarchical format – SD is used for strategic level and DES for operational level decision.

4.10 Modelling Opportunities

Many Chlamydia screening models have incorporated some behavioural factors such as: contraceptive use, frequency of sexual partnerships and acts. Unlike models of HIV/AIDS where behavioural interventions are scenarios which are evaluated in the models, Chlamydia screening models tended to focus on screening uptake and targeting specific risk groups rather than assessing the impact of behavioural change. There are Chlamydia screening models that adjust partnership frequency based on age. The possibility of behavioural change following treatment is rarely considered. A SD model of Chlamydia screening incorporating: gender, age, risk group, births, death, migration and behavioural change associated with ageing and following treatment will be developed, see chapter 11.

The author was aware of a DES model of a GUM developed by the Bensley and Sinclair from the DH, other than this model, which was not published in the literature; no other models of GUM departments were identified. DES has been shown in other similar healthcare settings such as: walk in centres, A&E and outpatient departments to be an effective method to evaluate alternative configurations and scenarios. A DES of the walk in clinic of a GUM department will be developed, see chapter 10. The aim of the

DES was to enable evaluation of proposed configuration of the GUM department in terms of: staff and other resources.

Hybrid modelling has been shown in other fields to be an effective approach in capturing the complexities, and providing a more holistic view of systems that exhibit both continuous and discrete traits, which cannot be easily decoupled.
The development of a new hybrid model of sexual health incorporating the new modelling opportunities identified above is proposed. The SD model which models the prevalence of Chlamydia within a population will provide demand information for the detailed DES model of the GUM department. The DES model accurately captures the process of how the demand identified by the SD model is processed by the GUM department. The number of people seen in the GUM model is then fed back into the SD model, before the process continues. The development of the hybrid model is discussed in detail, see chapter 12.

4.11 Chapter Summary

The chapter reviewed a selection of the literature from the field of STI and sexual health modelling incorporating several conditions including HIV/AIDS, Syphilis, Chlamydia and Gonorrhoea. The chapter highlighted the development of modelling process to capture the principles associated with disease transmission. Modelling of STIs has moved away from traditional static models which failed to take into account the changing prevalence levels of infections and the possibility of re-infection.

Literature was also examined in relation to modelling conducted in other healthcare settings with a particularly focus given to the development of operational level models relating to the supply of health service, most notably, DES models of outpatient hospital departments.

The literature suggested that many OR practitioners are moving towards the combination of modelling approaches to improve stakeholder “buy-in” and implementation of modelling results. In non-healthcare situations hybrid simulation models have been shown to model efficiently and effectively systems that exhibit continuous and discrete characteristics.

Following the review of the literature, modelling opportunities were identified and stated in section 4.10. These opportunities will be addressed in subsequent chapters.

5 Choice of Methods

5.1 Chapter Introduction

This chapter provides a justification of the methods employed in this research. It demonstrates how the methods were used in relation to research tasks developed to address the research questions. Section 5.2 identifies research tasks to address the research questions. The methods used to address the tasks are justified in section 5.3.

5.2 Research Tasks

To address the research questions (see chapter 1) and to obtain ethical approval, specific research tasks and the methods used to address them needed to be made explicit at the outset of the research. The tasks which received NHS ethics committee and University of Southampton Research Governance Office approval were:

T1. What is the prevalence and incidence rate of Chlamydia in Portsmouth and surrounding area?

T2. What are the factors (e.g. socioeconomic and behavioural) that are associated with Chlamydia prevalence/incidence in an area?

T3. What is the difference in sexual behaviour, knowledge and attitudes between: attendees at the St Mary's GUM department and students from the University of Southampton?

T4. Can DES be used to model a GUM department to assess scenarios that the stakeholders are interested in?

T5. Can behavioural dynamics be adequately captured in a System Dynamics model of Chlamydia? Does the inclusion of behavioural factors make a difference in the evaluation of Chlamydia screening strategies?

T6. Can the developed DES and SD models be successfully integrated? Is the combination of DES and SD models in this healthcare context beneficial?

Table 5-1 illustrates how the research tasks mentioned above relate to the two research questions. How to reduce the prevalence of STIs (R1) is addressed by all of the research tasks. How to organise sexual health services to operate more effectively and efficiently (R2), is addressed specifically by research tasks T4, T5 and T6.

Research Question	Research Tasks
R1	T1, T2, T3, T4, T5,T6
R2	T4, T5, T6

Table 5-1: Which research tasks address which research question

Table 5-2 illustrates which chapters address which research tasks.

Research Task	Chapter(s)
T1	6 and 7
T2	6, 7, 8 and 9
T3	9
T4	6 and 10
T5	6, 8, 9 and 11
T6	10, 11 and 12

Table 5-2: Which chapters address which research tasks

5.3 Justification of methods

Data mining techniques and regression analysis were used to identify factors that were associated with Chlamydia from multiple data sources. These techniques were appropriate to reduce the number of data sources to a more select subset. These techniques were used in relation to research tasks T1 and T2.

A questionnaire was developed to ascertain qualitative behavioural factors relating to sexual behaviour, knowledge and attitude. Interviews and observation perhaps would be superior methods to obtain such information, however, how these methods would be deployed and obtaining ethical approval would have been more challenging. Although the questions were of a sensitive nature, they received ethical approval, as they were based on existing questionnaires included in studies including NATSAL (Johnson et al, 2001). The paper based and electronic questionnaire developed consisted of many questions to obtain the necessary information. The questionnaire was used to address research task T3.

Discrete Event Simulation (DES) was used to model the flow of patients through the GUM department. DES was an ideal approach given the queuing nature of the department. DES enabled the department to be modelled accurately and provided a tool which enabled different configurations of the department to be assessed. These "what-if" experiments can be quickly developed, run and evaluated prior to any implementation in the actual department. The visual nature of Simul8, the DES software used to model the department was also a bonus. It promoted stakeholder "buy-in" during the model construction as well as aiding in model validation and verification. DES was used primarily to address research task T4 and contributed towards T6.

System Dynamics (SD) Simulation was chosen as the method to model the spread of Chlamydia. This method was chosen primarily for the manner in which it incorporates feedback into the model. This is a key feature when modelling infectious diseases such as Chlamydia. The method can adequately capture the progression and regression through disease states. Given the size of the population being modelled of Portsmouth and the surrounding "PO" postcode area this further supports the use of an SD model. SD models are better suited than say DES models when modelling very large populations. The SD model like the DES model enables "what-if" scenarios to be evaluated, such as the impact of screening strategies. SD was used primarily to address research task T5 and contributed towards T6.

5.4 Chapter Summary

This chapter has:

- Developed a number of research tasks devised to address the research questions
- How the research tasks address the research questions
- Emphasize which chapters of the thesis address which research tasks
- Provided a justification of the methods used in this thesis

6 Chlamydia Screening Data Analysis

6.1 Research Tasks Addressed

T1. What is the prevalence and incidence rate of Chlamydia in Portsmouth and surrounding area?

T2. What are the factors (e.g. socioeconomic and behavioural) that are associated with Chlamydia prevalence/incidence in an area?

T4. Can DES be used to model a GUM department to assess scenarios that the stakeholders are interested in?

T5. Can behavioural dynamics be adequately captured in a System Dynamics model of Chlamydia? Does the inclusion of behavioural factors make a difference in the evaluation of Chlamydia screening strategies?

6.2 Chapter Introduction

The analysis presented in this chapter was based on Chlamydia screening data held by the GUM department at St Mary's Hospital, Portsmouth. The data was collected from May 2003 to April 2007 and will be referred to as the "new data". The data analysed by Evenden (2003), related to opportunistic screening data, GUM data and referral data for the period October 1999 to September 2000, this will be referred to as "old data".

The data analysis undertaken in this chapter aims to replicate the statistical analysis undertaken on the old data with the new data to enable comparison between the data sets. The similarities and differences between the new data and the old data will be highlighted. The graphs and tables presented in this chapter relate to the new data.

This chapter primarily addresses research task T1 but the analysed data is then incorporated in models developed in later chapters addressing research tasks: T2, T4 and T5.

6.3 Data Description

The new data consisted of over 47,000 Chlamydia test results, covering the period May 2003 to April 2007. This new data included repeat tests, which were visits by an individual to the same and different medical facilities recorded in the database over the time period. The total number of episodes extracted from the Chlamydia screening database (which will be referred to as the "database") was 47,134, and this data was made available on 4th April 2007.

The database was developed in Microsoft Access, in house, by St Mary's Hospital to record the core data and additional/optional data required for the National Chlamydia Screening Program (NCSP). The database records test data not only from the GUM department but from multiple sites from within the PO postcode area (see table 6-8). A detailed description of the database can be found in appendix B and the data extracted from it is discussed in appendix J. What follows is a description of the key components of the database, and the number of records contained within each of these components.

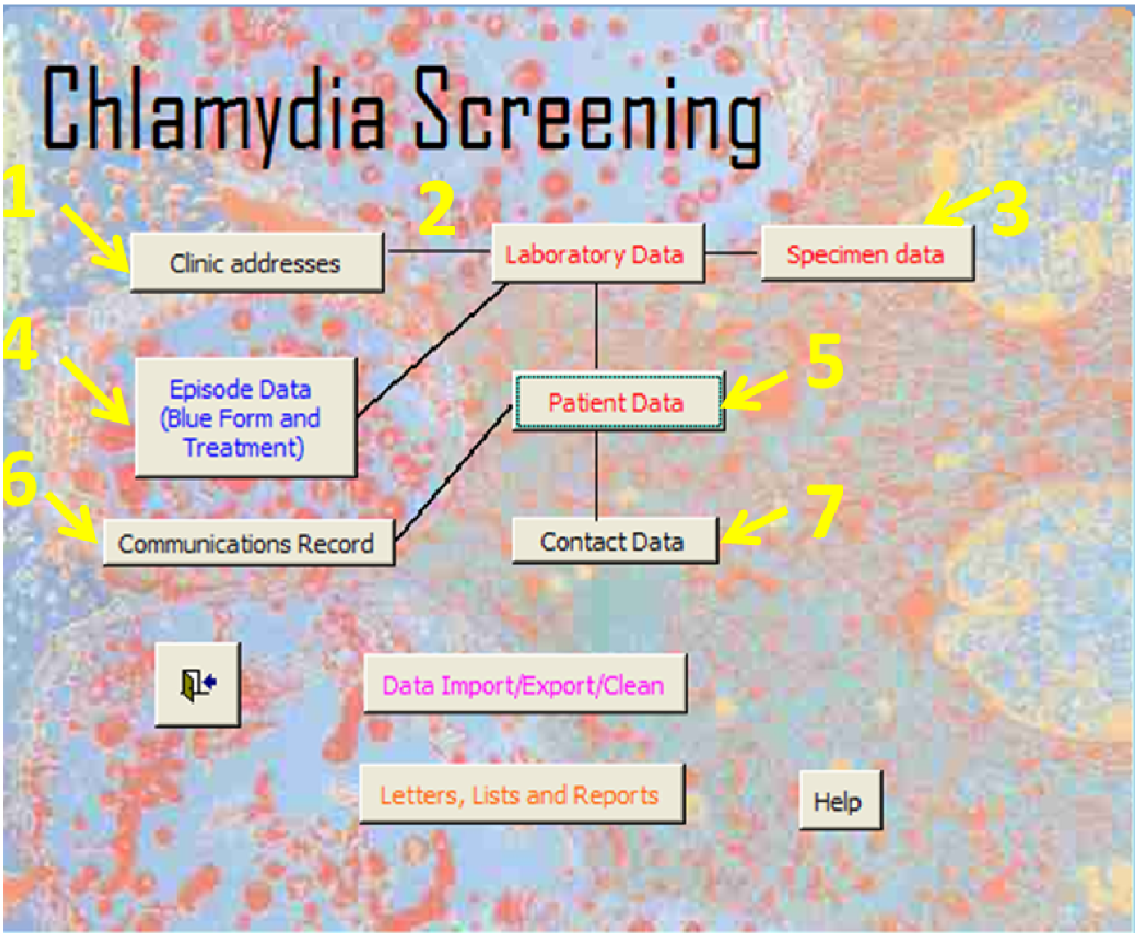

Figure 6-1: St Mary's Hospital GUM, Chlamydia Screening Database

Figure 6-1 above provides a screenshot of the database. Figure 6-1 has been annotated with numbers associated with a specific part of the database. Patients entered into the database were assigned a unique Hospital number which can be used to identify them. Each episode recorded is also assigned a unique episode number which when combined with the patient's hospital number can be used to identify how many times a patient has been screened for Chlamydia over the time period. Data was provided in an anonymous format; personal details such as name, and address were removed.

Table 6-1 provides a brief description of each element of the database, which has been highlighted. The Ref column of table 6-1 relates to the yellow annotated number on figure 6-1.

Ref.	Form	Records	Description
1	Clinic Data	186	Details of medical facilities, address, unique identifier
2	Laboratory Data	47,367	Details on test result, symptoms, basic patient information
3	Specimen Data	47,373	Tests run on specimen, test results
4	Episode Data	47,134	Patient details, data recorded for NCSP, Test result, Contacts
5	Patient Data	34,471	Unique patient Identifier, DOB, Gender
6	Communication Record	2,738	Communication with patients, reason, date, outcome
7	Contact data	7,647	Contacts of patient who attend, index patient results, contacts results

Table 6-1: Summary description of the main elements of the Chlamydia Screening Database

6.4 Confidence Interval Calculation

Confidence intervals (CI) were calculated for all incidence and prevalence calculations. This analysis used 95% confidence intervals throughout, which meant that there was 95% confidence that the true population value (prevalence and incidence, in this context) lies within the calculated limits. A population statistic is a (nominally) fixed value, and it was the uncertainty of the sample measurement which was being described using confidence intervals.

The Wilson score interval statistic was used to calculate confidence intervals for the prevalence and incidence rates, where $\hat{p}$ = calculated prevalence/incidence from the sample n, and $z_{1-\alpha/2} = 1.96$ for a 95% confidence interval, assuming a normal distribution approximation to a binomial (http://www.itl.nist.gov/div898/handbook/):

$$\frac{\hat{p} + \frac{1}{2n} z_{1-\alpha/2}^2 \pm z_{1-\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n} + \frac{z_{1-\alpha/2}^2}{4n^2}}}{1 + \frac{1}{n} z_{1-\alpha/2}^2}$$

6.5 Postcode District

Postcode districts are the first element of a postcode. For example the University's postcode SO17 1BJ, district would be SO17. Evenden (2003) focussed on the geographical analysis of the old data using postcode district and postcode sector. Postcode district will be discussed in section 6.5 and postcode sector in section 6.6. As such every effort was made to obtain data in a format that was comparable with the old data.

Data collected included, Hospital Number, Episode Number, Date of Birth, Sex, Postcode, whether the patient had a new sexual partner in the last 3 months, whether the patient had 2 or more sexual partners in the last 12 months, Ethnicity, Chlamydia Result, Date of Chlamydia Result. Data was obtained by running Microsoft Access queries on the Episode data contained in the database. Figure 6-2 demonstrates how 28,802 records were identified for further analysis from the original 47,134 records.

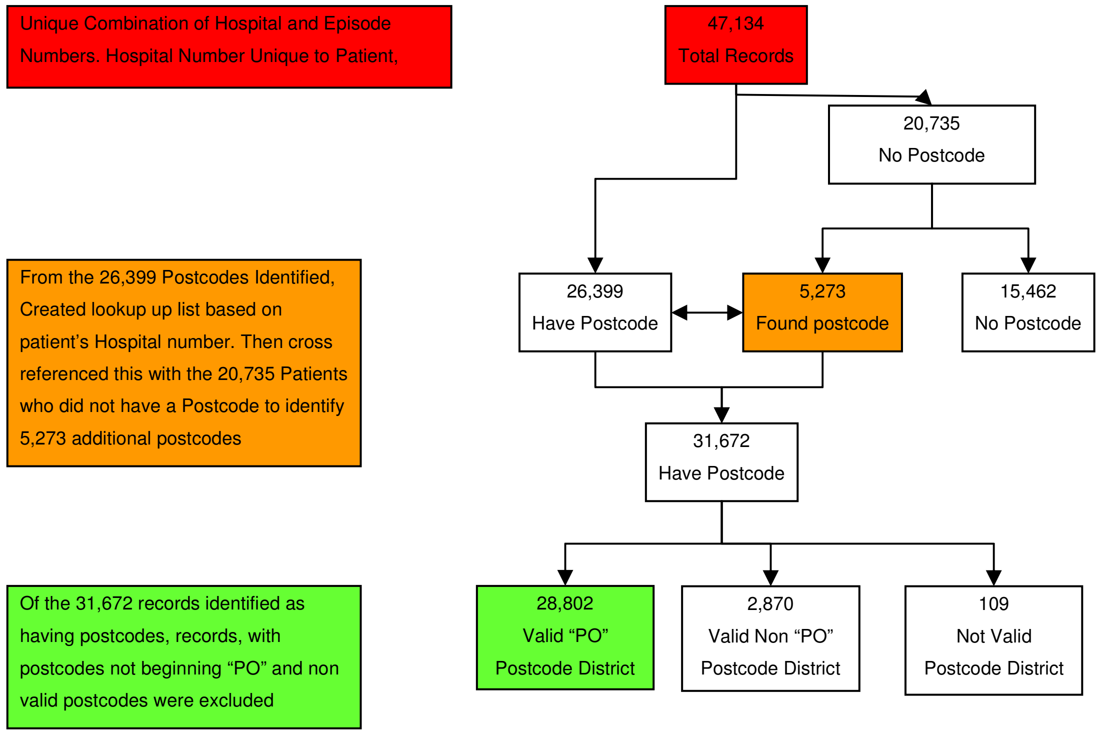

Figure 6-2: Data extraction from Chlamydia Screening Database

Not all patients had postcodes data associated with their record. 32.8% (15,462/47,134) had no entry in the postcode field of their record. This may have been due to the patient not providing the necessary details. However, correct data entry is less important than successfully treating a patient, even if it makes the analysis of the data more complicated and possibly less effective as it could have been.

31,672 records were identified as having some form of postcode. Further analysis of this data found that 28,802 records related to a "PO" postcode and these records remained in the study. Of the 2,979 postcodes that did not relate to a "PO" postcode, 2,870 related to non-"PO" postcodes. These non-"PO" postcodes related to 112 other locations within the UK. This could be due to the fact that Portsmouth is a University Town, so patients could have used their home rather than term time postcode; also Portsmouth is a Naval Port and is a Military Port so like the students', patients could have entered their home postcodes. 109 of those who had some form of postcode entered which were not valid were entered as text , E.g. HANTS, Fareham, Cosham etc. or as phone numbers.

Figure 6-3 provides a graph illustrating the total number of individuals within a postcode district aged between 13 and 26 in green and the number of people tested for Chlamydia in blue from the 28,802 postcode districts identified. The population data for each district has been derived from CENSUS data available from CASWEB (http://casweb.mimas.ac.uk/). The data analysis by Evenden (2003) focussed on the 16 to 24 age group. The current data relates to the 13 to 26 age group, as the 16 to 24 age group only accounted for 91.3% (26,320/28,802) of the records, whereas the 13 to 26 age group accounted for 99% (28,522/28,802) of the records.

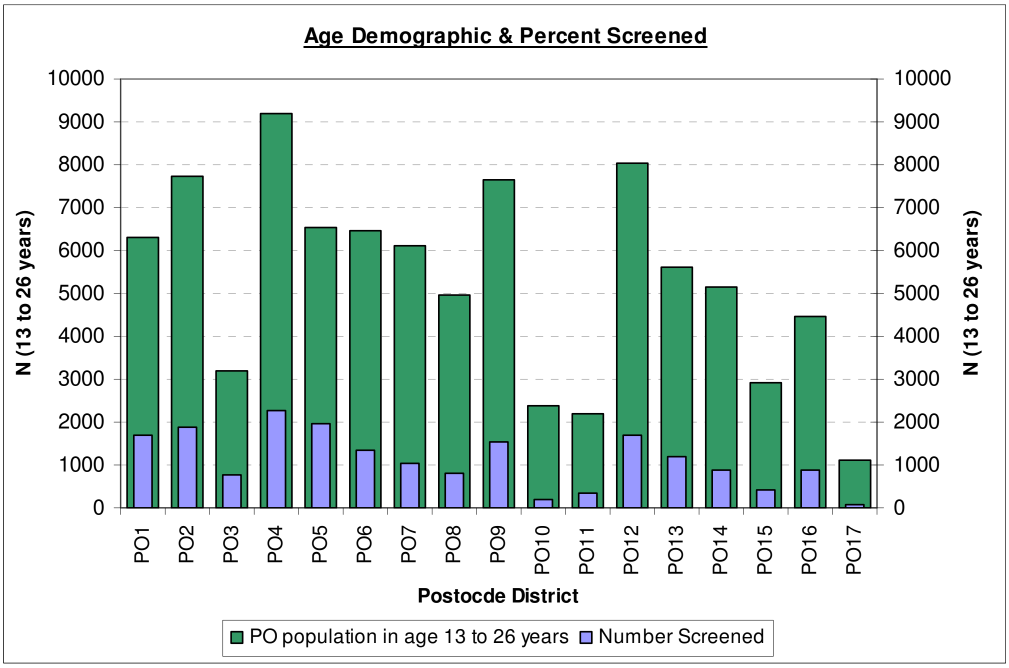

Figure 6-3: Age demographic by district and screened percentage

The percentage of each postcode district tested over the data collection period is shown in figure 6-4. Values were generally good (between 15-25%). PO17 had the lowest counts (113 tests) followed by PO10 (202 tests), and although they are included in the analysis care must be taken when interpreting the results. The pilot study data was likely to be influenced by incentives which were in place to encourage a high coverage level of the 16-24 year olds. The current data district populations are higher as they relate to a wider age range 13-26 year olds compared to Evenden (2003).

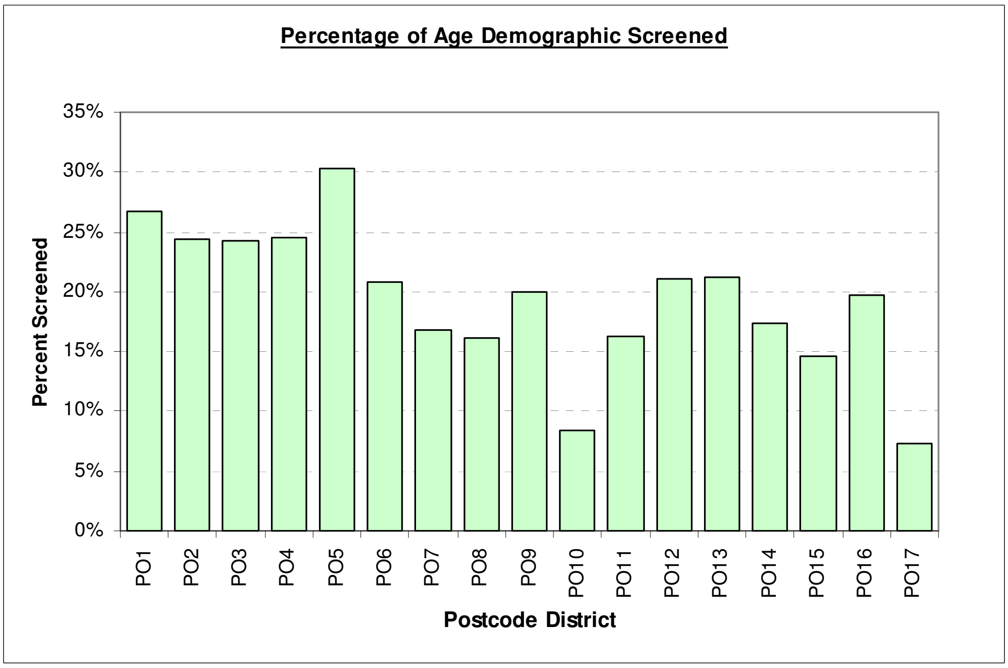

Figure 6-4: Percentage of 13-26 year olds screened

Figure 6-5 provides information on the infection rate between the genders. There is a significant difference between males (25.46%) and females (16.02%) (Chi Square=0.000, 1 d.f), therefore analysis on the new data was split by gender.

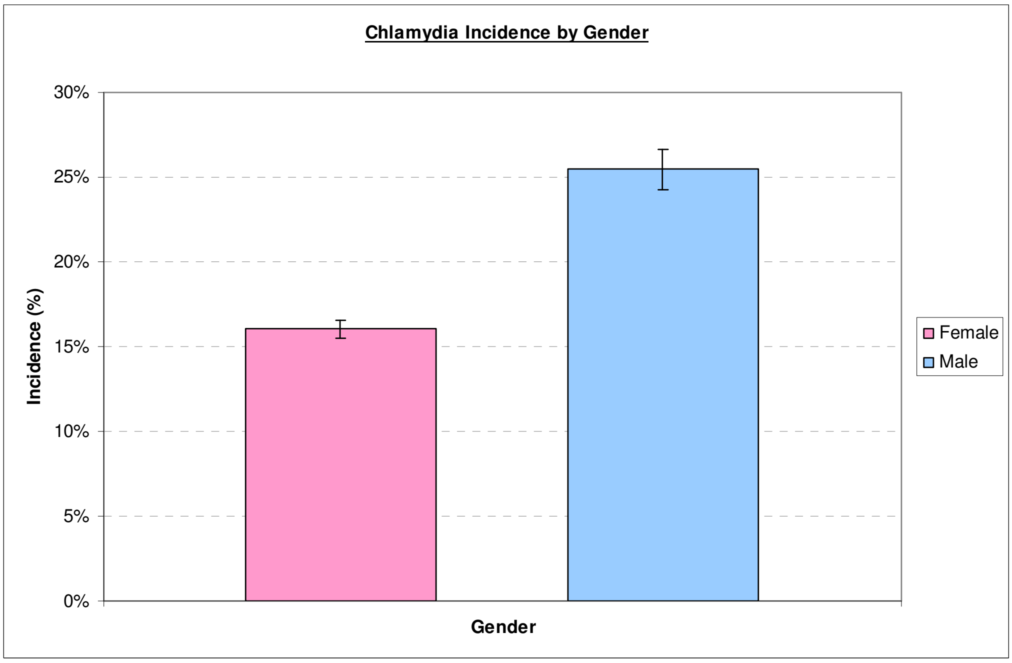

Figure 6-5: Incidence by gender

This differs from the old data where the data for males and females were combined, as the incidence rate was similar between the genders (~9% for females and ~8% for male). The incidence rates with the current data are 16.02% (CI=15.49–16.57) for females and 25.46% (CI=24.29–26.67) for males. The large difference between the two genders can be accounted for as the male patients who attend the department tend to be contacts of positive female patients. 14.4% of the male patients are contacts of positive patients, compared with 3.6% of the female patients; this is shown in table 6–2. From table 6–2 it can also be seen that nearly 65% of female patients were tested as part of screening when compared to 46% of male patients.

Reason	Total (Female)	Percentage (Female)	Total (Male)	Percentage (Male)
Not Stated	2408	11.04	1379	19.80
Chlamydia Screen	14152	64.87	3222	46.27
Screening and Symptoms	10	0.05	6	0.09
Screening and Contact of Positive	7	0.03	0	0
Symptoms	4445	20.37	1345	19.32
Symptoms and Contact of Positive	8	0.04	7	0.10
Contact of Positive	786	3.60	1004	14.42
Total	**21816**	**100.00**	**6963**	**100.00**

Table 6–2: Reason by gender

The Chlamydia incidence for females and males are shown in table 6–3 by reason for the test. The incidence of those who attend for Chlamydia screening was similar for female (15.06%) and males (17.47%). The incidence for contacts of positive, 60.05% of females who had a positive partner tested positive, compared to 68.23% for males.

Reason	Incidence (Female)	CI (Female)	Sample (Female)	Incidence (Male)	CI (Male)	Sample (Male)
Not Stated	0.91%	(0.60-1.38)	2,408	1.02%	(0.60-1.69)	1,379
Chlamydia Screen	15.06%	(14.47-15.66)	14,152	17.47%	(16.20-18.82)	3,222
Screening and Symptoms	10.00%	(1.78-40.42)	10	16.67%	(3.00-56.35)	6
Screening and Contact of Positive	0.00%	(0-35.43)	7	-	-	-
Symptoms	19.55%	(18.41-20.74)	4,445	37.47%	(34.92-40.09)	1,345
Symptoms and Contact of Positive	12.50%	(2.24-47.09)	8	85.71%	(48.68-97.43)	7
Contact of Positive	60.05%	(56.58-63.42)	786	68.23%	(65.28-71.03)	1,004

Table 6–3: Incidence by reason recorded by gender

Incidence was calculated for postcode district and separated by gender. The female and male incidence by district is displayed in figure 6-6 and figure 6-7 respectively. Female incidence appears to be fairly consistent in the postcode districts, varying between 13 – 18% and where appropriate confidence intervals have been added to each district. The data suggests that the variability displayed in the old data has been reduced however the overall incidence has increased. The postcode districts appear to be closely aligned as suggested by the smaller variability. The old data had some districts with relatively low incidence but these districts have appeared to increase considerably to similar levels as the districts with previously higher incidence. The variability in the incidence levels may have been lessened due to the extraction of the male data. This will be discussed in a later part of this chapter.

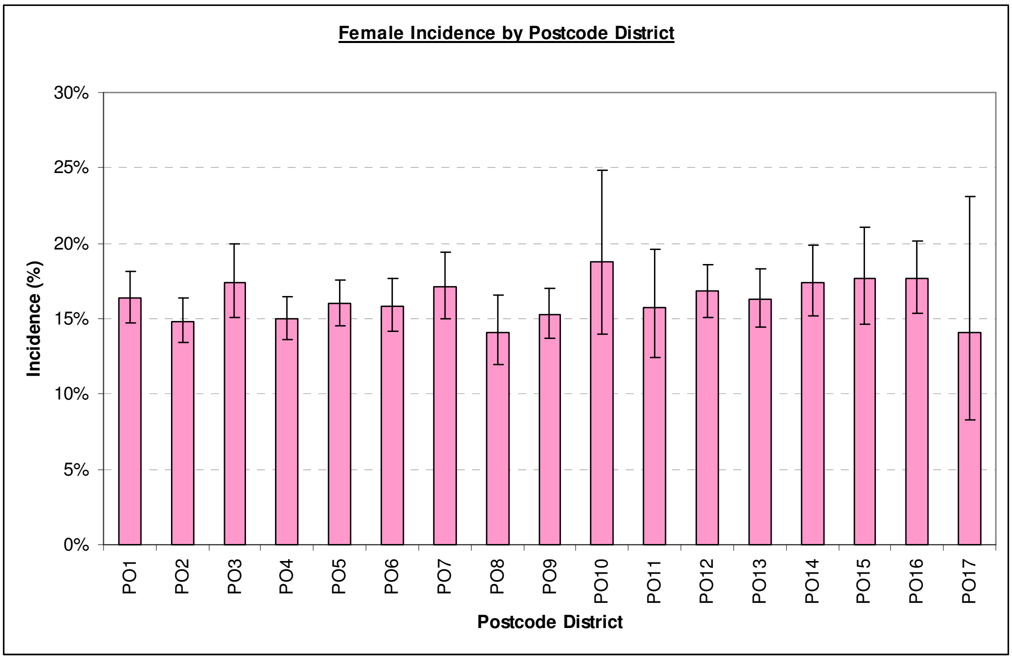

Figure 6-6: Female Chlamydia incidence by postcode district

Table 6-4 displays the data that figure 6-6 is based on. The table contains a population count and the sample size in each district, in the “Pop 13-26” and “Total” columns respectively. The confidence intervals are relatively small given the size of the sample, apart from district PO10 and PO17 which have relatively small sample size. As previously mentioned the old data relates to the 16 to 24 year old age group, therefore the pop 13 to 26 in table 6-4 is referred to as pop 16-24 in the old data table. General conclusions, PO10 (Emsworth and Wetbourne areas), PO15 (Fareham west and Whitely areas), PO16 (Fareham East, Portchester and Paulsgrove areas), PO14 (Fareham South and Stubbington areas), PO3 (Copnor and Baffins areas) and PO7 (Purbrook and Stakes areas) could be considered as districts with particularly high incidence. There are relatively few postcodes with low incidence an example being PO17 (consisting of Fareham North and Boarhunt and Southwick wards).

Female Screening Trial District Count							
District	**Pop 13-26**	**Total**	**Neg**	**Positive**	**Pos%**	**CI**	**Other**
PO1	6,301	1,869	1,527	306	16.37%	(14.76-18.12)	36
PO2	7,717	2,246	1,866	333	14.82%	(13.41-16.35)	47
PO3	3,181	921	741	160	17.37%	(15.06-19.95)	20
PO4	9,181	2,521	2,080	378	14.99%	(13.65-16.44)	63
PO5	6,545	2,279	1,867	365	16.01%	(14.57-17.58)	47
PO6	6,481	1,688	1,386	267	15.81%	(14.15-17.63)	35
PO7	6,098	1,089	879	186	17.07%	(14.96-19.43)	24
PO8	4,945	893	752	126	14.10%	(11.98-16.55)	15
PO9	7,655	1,821	1,501	278	15.26%	(13.69-16.99)	42
PO10	2,389	197	154	37	18.78%	(13.94-24.81)	6
PO11	2,180	396	329	62	15.65%	(12.41-19.56)	5
PO12	8,041	1,830	1,491	307	16.77%	(15.13-18.56)	32
PO13	5,598	1,415	1,161	231	16.32%	(14.49-18.34)	23
PO14	5,154	996	807	173	17.36%	(15.14-19.85)	16
PO15	2,922	538	426	95	17.65%	(14.67-21.11)	17
PO16	4,470	974	783	172	17.65%	(15.39-20.18)	19
PO17	1,114	85	69	12	14.11%	(8.26-23.07)	4

Table 6-4: Female screen test results by district

The incidence by postcode district for males shown in figure 6-7, as expected was considerably higher than females, which were given in by figure 6-6. Male incidence was more variable between the postcode districts varying from 20-35%. This could be due to the smaller numbers, in comparison with the female data. Like the female incidence data the graph suggests that the incidence in the areas with lower incidence have come more into line with the other districts.

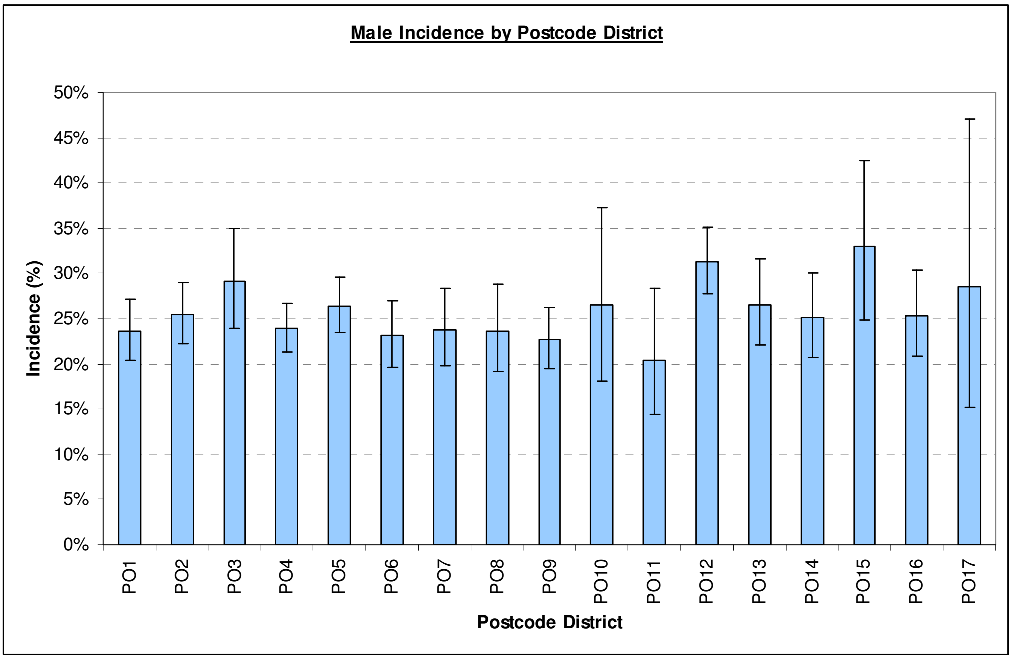

Figure 6-7: Male Chlamydia incidence by postcode district

As with table 6-4, table 6-5contains the data that figure 6-7 is based on. As can be seen from table 6-5, districts PO10 and PO17 have a relatively low sample (count = 79 and 28 respectively), this accounts for their relatively high confidence interval. Incidence levels for all male postcode districts are high, but those with particularly high incidence levels include PO12 (Anglesey, Leesland and Hardway areas), PO3 (Copnor and Baffins areas), PO17 (Fareham North and Boarhunt and Southwick) and PO5 (St Jude and St Thomas areas).

Screening Trial District Count							
District	**Pop 13-26**	**Total**	**NEG**	**POS**	**Pos%**	**CI**	**Other**
PO1	6,301	594	449	140	23.57%	(20.33-27.15)	5
PO2	7,717	640	469	163	25.47%	(22.25-28.98)	8
PO3	3,181	257	182	75	29.18%	(23.96-35.01	0
PO4	9,181	970	729	232	23.92%	(21.34-26.70)	9
PO5	6,545	780	570	206	26.41%	(23.44-29.61)	4
PO6	6,481	493	377	114	23.12%	(19.62-27.04)	2
PO7	6,098	386	293	92	23.83%	(19.85-28.33)	1
PO8	4,945	292	223	69	23.63%	(19.12-28.83)	0
PO9	7,655	590	455	134	22.71%	(19.51-26.26)	1
PO10	2,389	79	56	21	26.58%	(18.09-37.24)	2
PO11	2,180	127	99	26	20.47%	(14.37-28.31)	2
PO12	8,041	600	407	188	31.33%	(27.75-35.15)	5
PO13	5,598	331	241	88	26.59%	(22.12-31.59)	2
PO14	5,154	319	239	80	25.08%	(20.64-30.11)	0
PO15	2,922	106	71	35	33.02%	(24.80-42.43)	0
PO16	4,470	324	239	82	25.31%	(20.88-30.31)	3
PO17	1,114	28	20	8	28.6%	2.7%	0

Table 6-5: Male screen test results by district

6.6 Postcode Sector

Postcode Sectors consist of the postcode district plus the digit of the second part of the postcode for example the University's postcode is SO17 1BJ, the postcode sector would be SO17 1. Postcode sectors provide a finer level of detail in comparison to Postcode districts. As a comparison there are 130 postcode sectors in the Portsmouth (PO) area, compared to 34 postcode districts (National Statistics Postcode Directory, 2008). 28,802 records were identified with valid "PO" districts, figure 6-2. Of these 28,802 records, 15,045 had a valid "PO" sector. 13,757 records were either postcode district only as patients were reluctant to give their full details, or these data were omitted, or they were invalid. Therefore the finer level analysis was conducted with a smaller dataset. Figure 6-8 provides an overview of the number of sectors derived from the identified postcode districts.

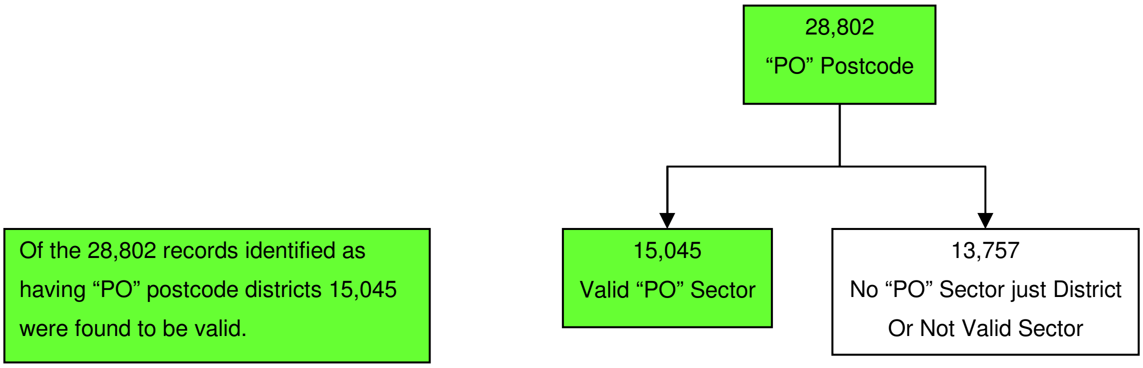

Figure 6-8: Sector breakdown from Chlamydia screening database

Sectors were only analysed if patients from within those sectors presented for treatment. 59 of the 130 possible sectors are discussed in relation to the female patients, and 53 of the 130 possible sectors are discussed in relation to the male patients.

Table 6-6 shown over the following pages provides a breakdown of the sector populations, and incidence with confidence intervals for the female population.

Sector	Pop 13-26	Total	NEG	POS	Pos%	CI	Other
PO1 1	1101	206	171	30	14.56%	(10.40-20.03)	5
PO1 2	852	128	108	17	13.28%	(8.46-20.24)	3
PO1 3	1239	221	198	19	8.60%	(5.57-13.04)	4
PO1 4	1191	194	166	20	10.31%	(6.77-15.39)	8
PO1 5	1918	365	329	30	8.22%	(5.82-11.49)	6
PO2 0	2154	374	338	32	8.56%	(6.13-11.83)	4
PO2 7	2383	558	478	67	12.01%	(9.57-14.97)	13
PO2 8	1658	238	209	21	8.82%	(5.84-13.11)	8
PO2 9	1521	307	266	32	10.42%	(7.48-14.34)	9
PO3 5	1565	212	181	24	11.32%	(7.73-16.29)	7
PO3 6	1616	345	295	43	12.46%	(9.39-16.37)	7
PO4 0	3139	535	470	47	8.79%	(6.67-11.49)	18
PO4 8	2774	426	380	32	7.51%	(5.37-10.41)	14
PO4 9	3268	408	364	37	9.07%	(6.65-12.25)	7
PO5 1	2037	417	372	37	8.87%	(6.51-11.99)	8
PO5 2	1687	315	264	38	12.06%	(8.92-16.12)	13
PO5 3	1307	222	184	32	14.41%	(10.40-19.64)	6
PO5 4	1514	350	301	43	12.29%	(9.25-16.14)	6

Sector	Pop 13-26	Total	NEG	POS	Pos%	CI	Other
PO6 1	1000	105	91	11	10.48%	(5.95-17.79)	3
PO6 2	1811	253	222	28	11.07%	(7.77-15.53)	3
PO6 3	1638	361	311	44	12.19%	(9.21-15.97)	6
PO6 4	2032	281	248	28	9.96%	(6.98-14.02)	5
PO7 5	1861	202	168	28	13.86%	(9.77-19.30)	6
PO7 6	1260	107	94	11	10.28%	(5.87-17.48)	2
PO7 7	1366	143	121	21	14.69%	(9.81-21.41)	1
PO7 8	1481	166	136	22	13.25%	(8.92-19.5)	8
PO8 0	1357	129	115	10	7.75%	(4.26-13.68)	4
PO8 8	1483	140	123	14	10.00%	(6.05-16.09)	3
PO8 9	2105	270	239	27	10.00%	(6.96-14.16)	4
PO9 1	707	90	76	10	11.11%	(6.15-19.26)	4
PO9 2	1547	204	171	26	12.75%	(8.85-18.02)	7
PO9 3	1596	219	187	24	10.96%	(7.48-15.79)	8
PO9 4	1829	367	312	46	12.53%	(9.53-16.31)	9
PO9 5	1679	269	232	31	11.52%	(8.24-15.89)	6
PO9 6	296	17	14	3	17.65%	(6.19-41.03)	0
PO10 7	1108	72	62	9	12.50%	(6.72-22.08)	1
PO10 8	1281	34	26	5	14.71%	(6.45-30.13)	3
PO11 0	892	111	95	13	11.71%	(6.97-19.01)	3
PO11 9	1288	119	102	15	12.61%	(7.79-19.76)	2
PO12 1	1128	243	211	29	11.93%	(8.44-16.61)	3
PO12 2	1599	208	189	18	8.65%	(5.54-13.26)	1
PO12 3	2718	306	267	37	12.09%	(8.90-16.22)	2
PO12 4	2596	471	407	51	10.83%	(8.33-13.96)	13
PO13 0	2863	454	394	53	11.67%	(9.04-14.95)	7
PO13 8	1015	227	191	32	14.10%	(10.17-19.22)	4
PO13 9	1720	268	233	28	10.45%	(7.33-14.69)	7
PO14 1	1155	312	264	41	13.14%	(9.87-17.34)	7
PO14 2	1675	130	112	17	13.08%	(8.33-19.95)	1
PO14 3	1214	149	134	12	8.05%	(4.67-13.55)	3
PO14 4	1110	117	100	15	12.82%	(7.93-20.08)	2
PO15 5	948	89	72	15	16.85%	(10.49-25.96)	2
PO15 6	1331	218	181	28	12.84%	(9.04-17.94)	9
PO15 7	643	66	52	11	16.67%	(9.57-27.43)	3
PO16 0	801	149	121	26	17.45%	(12.20-24.34)	2

Sector	Pop 13-26	Total	NEG	POS	Pos%	CI	Other
PO16 7	1024	160	137	18	11.25%	(7.24-17.08)	5
PO16 8	1514	197	166	27	13.71%	(9.59-19.21)	4
PO16 9	1131	188	165	19	10.11%	(6.57-15.24)	4
PO17 5	414	26	22	4	15.38%	(6.15-33.53)	0
PO17 6	700	27	24	1	3.70%	(0.66-18.28)	2

Table 6-6: Female screen test results by sector

Table 6-6 demonstrates that some of the sectors shown are based on relatively small samples (sample sizes shown in brackets), such as PO9 6 (17), PO10 8 (34), PO17 5 (26) and PO17 (27) so care may need to be taken in their analysis.

Table 6-7 shown on the following pages provides a breakdown of the sector populations, and incidence with confidence intervals for the male population.

Sector	Pop 13-26	Total	NEG	POS	Pos%	CI	Other
PO1 1	1,101	21	14	7	33.33%	(17.19-54.63)	0
PO1 2	852	14	10	4	28.57%	(11.72-54.65)	0
PO1 3	1,239	20	16	4	20.00%	(8.07-41.60)	0
PO1 4	1,191	15	11	4	26.67%	(10.90-51.95)	0
PO1 5	1,918	41	38	1	2.44%	(0.43-12.60)	2
PO2 0	2,154	39	39	0	0.00%	(0-8.97)	0
PO2 7	2,383	46	38	8	17.39%	(9.09-30.72)	0
PO2 8	1,658	29	26	3	10.34%	(3.58-26.39)	0
PO2 9	1,521	23	22	1	4.35%	(0.77-20.99)	0
PO3 5	1,565	12	9	3	25.00%	(8.89-53.23)	0
PO3 6	1,616	20	16	4	20.00%	(8.07-41.60)	0
PO4 0	3,139	59	50	8	13.56%	(7.03-24.54)	1
PO4 8	2,774	68	57	11	16.18%	(9.28-26.69)	0
PO4 9	3,268	41	33	5	12.20%	(5.32-25.54)	3
PO5 1	2,037	48	43	3	6.25%	(2.15-16.84)	2
PO5 2	1,687	37	35	2	5.41%	(1.50-17.70)	0
PO5 3	1,307	8	5	3	37.50%	(13.68-69.43)	0
PO5 4	1,514	24	21	3	12.50%	(4.34-31.00)	0
PO6 1	1,000	7	6	1	14.29%	(2.57-51.31)	0
PO6 2	1,811	17	14	3	17.65%	(6.19-41.03)	0
PO6 3	1,638	29	23	6	20.69%	(9.85-38.39)	0
PO6 4	2,032	33	29	3	9.09%	(3.14-23.57)	1

Sector	Pop 13-26	Total	NEG	POS	Pos%	CI	Other
PO7 5	1,861	28	24	4	14.29%	(5.70-31.49)	0
PO7 6	1,260	12	12	0	0.00%	(0-24.25)	0
PO7 7	1,366	23	18	4	17.39%	(6.98-37.14)	1
PO7 8	1,481	23	23	0	0.00%	(0-14.31)	0
PO8 0	1,357	19	18	1	5.26%	(0.94-24.64)	0
PO8 8	1,483	28	23	5	17.86%	(7.88-35.59)	0
PO8 9	2,105	25	22	3	12.00%	(4.17-29.96)	0
PO9 1	707	7	5	2	28.57%	(8.22-64.11)	0
PO9 2	1,547	32	29	3	9.38%	(3.24-24.22)	0
PO9 3	1,596	32	27	5	15.63%	(6.86-31.75)	0
PO9 4	1,829	45	40	4	8.89%	(3.51-20.73)	1
PO9 5	1,679	33	30	3	9.09%	(3.14-23.57)	0
PO9 6	296	2	2	0	0.00%	(0-65.76)	0
PO10 7	1,108	8	7	0	0.00%	(0-32.44)	1
PO10 8	1,281	11	7	4	36.36%	(15.17-64.62)	0
PO11 0	892	13	11	1	7.69%	(1.37-33.31)	1
PO11 9	1,288	20	17	3	14.00%	(5.24-36.04)	0
PO12 1	1,128	25	20	4	16.00%	(6.40-34.65)	1
PO12 2	1,599	27	21	5	18.52%	(8.18-36.70)	1
PO12 3	2,718	43	35	8	18.60%	(9.74-32.62)	0
PO12 4	2,596	64	48	14	21.88%	(13.50-33.43)	2
PO13 0	2,863	45	34	11	24.44%	(14.24-38.67)	0
PO13 8	1,015	11	9	2	18.18%	(5.14-47.70)	0
PO13 9	1,720	38	35	3	7.89%	(2.72-20.80)	0
PO14 1	1,155	52	43	9	17.31%	(9.38-29.73)	0
PO14 2	1,675	7	6	1	14.29%	(2.57-51.31)	0
PO14 3	1,214	40	29	11	27.50%	(16.11-42.84)	0
PO14 4	1,110	16	12	4	25.00%	(10.18-49.50)	0
PO15 5	948	12	8	4	33.33%	(13.81-60.94)	0
PO15 6	1,331	15	14	1	6.67%	(1.19-29.82)	0
PO15 7	643	2	2	0	0.00%	(0-65.76)	0

Table 6-7: Male screen test results by sector

Table 6-7 indicates that some sectors within districts contribute towards the high incidence of that district, e.g. PO1 1, PO5 3 and PO15 5. The total number of tests carried out in the sectors relating to males is much lower so care needs to be taken interpreting the male results. The average number of tests carried out in the male sectors was 26.58, which is almost as low as the small sample sizes for the female patients. This is primarily a result of males being screened as a result of contact tracing from a female partner who has tested positive for Chlamydia.

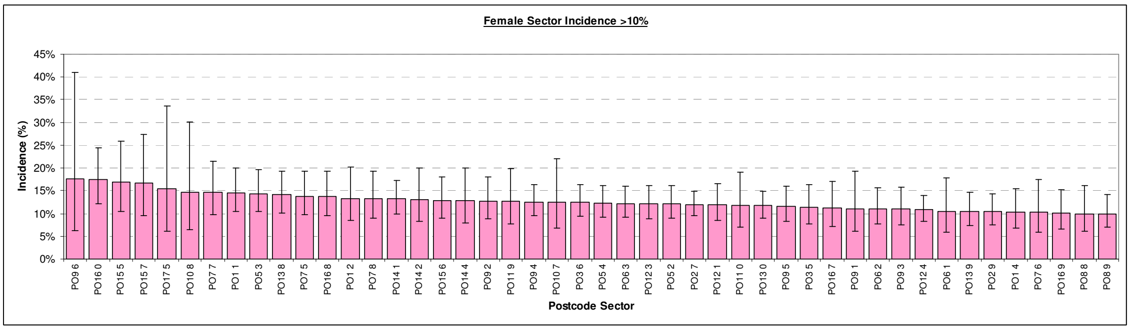

Figure 6-9: Female ranked sector incidence > 10%

27 sectors were identified in the analysis on the old data as having a Chlamydia of 10% or greater. The ranked sector incidence for those female sectors with >10% identified 47 sectors, which are shown in figure 6-9. The ranked sector incidence for those male sectors with >10% identified 35 sectors, which are shown in figure 6-10. If the two data sets are combined and cross referenced there are 52 sectors with incidence over 10%. This represents a 192% increase in the number of sectors with an incidence of 10% or greater. However this could be explained as the new data set is over the period where the Chlamydia screening programme is up and running and is no longer a pilot study and the increase in tests that were conducted were more likely to identify positive patients.

Two of the postcode sectors identified in the analysis on the old data, PO17 6 and PO2 0, no longer have an incidence level over 10% in either the female or male analysis. The remaining 25 sectors still maintain Chlamydia incidence over the 10% level. Does this mean that the Chlamydia screening programme has been effective in reducing the incidence level within those two areas and unsuccessful in the other 25?

Following the trend of other aspects of this analysis it can be seen in figure 6-10 that the incidence is significantly higher for males in comparison with females, with some sectors having incidence rates of >25%. These sectors require further analysis, and are based on relatively small samples.

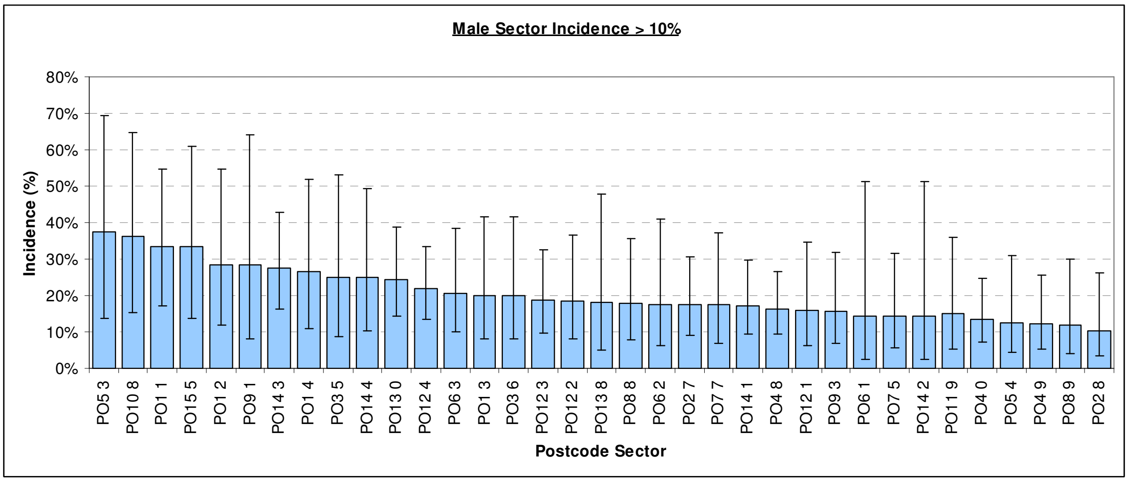

Figure 6-10: Male ranked sector incidence >10%

The screening location was recorded in the same manner as old data. The descending order of reported incidence by location was as follows: Genitourinary Medicine (GUM, 25.81%), General Practitioners East Hampshire (GPE, 19.60%), General Practitioners Portsmouth, (GPP, 16.18%), Family Planning Clinic (FPC, 13.56%), Ella Gordon Unit (EGU, 8.03%), General Practitioners Fareham (GPF, 5.82%), General Practitioners Gosport (GPG, 5.34%) and then the other types of test location. During the pilot study GP surgeries were encouraged to take part in the screening process. Figure 6-11 and figure 6-12 display the screening locations for female and male patients based on the equivalent screening locations provided in table 6-8 which will be discussed later.

Figure 6-11 demonstrates that >75% of the female tests were undertaken at GUM (42.8%, 8,739/20,390) or FPC (33.5%, 6,826/20,390). The total percentage screened at GPs accounts for 11.22% of the data, marking a step decline in the number of women being tested for at GPs; this has been offset with the steep increase in the number of tests being carried out at GUM and FPC. The decline of screening at GPs is a likely result of the financial incentives that were in place during the pilot study being withdrawn, once the NCSP was rolled out.

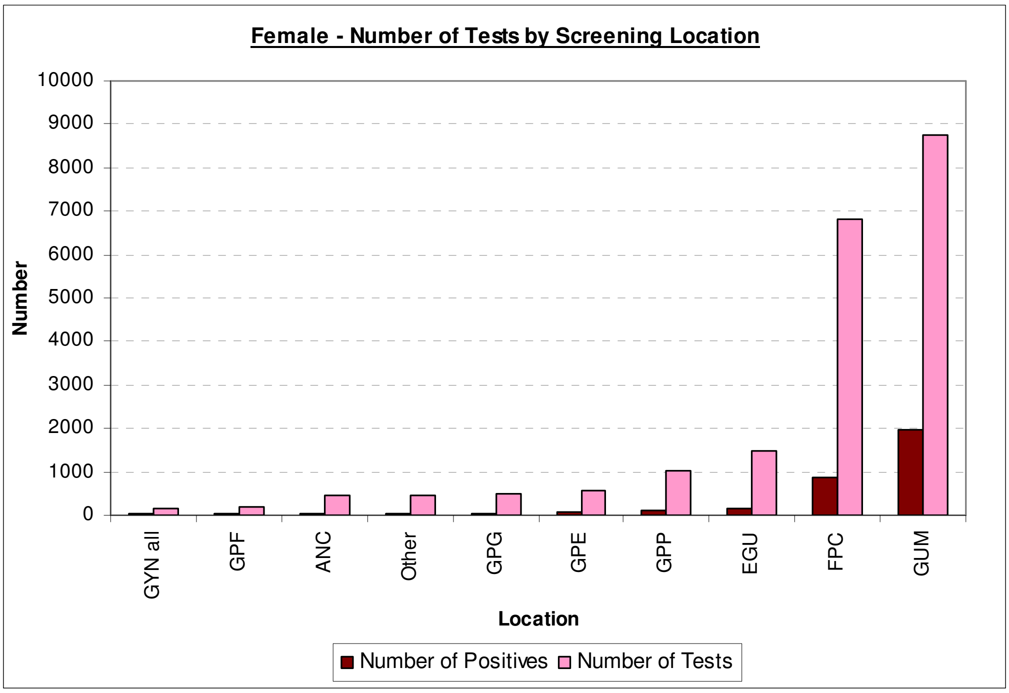

Figure 6-11: Ordered number of tests by screening location, female

Figure 6-12 clearly demonstrates that the majority of men (86.7%) are seen at GUM with 6.4% being seen at FPC. The number of men seen at a GP equates to 1.9%, which is significantly lower than the female patients.

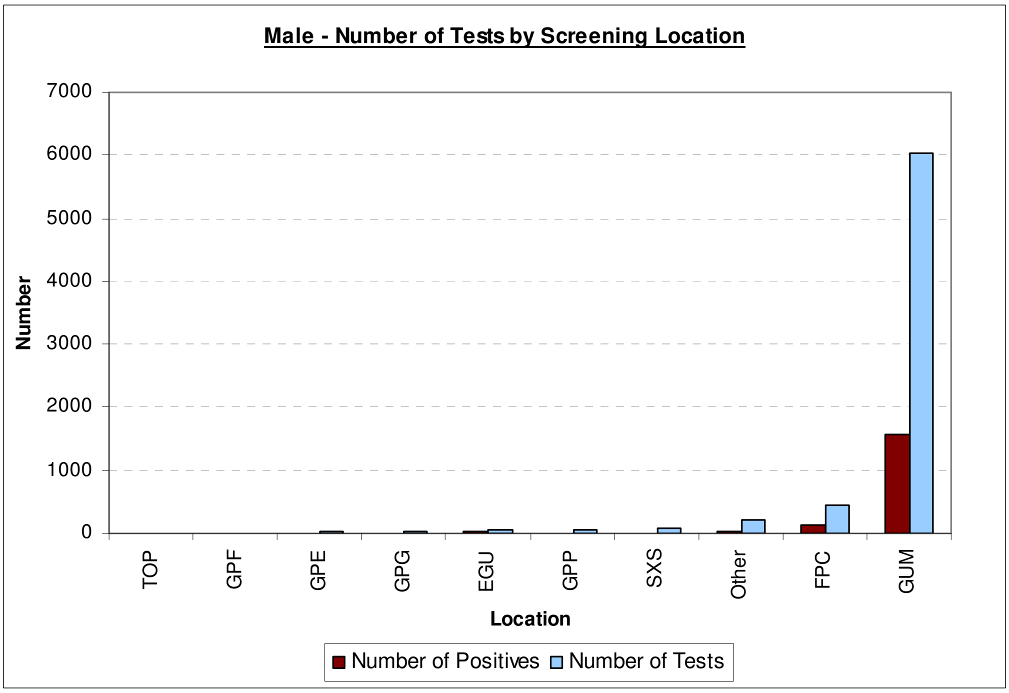

Figure 6-12: Ordered number of tests by screening location, male

Table 6-8 lists the test locations with their corresponding code. The table is similar to that of the original analysis with the addition of an "Other" category and the removal of the "TAR" categories (which was included in the original analysis).

Code	Description
ANC	Ante-natal Clinic
EGU	Ella Gordon Unit
FPC	Family Planning Clinic
GPE	GP East Hants
GPF	GP Fareham
GPG	GP Gosport
GPP	GP Portsmouth
GUM	GU Medicine
GYN_ALL	Gynaecology, Colposcopy, Hospital & Infertility Clinic
Other	Other
SXS	Sex Sense
TOP	Termination of Pregnancy

Table 6-8: Test location codes

Figure 6-13 and figure 6-14 illustrate the incidence levels for women and men respectively based on the screening location data discussed in figure 6-11 and figure 6-12. Figure 6-13 displays the incidence among women and it can be clearly seen that the incidence is greatest at GUM however the incidence appears to be relatively comparable at the other test locations, GPs and FPC. Figure 6-11 in relation to the old data agrees that GUM is the location with the highest incidence. Gyn_all has increased from the second least prevalent screening location from the old data to the second most prevalent screening data in the new data.

Figure 6-13: Ordered incidence by screening location, female

Figure 6-14 shows a greater range of incidence with the higher incidence levels associated with EGU followed by FPC and GUM. These locations replace GUM, SXS and TOP which were the locations with the highest incidence in the old data. The male population contains those patients who are screened at SXS and TOP. No female patients are reported to have been screened at SXS and TOP.

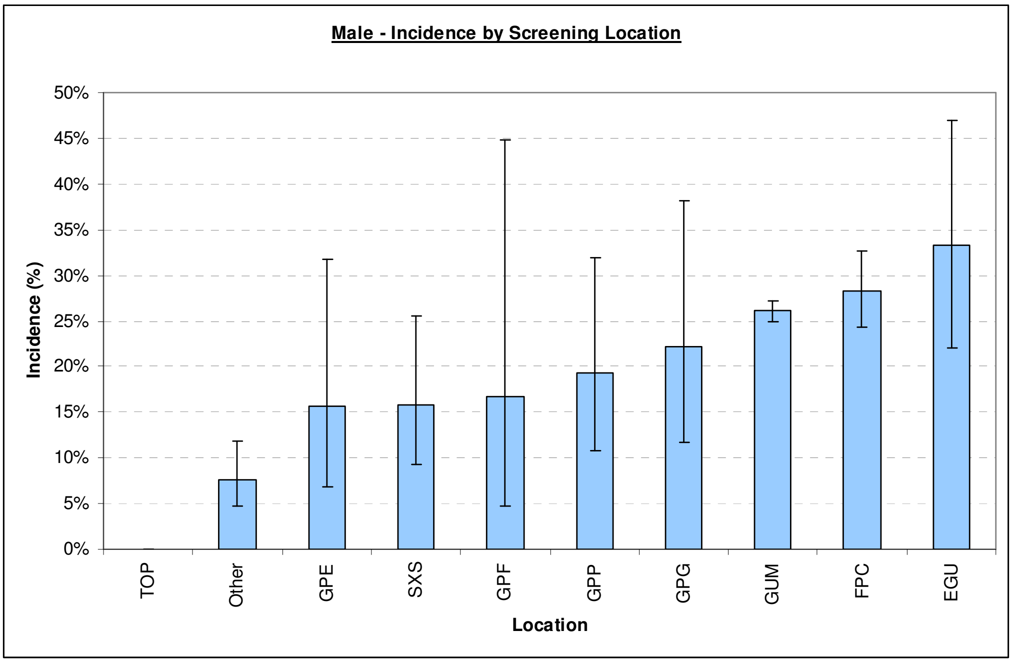

Figure 6-14: Ordered incidence by screening location, male

Figure 6-15 provides a monthly breakdown of the number of tests and the number of associated positive results over the data collection period for women. It can be seen that during May 2003 to September 2003 the number of tests increased fivefold. From September 2003 the number of tests remains fairly constant apart from in March 2005 where the number increases to 900 before levelling back out at around the 500 level.

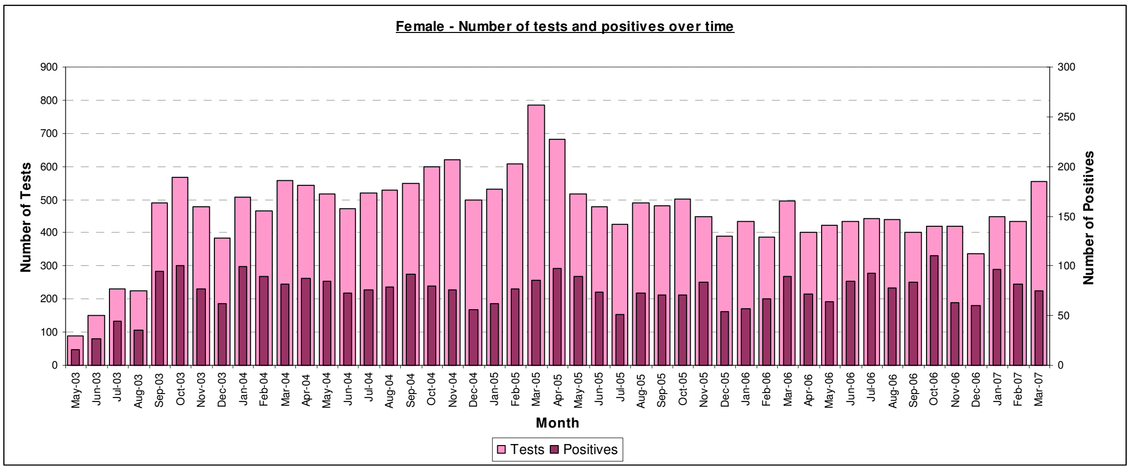

Figure 6-15: Female number of tests and positives by test date

Figure 6-16 displays the Chlamydia incidence for women over the data collection period by month. The incidence level is fairly constant apart from in March 2005 where the increase in the number of tests reduces the perceived level, and there is a noticeable increase in October 2006.

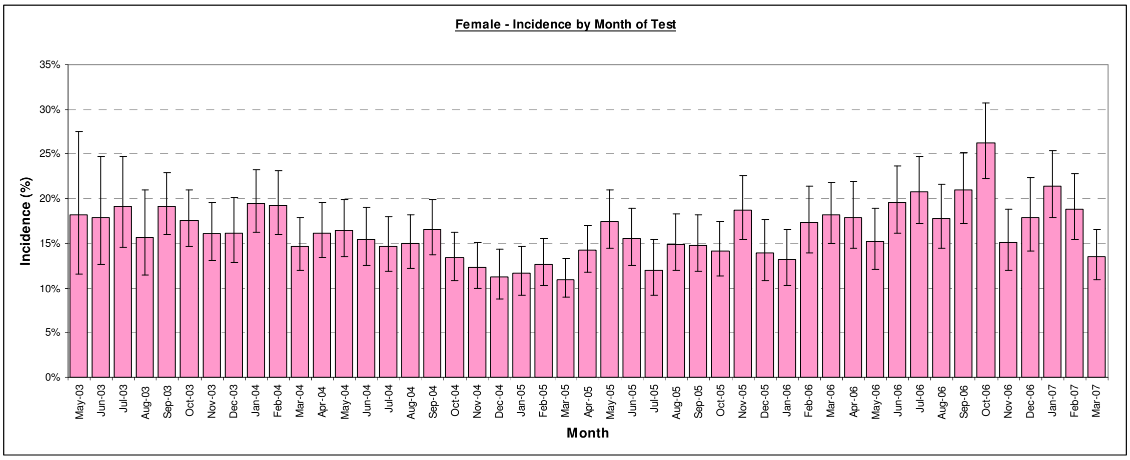

Figure 6-16: Female incidence by test date

Figure 6-17 is the male equivalent of figure 6-15. As can be clearly seen there is a marked drop in the number of tests carried out on men in March 2005. When comparing figure 6-15 and figure 6-17 it can be seen that between May 2003 and March 2005 there are roughly 300 fewer tests carried out on men. From April 2005 to March 2007 the number of tests carried out on men drops down to around 100. This drop in the number of tests carried out on male patients could be due to a shift in focusing on male patients identified via contact tracing, rather than screening.

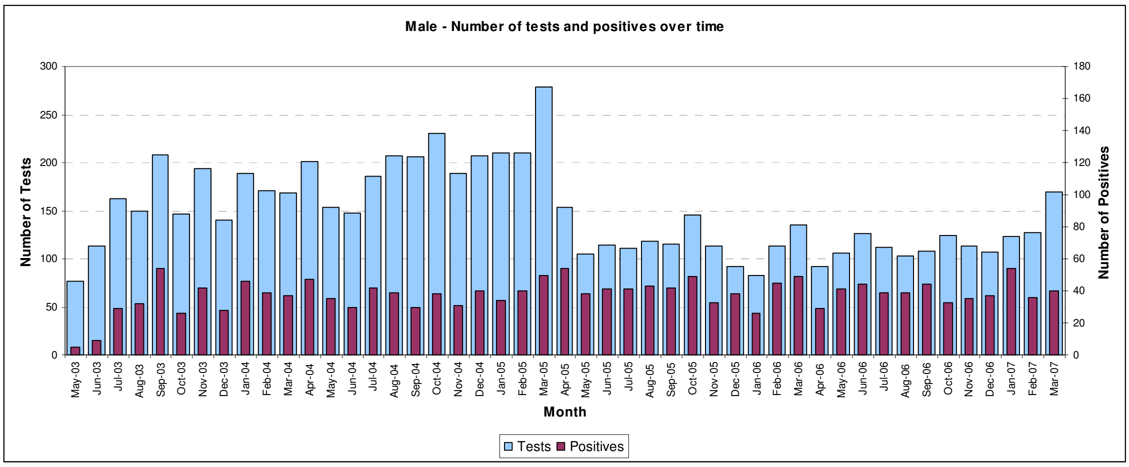

Figure 6-17: Male number of tests and positives by test date

Figure 6-18 is the male equivalent of figure 6-16. The perceived incidence noticeably jumps in April 2005. This corresponds to a reduction in the number of test carried out on men. This pushes the incidence up from the 20% monthly level previous observed to the 35% level from April 2005 until January 2007, as approximately the same number of positive male patients are identified.

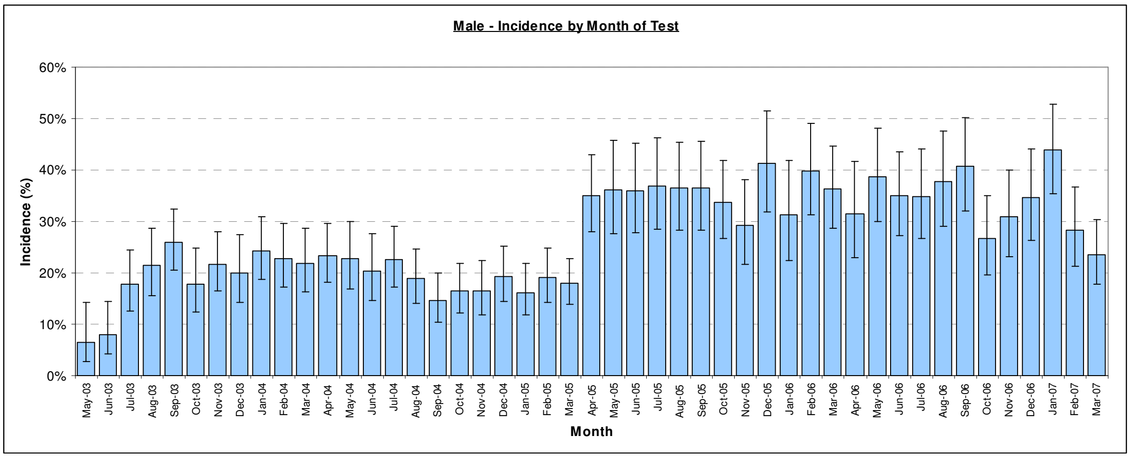

Figure 6-18: Male incidence by test date

The coding structure for the new Chlamydia screening database is different to old data, in a number of respects. The new structure has a finer breakdown, but an effort has been made to combine categories where appropriate to enable comparison with the old data. The patient's ethnicity is an example of this; the new system provides greater choice in terms of the ethnic origin category that can be recorded. To allow comparison with the old data, White, British, Irish, and Other White were into a White Category. This combination process was carried out on the mixed race category as well. As the majority of the patients were of white ethnic origin no further analysis was undertaken examining any potential differences between and within the ethnic groups. The ethnic breakdown of the new data can be found in table 6-9.

Group	Group Name	Total (Female)	% of Total (Female)	Total (Male)	% of Total (Male)
1	White	16,347	74.9%	4,630	66.5%
2	Caribbean	40	0.2%	32	0.5%
3	African	220	1.0%	137	2.0%
4	Other Black	42	0.2%	54	0.8%
5	Indian/Pakistan	71	0.3%	22	0.3%
6	Chinese/Asian	181	0.8%	30	0.4%
7	Other	66	0.3%	57	0.8%
8	Mixed	172	0.8%	48	0.7%
53	Bangladeshi	4	0.0%	1	0.0%
54	Other Asian	1	0.0%	2	0.0%
99	Unknown	4,672	21.4%	1,950	28.0%
	Total	**21,816**	**100%**	**6,963**	**100%**

Table 6-9: Ethnic group codes

Although the white ethnic group for both the female and male groups is the most dominant 74.9% and 66.5% respectively, there does appear to be greater ethnic dispersion compared to the old data where 87.07% of the patients were White.

Figure 6-19 and figure 6-20 provide the number of positives and total number of tests for the female and male groups respectively. The ages needed to be validated. The raw data ages ranged from -87 to 107. Individuals under the age of 12 were not included in the analysis. Any records with no date of birth added were updated with a missing value. 91.4% relate to the 16-24 age range (26,320/28,802). It was decided by the author and the clinical collaborators to expand the age range from 13 to 26 which accounted for 99% of the data (28,522/28,802).

Figure 6-19 indicates that the majority of the female patients tested are aged between 18 and 22 (60.1%). Then the number of tests decreases.

Figure 6-19: Female number of tests and number of positives by age

Figure 6-20 indicates that the majority of the male patients are aged between 20 and 24 (68.7%). There appears to be a shift in the age group with the male patients, which suggests that the male patients are older than the female patients.

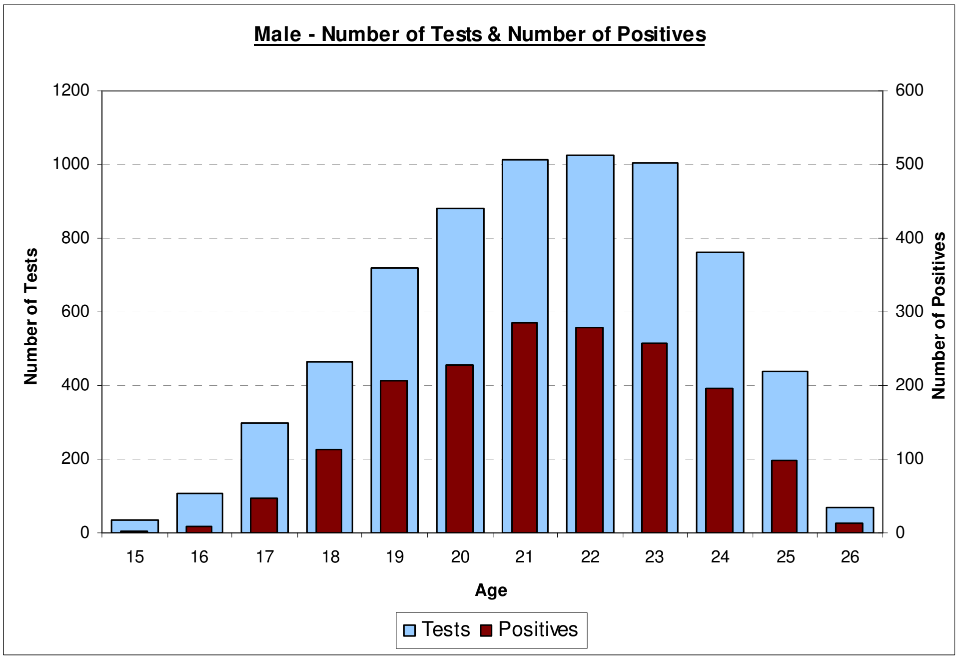

Figure 6-20: Male number of tests and number of positives by age

Figure 6-21 and figure 6-22 provide information on the infection incidence for the female and male groups respectively. The incidence for the females' figure 6-21 has two distinct peaks, one at 19 and one at 26. The number of tests carried out on 26 year olds is relatively low (84 tests) however these individuals, may be partners of positive patients. The incidence in figure 6-21 appears to have the same shaped distribution as the old data although the incidence levels have increased.

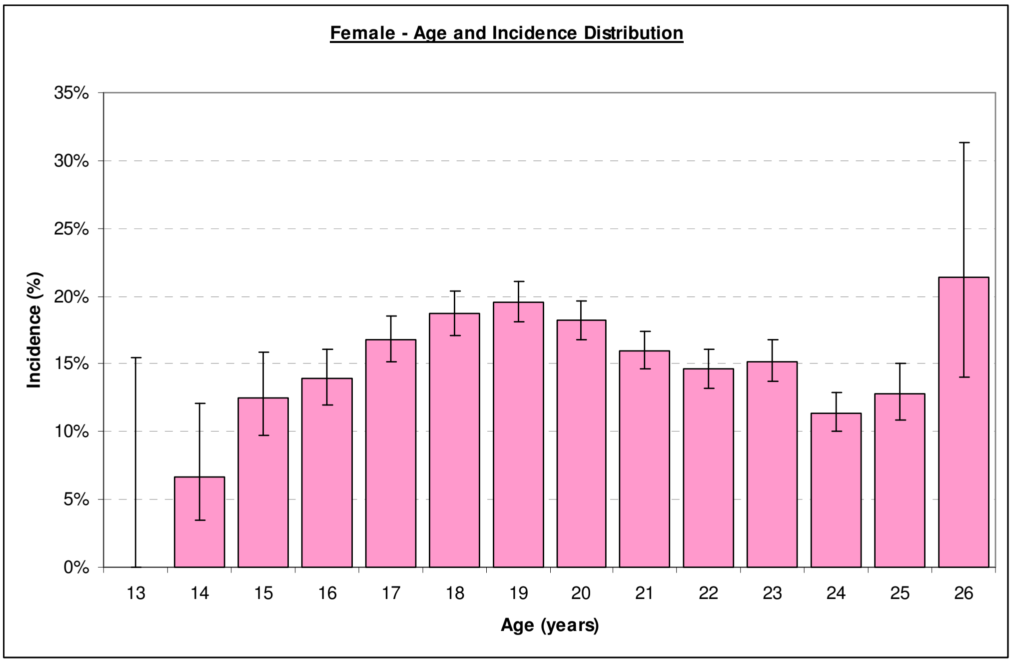

Figure 6-21: Female age and incidence distribution

It can be seen by examining the y-axis of figure 6-21 and figure 6-22 that the incidence is noticeably higher for the male patients. What is interesting to note, is that the male group exhibit a peak in incidence at 19 year olds as well. Figure 6-22 has a similar shaped distribution to the female data figure 6-21 and also the old data, although the incidence levels are considerably higher.

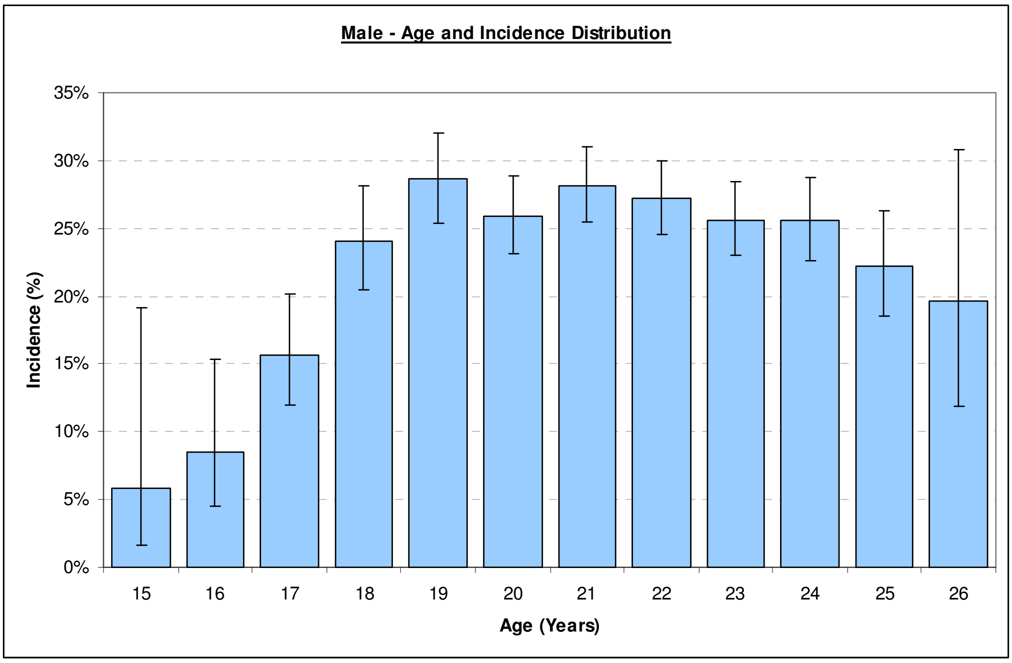

Figure 6-22: Male age and incidence distribution

The new data analysis examined data over a longer time period than the old data. There is a greater possibility that a patient may be screened multiple times. The patients' hospital number and episode number(s) combinations can be used to identify the number of tests a person has over the time period. The data shown in table 6-10 provide information about the number of screening visits by gender, it can be seen that 70.7% and 71.1% of the female and male patients respectively were tested once. There are many reasons for having multiple tests, including tests of cure, family planning tests and re-infection.

Visits	Female	Male
1	70.7%	71.1%
2	18.7%	17.7%
3	6.3%	6.0%
4	2.2%	2.8%
5+	2.0%	2.5%
Total	**100.0%**	**100.0%**

Table 6-10: Number of visits to the clinic by gender

The old data had information relating to the number of sexual partners that patients had. The new data had information on sexual partnerships but the number of sexual partners was not recorded. The data provided in table 6-11 is based on the standard information required by the NCSP, if the person has had a new sexual partner in the last 3 months, and if the patient has had 2 or more sexual partners in the last 12 months.

The data suggests that male group are more likely to have had a new sexual partner in the last 3 months than the female group, 42.4% compared to 29.3% respectively. The male group are also more likely to have had 2 or more sexual partner in the last 12 months than the female group, 54.1% compared to 36.2% respectively.

New Sexual Partner in last 3 months	Female	%Female	Male	%Male
Unknown	2,528	17.2%	763	16.6%
Yes	4,311	29.3%	1,949	42.4%
No	7,704	52.3%	1,867	40.6%
Patient Declined	183	1.2%	20	0.4%
Total	14,726	100.0%	4,599	100.0%

Two or more Sexual Partner in last 12 months	Female	%Female	Male	%Male
Unknown	2,711	18.4%	845	18.4%
Yes	5,328	36.2%	2,486	54.1%
No	6,395	43.4%	1,205	26.2%
Patient Declined	292	2.0%	63	1.4%
Grand Total	14,726	100.0%	4,599	100.0%

Table 6-11: Sexual history recorded during screen, by gender

6.7 Chapter Summary

The key findings of this analysis are:

- Of the 47,134 patient records 28,802 records (61.1%) were used in the postcode district analysis.
- Screening rates 15-25% of the 13-26 age group in the districts under investigation, with the greatest number of tests (1,065) taking place in March 2005.
- In the Portsmouth area the Chlamydia incidence among those tested was 16% and 25.5% for female and male groups respectively.
- Incidence among the male group was statistically different to that of the female group. It was significantly higher for males, suggesting that males need to be focussed upon. However, a potential reason why males have a higher incidence is that they are contacts of positive partners.
- The majority of patients included in the data analysis have one test for Chlamydia only (70.7% female and 71.7% male).
- Results were tabulated for postcode district and postcode sector for geographical referencing which is discussed in chapter 7.
- Postcode sector incidence varies between 0% and 37.5% for males and 3.7% and 23.5% for females. Some values were associated with very small samples.

- Postcode district level incidence varies between 20.5% and 33.0% for males, and 14.1% and 18.8% for females. However clustering and averaging effects reduce incidence.
- Test location analysis, indicated the top 4 locations for each gender, with GUM (22.6%), Gyn_all (14.5%), FPC (12.5%) and GPE (11.7%) for females. For males EGU (33.3%), FPC (28.3%), GUM (26.1%) and GPG (22.2%)
- For the female patients 15,565 of the 20,390 (76%) were seen at FPC and GUM with an average incidence of 17.5%. For the male patients 6,042/6,963 (86.7%) were seen at GUM with an incidence of 26.1%.
- High incidence levels were also observed for female patients at Gyn_all (14.5%) and East Hampshire (11.7%), although fewer than 750 patients were seen. High incidence levels were also observed for males EGU (33.3%) and FPC (28.3%) however there were fewer than 500 patients.
- Tests carried out at GPs were considerably lower than originally observed in Evenden (2003). 2,088 female tests were carried out at GPs with an associated incidence of 10.6%. Far fewer tests were carried out in GPs relating to men, 80 tests were carried out with an associated incidence of 18.2%.
- Statistics for ethnic origin showed clearly that the White ethnic group dominated the other groups. 74.9% of the female and 66.5% of the male patients were of white ethnic origin. Further analysis could be undertaken based on ethnic origin, but due to time constraints was not included in this research.
- Incidence peaks for both women and men for the 19 year olds. Higher incidence is associated with the female age group 18-22 and for the male age incidence 20-24.
- 29.3% of female patients reported having a new sexual partner in the last 3 months compared to 42.4% of male patients.
- 36.2% of female patents reported having 2 or more sexual partners in the last 12 months compared to 54.1% of the male patients.

7 Geographical Referencing

7.1 Research Tasks Addressed

T1. What is the prevalence and incidence rate of Chlamydia in Portsmouth and surrounding area?

T2. What are the factors (e.g. socioeconomic and behavioural) that are associated with Chlamydia prevalence/incidence in an area?

7.2 Chapter Introduction

Chapter 6 provided graphical and tabular information about Chlamydia incidence by postcode district and sector. As Evenden (2003) highlighted "postcodes were found to be fairly anonymous descriptors unless one happens to be familiar with the area". The analysis presented in chapter 6 contains many more sectors than the old data and hence geographic referencing or geomapping was deemed a more appropriate method of displaying the information. This was the case as otherwise very complex and clustered bar charts and tables would need to be produced.

Geographical referencing is used in this thesis to provide a visual understanding of the context of the incidence and prevalence of Chlamydia in an area and to complement analysis conducted in chapter 6 and contributing towards research tasks T1 and T2.

7.3 Geographical Referencing

Geographical referencing or geomapping is a technique for representing data layered onto maps. It places the data values in location context. Any map can be used: street maps, Ordnance Survey maps, or hand drawn maps which can be imported or scanned into Geographical Information System (GIS) software which is used to perform geographical referencing.

Figure 7-1 is an example of a thematic map which has been produced in the GIS software MapInfo version 9.02 (www.mapinfo.com) which has been used to conduct the geographical referencing in this chapter. A thematic map is a map of an area with data layered or plotted upon it which illustrates a particular topic. Figure 7-1 is a postcode polygon map of the Portsmouth area broken into postcode sector shaded based on population levels. Darker shades of red represent postcode sectors with a large populations whereas postcode sectors who have lighter shades of red and shades of grey represent areas with a smaller population density.

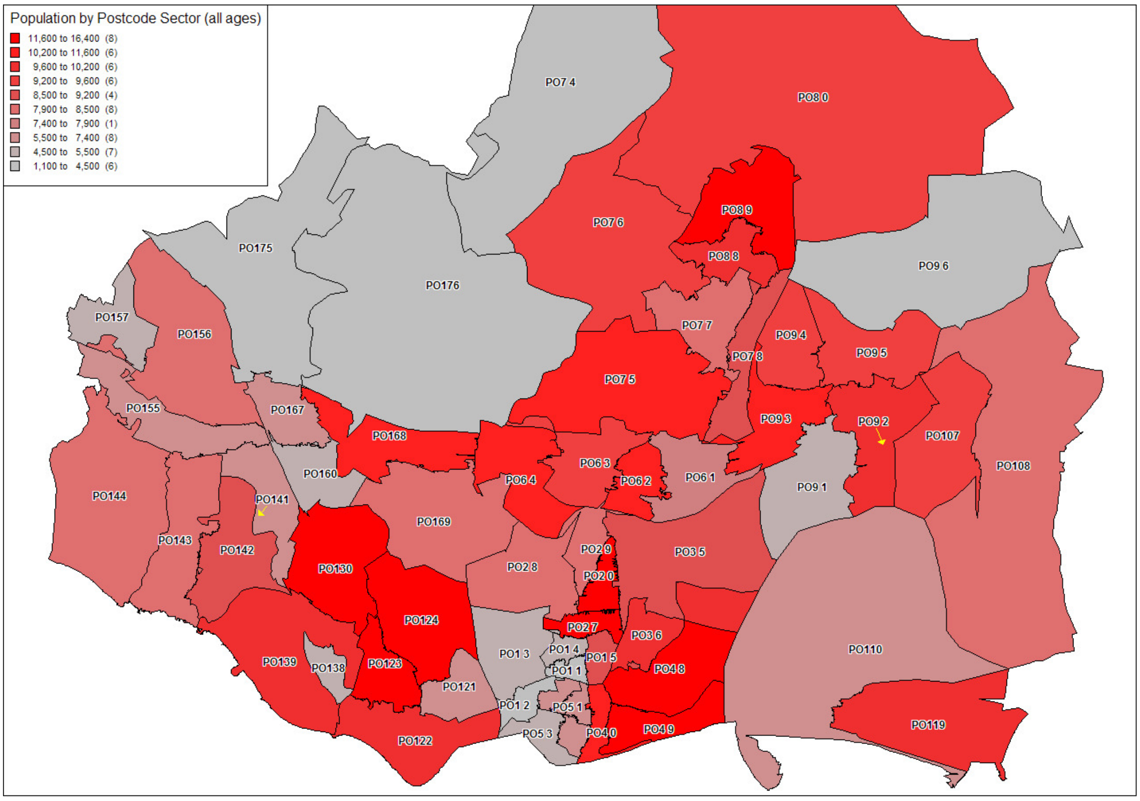

Figure 7-1: Population by Postcode Sector for screening area under investigation

7.4 What does Geographical Referencing Add?

Geographical referencing compliments and enhances the analysis discussed in chapter 6. Through the use of geographical referencing additional insight can be gained that perhaps would have been missed through the use of merely looking at tables and graphs. For instance healthcare facilities can be layered onto a map of the area, incidence levels of infections can also be layered to show the impact proximity to healthcare facilities has. Geographical referencing can illustrate to those unfamiliar with postcode districts and sectors a more familiar view of how the incidence levels are distributed in an area.

Chapter 8 examines social economic indicators obtained from the census and various sources which shall be discussed and how they relate to Chlamydia incidence within an area, be that census ward, postcode sector or postcode district. It could be possible to plot these indicators along with the Chlamydia incidence onto maps of the area possibly revealing additional insight.

7.5 Map Data

The map data relating to the Portsmouth area was obtained from EDINA, the DigiMap (http://edina.ac.uk/digimap/) service which provides Ordnance Survey maps. Postcode polygon maps were obtained from UKBOARDERS (http://edina.ac.uk/ukboarders/), and transposed over the Ordnance Survey maps.

Figure 7-1 is an example of a postcode polygon map of the Portsmouth area. Figure 7-2 is a Meridian Ordnance Survey map of the Portsmouth area which covers the screening area which included the pilot screening area. Both the polygon and meridian maps represent the same area. The postcode polygon map does not differentiate the Portsmouth harbour areas which can be seen more clearly in figure 7-2. The built up areas can be identified in figure 7-2 by the dense road networks. The screening area represented in the maps is from Fareham in the West through Portsmouth represented in the central area of the map to Havant in the East.

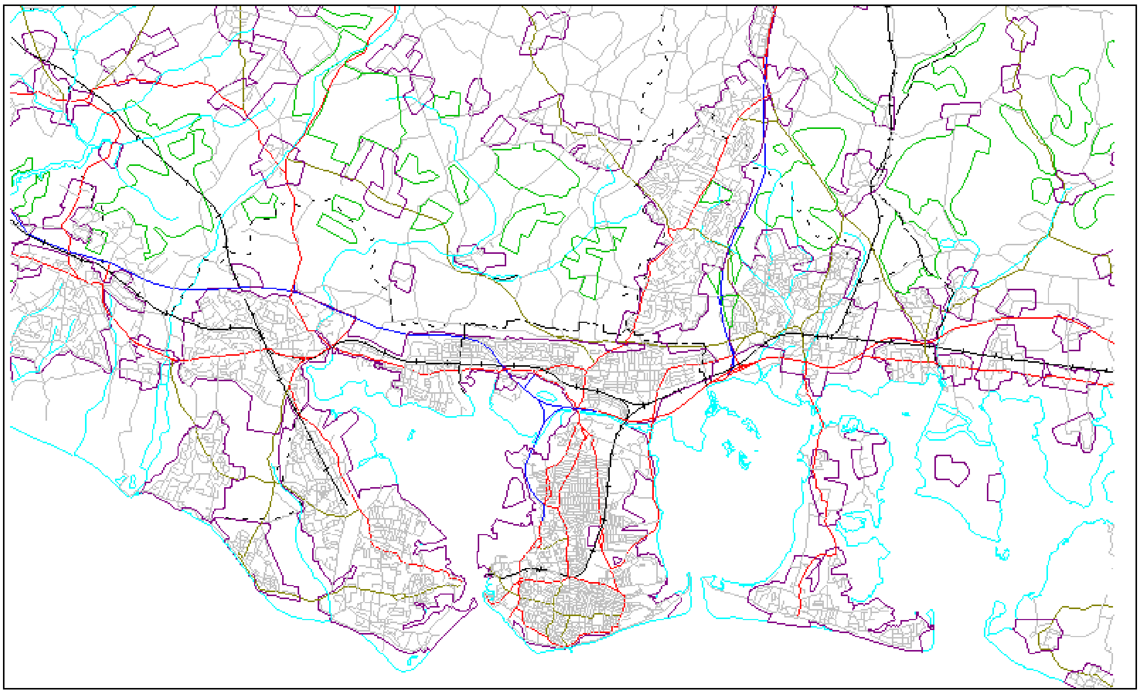

Figure 7-2: Example of EDINA DigiMap & MapInfo Ordnance Survey map (Evenden, 2003)

7.6 Cartographic Principles

It was important to follow recommended cartographic principles (Evenden, 2003) when performing geographical referencing. Data derived relating to infection incidence in chapter 6 will be layered onto polygon maps and Ordnance Survey maps, at the district and sector level. The number of tests and positive results were plotted using bar charts. The colour scheme used for the graphs layered onto the maps follows the same colour as the graphs presented in the previous chapter (i.e. pink and blue for females and males respectively). To maintain clarity and given the female and male results were identified as being significantly different, a number of maps are presented in this chapter.

7.7 Postcode, Sector and District Polygons

Figure 7-1 and figure 7-2 represent the pilot screening area that was previously evaluated (Evenden, 2003). The actual Portsmouth postcode area (postcodes beginning "PO") is much larger than the screening area and can be seen in figure 7-3. The area shown represents postcode area which includes the Isle of Wight. The mainland UK part of the area ranges from the Eastern side of Southampton and Fareham on the West of the map to beyond Chichester in the East.

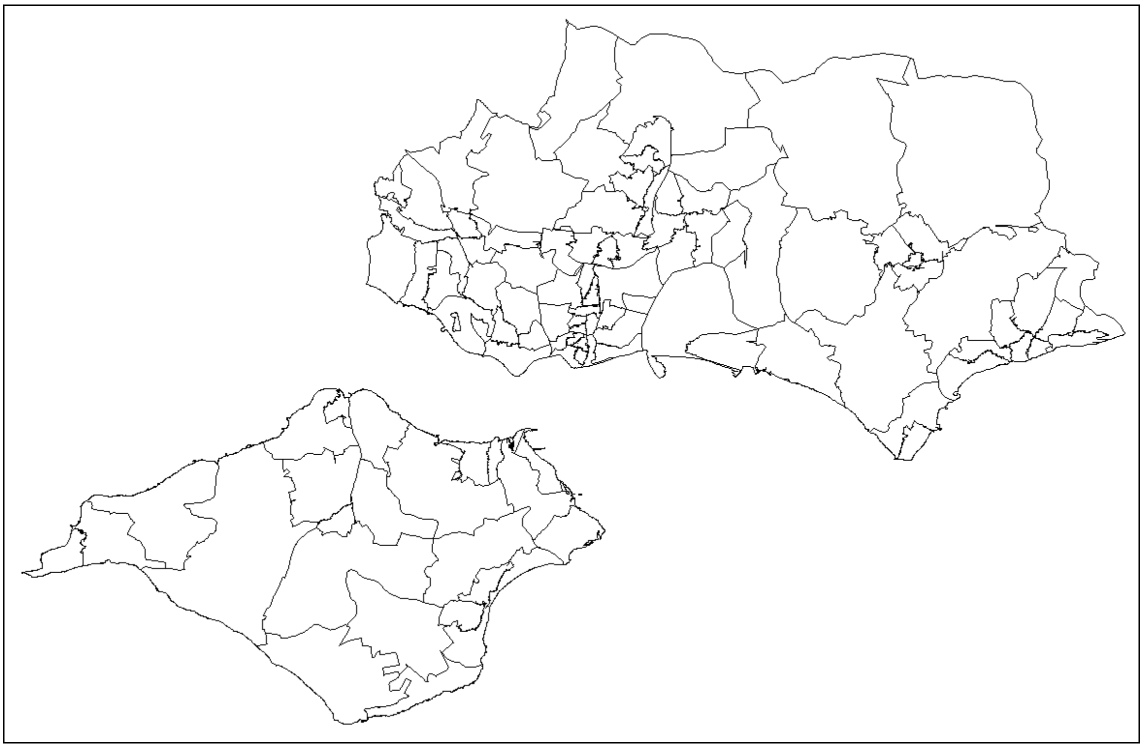

Figure 7-3: Scope of PO postcode area

Evenden et al (2003) study focused on the postcode districts PO1 to PO17. These districts were chosen as they covered the areas that were included in the opportunistic trial. As the new data were to be compared with the data analysed by Evenden et al (2003) the same postcode district breakdown was chosen for the subsequent geographical referencing, so as in the previous study the areas around Chichester and the Isle of Wight were not included in this thesis.

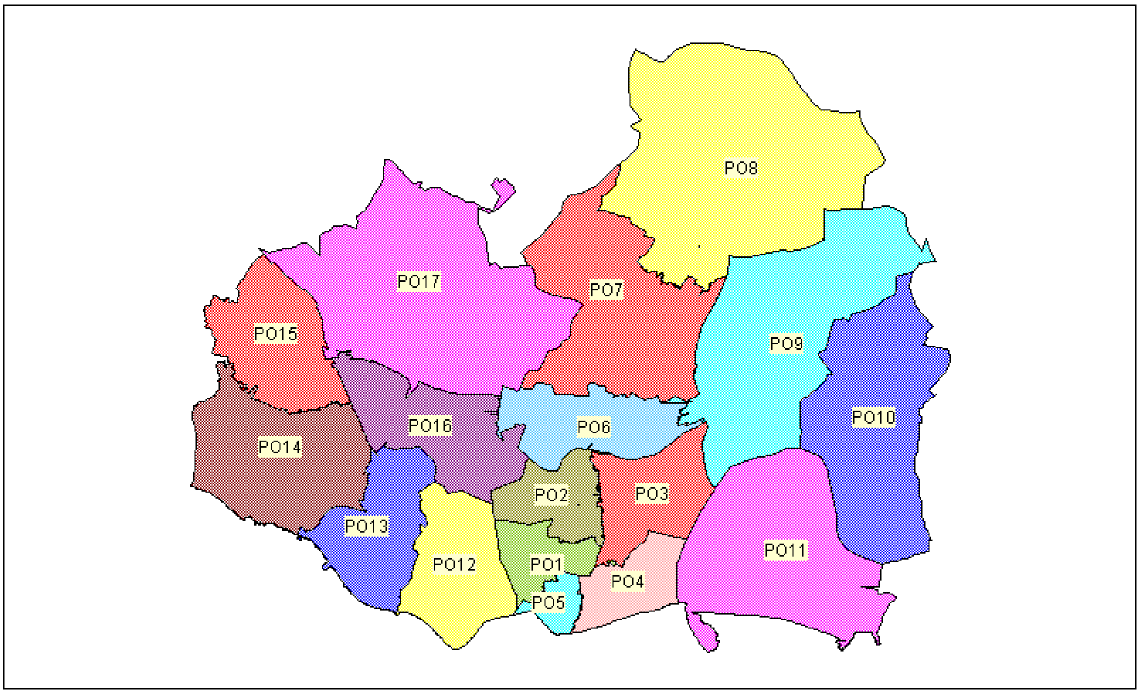

Figure 7-4: Postcode districts (Evenden, 2003)

The postcode districts identified in figure 7-4 were broken down further into postcode sectors ranging from two to six postcode sectors for each district. The complete postcode sector breakdown can be seen in figure 7-5. As was previously mentioned the polygon maps do not distinguish between the land masses and the harbour area, so in effect the postcodes cover areas of water as well. This applies to the postcode sectors: PO12 4, PO16 9, PO2 8, PO1 3 (which relate to the harbour area between Fareham, Gosport and Portsmouth) and PO3 5, PO4 8 and PO11 0 (which relate to the harbour area between Portsmouth, Havant and Hayling Island).

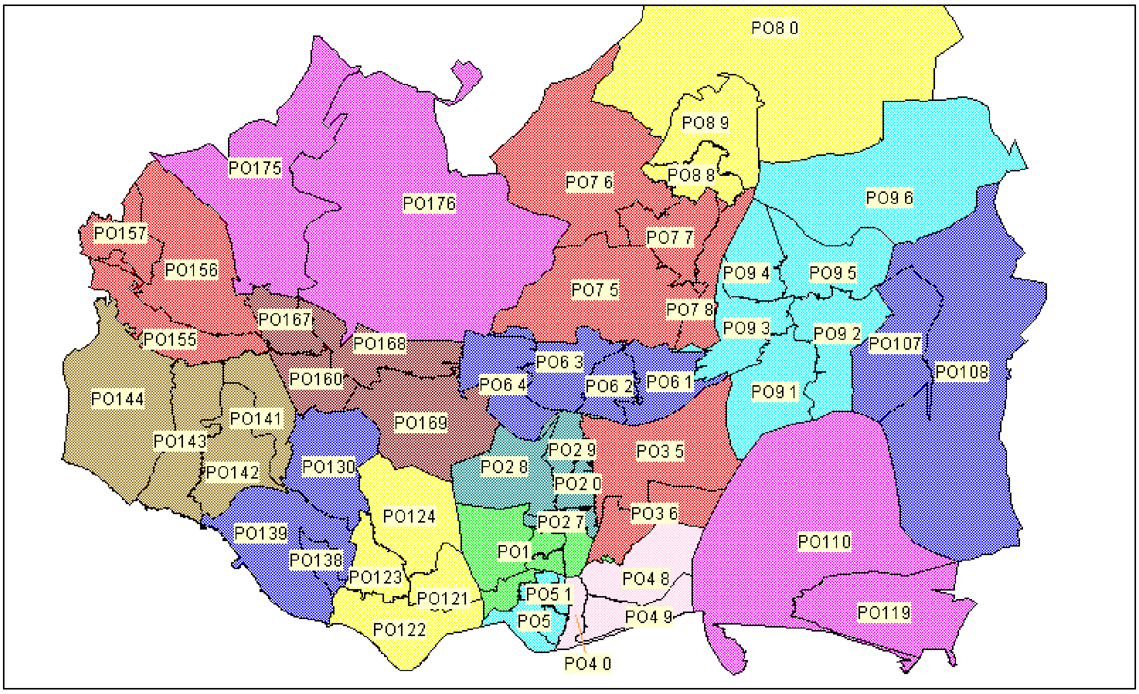

Figure 7-5: Postcode sectors (Evenden, 2003)

7.8 Screening and GP locations

The new data was obtained from the Chlamydia Screening Database (the database) which was discussed in section 6.3, and technical details are available in appendix B and appendix J. The GUM department were not the sole supplier of Chlamydia screening. In total 186 health organisations screened for Chlamydia over the period under investigation including: GPs, Family Planning Clinics, Gynaecology departments, Hospitals and Infertility clinics are a few of the many organisations that provided screening. Figure 7-6 displays the location of the screening by screening type on a map of the screening area. The reason why there are not 186 locations is that some of the locations are based at the same site i.e. a department within a hospital.

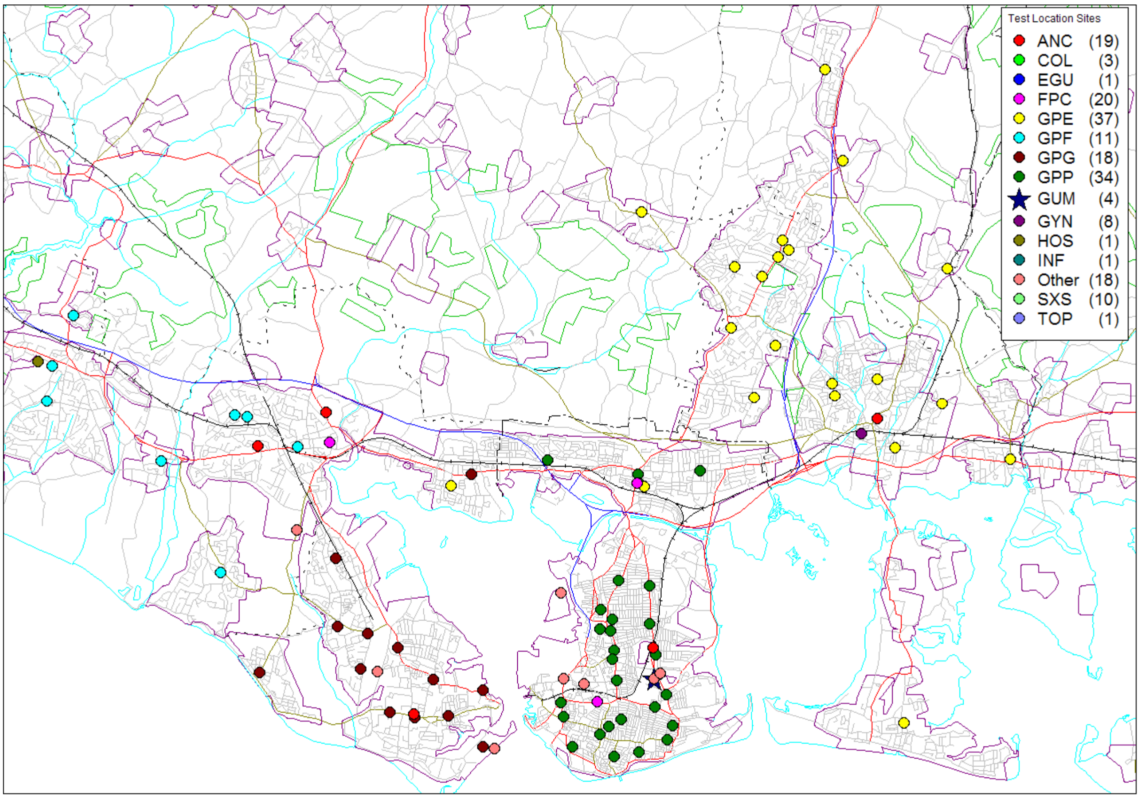

Figure 7-6: Screening locations from Chlamydia Screening Database (2003 to 2007)

As one would expect the location of the healthcare facilities coincide with the population density of the area, with few locations in the less dense areas providing data to the database.

To provide a fuller picture of the available healthcare resources in the area further analysis was undertaken by obtaining all the GPs in the country (Neighbourhood Statistics, 2004). The location of these GPs was layered onto a map, figure 7-7 of the screening area. It can be seen in comparison with figure 7-6 that a number of the points as expected overlap. Figure 7-7 also highlights that there were a number of GPs in the northwest (top left) of the map that serve the less densely populated areas of the screening area. These locations are not included in on the database which suggests that patients around these locations sought treatment at another location or were referred from these locations to larger healthcare facilities such as a Hospital, Family Planning Clinic or GUM at St Mary's Hospital.

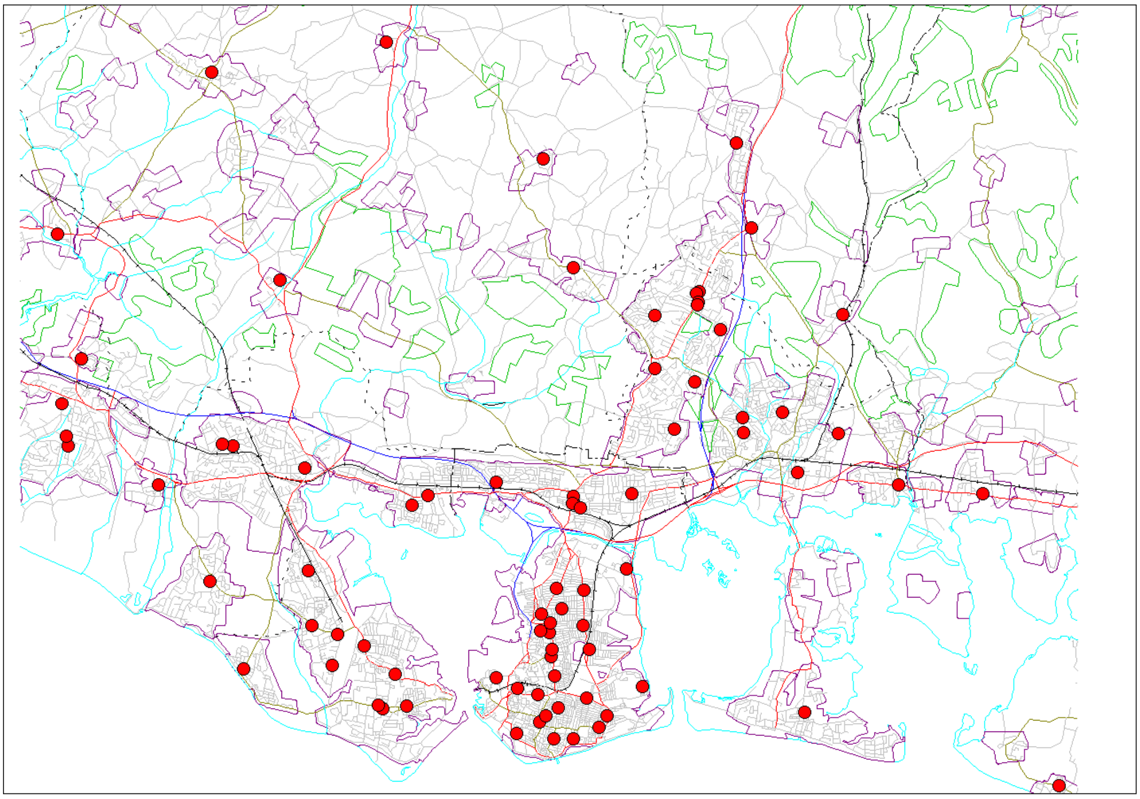

Figure 7-7: GP locations from Neighbourhood Statistics Website (2004)

7.9 Tests Result Counts, by Gender at District Level

Figure 7-8 provides detail about the female test results at the postcode district level. The data is presented on a logarithmic scale to enable clearer comparison, and the: pink bar representing the total number of tests; the green the number of positives; and, the red represents the other results, such as the equivocal results. Labelling is used to provide actual values for each district.

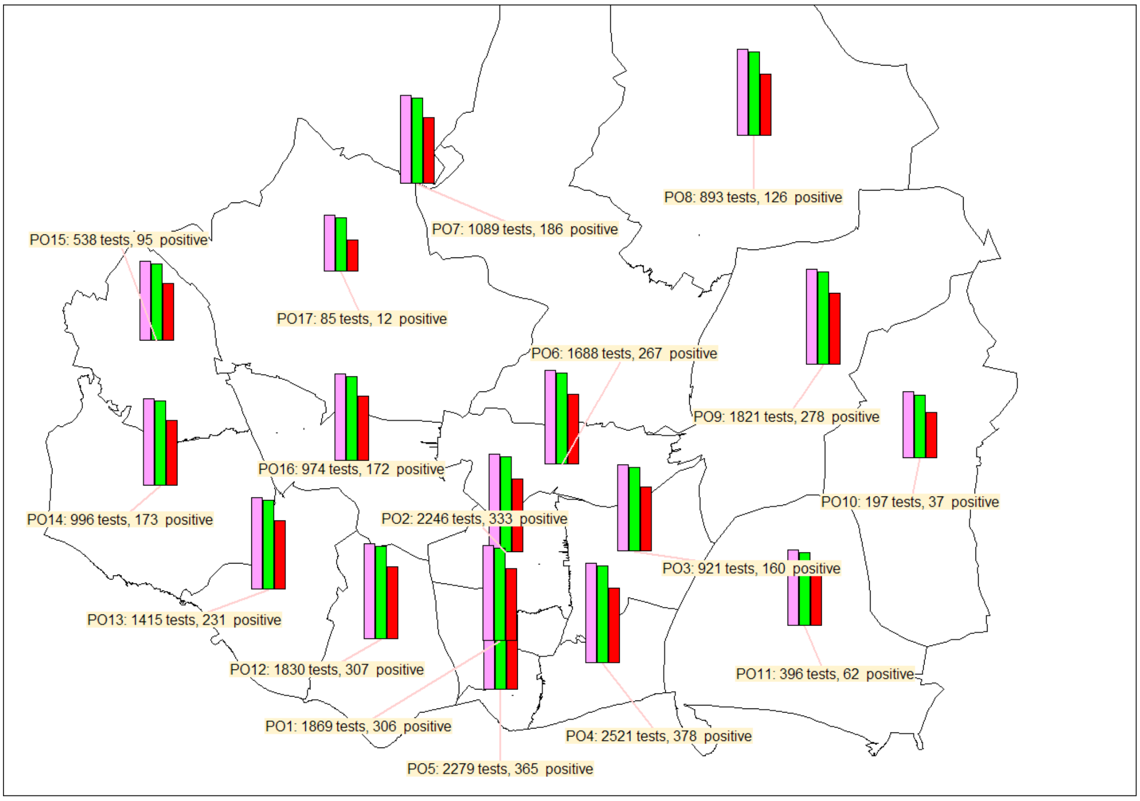

Figure 7-8: Log of female total tests, positive and other results by district

Figure 7-9 is the male equivalent of figure 7-8. A difference which will be maintained throughout this chapter is that as pink bars are used to indicate the total number of female tests have been undertaken in each district, blue bars are used to indicate the number of male tests that had been carried out. There after the same explanation applies as to the female map, i.e. green bars are the number of positives and red bars the number of other results.

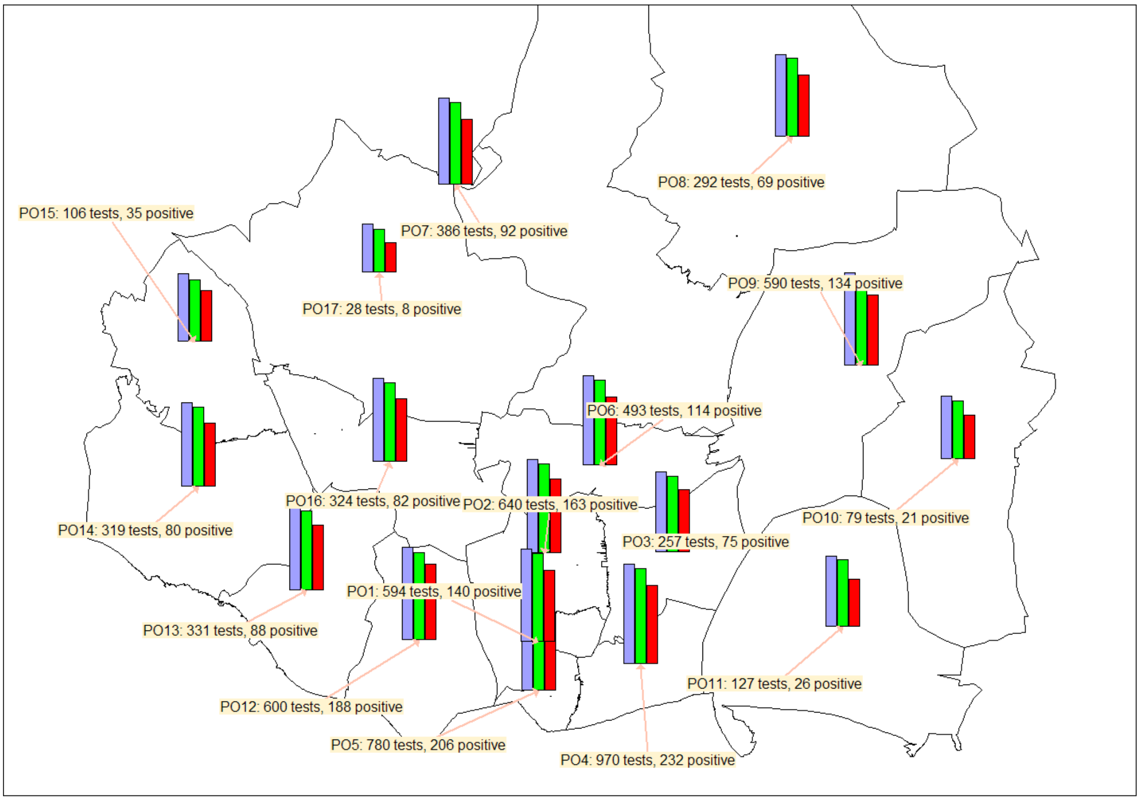

Figure 7-9: Log of male total tests, positive and other results by district

7.10 Tests Result Counts, by Gender at Sector Level

This section follows the same principle as the previous section although at a finer level of detail. Postcode sector as opposed to postcode district are used for the analysis. Figure 7-10 and figure 7-11 provide a zoomed in view of Portsmouth and the immediate area, for female and male patients respectively to provide a clearer view of the situation.

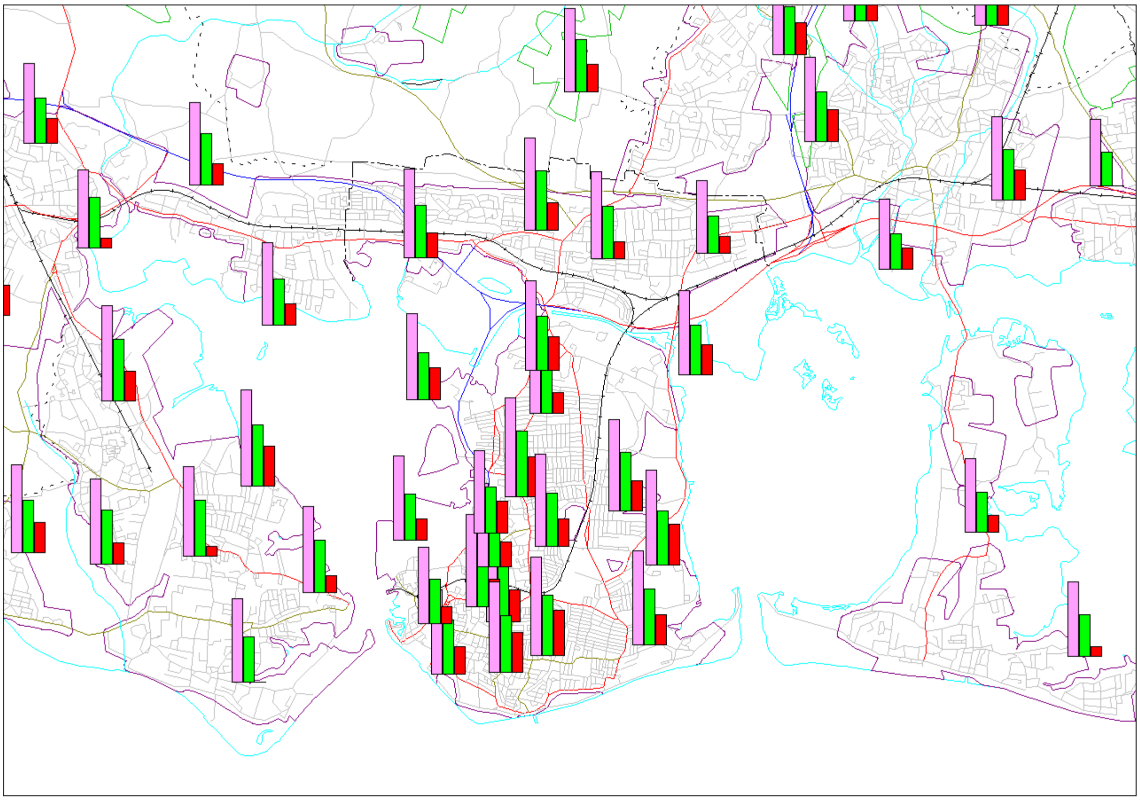

Figure 7-10: Log of female total and positive tests by sector – zoomed view

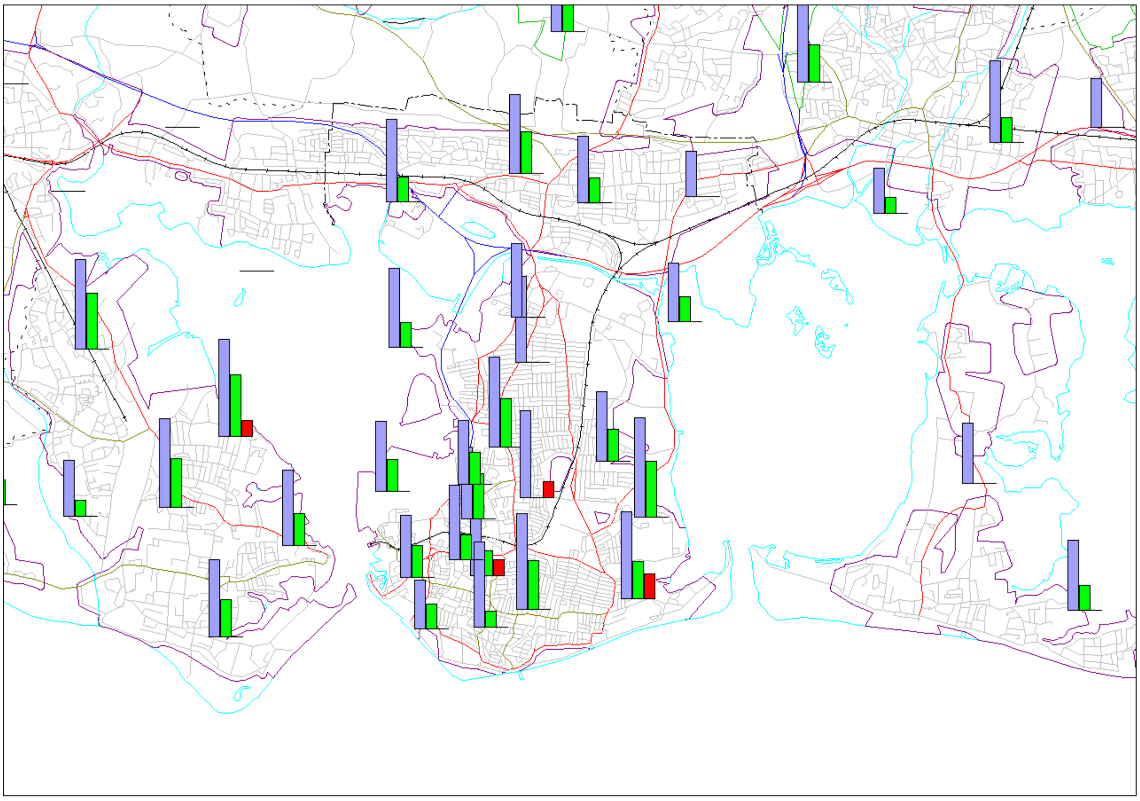

Figure 7-11: Log of male total and positive tests by sector – zoomed view

7.11 Screening Strategies

7.11.1 Identification of Screening Strategies

Intervention strategies were identified based on groupings of postcode sector incidence levels. Unlike Evenden (2003), gender specific strategies are proposed. This was a result of a significant difference in incidence level found for each gender. Table 7-1 and table 7-2 provide screening targets for female and male population respectively on the next two pages. The target postcode sector is provided along with the approximate area that represents. The screening intervention level previously assigned to that postcode sector (Evenden, 2003) is provided on the tables. Four levels of screening category were defined previously in ascending order to be: i) Upper Primary Targets, ii) Lower Primary Targets, iii) Secondary Targets, and iv) The Rest. This breakdown of screening categories is followed in this research with the new data.

Category	Target Sector	Approximate Areas	Evenden (2003) Areas
Upper Primary Targets	PO10 8	Wetbourne	The Rest
Top 9	PO15 7	Whitely	The Rest
Incidence	PO15 5	Fareham West	The Rest
Average 18.8%	PO16 0	Fareham East	Secondary Targets
Std Deviation 2.2%	PO7 8	Stakes	Lower Primary Targets
	PO9 6	Rowlands Castle	Upper Primary Targets
	PO5 3	St Jude	Secondary Targets
	PO1 1	Charles Dickens	Upper Primary Targets
	PO15 6	Fareham North-West	Upper Primary Targets
	PO7 5		The Rest
	PO5 2		The Rest
	PO9 2		Secondary Targets
Lower Primary Targets	PO13 8	Purbrook	Secondary Targets
Second 21	PO16 8	St Faith's	The Rest
Incidence	PO1 2	Grange	Secondary Targets
Average 15.1%	PO9 1	Portchester East	The Rest
Std Deviation 0.8%	PO17 5	St Thomas	The Rest
	PO7 7	Bedhampton	Lower Primary Targets
	PO14 1	Fareham North	Secondary Targets
	PO9 4	Fareham South	The Rest
	PO3 5	Barncroft	The Rest
	PO9 3	Copnor	Lower Primary Targets
	PO14 4	Titchfield	Secondary Targets
	PO3 6	Baffins	Secondary Targets
	PO1 4	Hayling East	Upper Primary Targets
	PO11 0	Fratton	Upper Primary Targets
	PO16 7		The Rest
	PO2 7		Secondary Targets
	PO11 9		Upper Primary Targets
	PO5 4		Secondary Targets
	PO10 7	Emsworth	The Rest

Category	Target Sector	Approximate Areas	Evenden (2003) Areas
	PO6 3	Cosham	Lower Primary Targets
	PO14 2	Stubbington	The Rest
Secondary Targets	PO9 5	Battins	Secondary Targets
Third 17	PO12 4	Hardway	Lower Primary Targets
Incidence	PO2 9	Hilsea	The Rest
Average 13.0%	PO6 1	Drayton and Farlington	Secondary Targets
Std Deviation 0.7%	PO13 0	Bridgemary North	Lower Primary Targets
	PO12 1	Christchurch	Upper Primary Targets
	PO13 9	Lee East	Secondary Targets
	PO12 3	Leesland	Secondary Targets
	PO6 2	Paulsgrove	The Rest
	PO16 9	Nelson	Secondary Targets
	PO2 8	Denmead	Secondary Targets
	PO7 6	Central Southsea	The Rest
	PO4 0	Cowplain	The Rest
	PO8 8		The Rest
	PO6 4		Lower Primary Targets
	PO8 9	Horndean Kings	The Rest
The Rests	PO17 6	Boarhunt and Southwick	Upper Primary Targets
Last 12	PO8 0	Horndean Hazleton and Blendworth	The Rest
Incidence	PO4 8	Milton	Secondary Targets
Average 10.6%	PO5 1	Eastney and Craneswater	Secondary Targets
Std Deviation 0.8%	PO4 9	Hill Head	The Rest
	PO1 3	Anglesey	Upper Primary Targets
	PO14 3		The Rest
	PO1 5		The Rest
	PO2 0		Secondary Targets
	PO12 2		Secondary Targets

Table 7-1: Female proposed screening targets

Category	Target Sector	Approximate Areas	Evenden (2003) Areas
	PO5 3		Secondary Targets
	PO10 8	St Jude	The Rest
	PO1 1	Wetbourne	Upper Primary Targets
	PO15 5	Charles Dickens	The Rest
	PO1 2	Fareham West	Secondary Targets
Upper Primary Targets	PO9 1	St Thomas	The Rest
Top 18	PO14 3	Bedhampton	The Rest
Incidence	PO1 4	Hill Head	Upper Primary Targets
Average 26.4%	PO3 5	Copnor	The Rest
Std Deviation 5.6%	PO14 4	Titchfield	Secondary Targets
	PO12 4	Hardway	Lower Primary Targets
	PO13 0	Bridgemary North	Lower Primary Targets
	PO12 2	Anglesey	Secondary Targets
	PO7 7	Stakes	Lower Primary Targets
	PO6 3	Cosham	Lower Primary Targets
	PO1 3	Baffins	Upper Primary Targets
	PO3 6	Christchurch	Secondary Targets

Category	Target Sector	Approximate Areas	Evenden (2003) Areas
	PO12 1		Upper Primary Targets
Lower Primary Targets	PO4 9		The Rest
Second 12	PO12 3	Eastney and Craneswater	Secondary Targets
Incidence	PO13 8	Leesland	Secondary Targets
Average 17.0%	PO8 8	Grange	The Rest
Std Deviation 1.5%	PO6 2	Cowplain	The Rest
	PO2 7	Fratton	Secondary Targets
	PO14 1	Fareham South	Secondary Targets
	PO4 8	Milton	Secondary Targets
	PO9 3	Hayling East	Lower Primary Targets
	PO11 0	Central Southsea	Upper Primary Targets
	PO4 0		The Rest
	PO11 9		Upper Primary Targets
Secondary Targets	PO6 1		Secondary Targets
Third 9	PO7 5	Drayton and Farlington	The Rest
Incidence	PO14 2	Purbrook	The Rest
Average 12.4%	PO5 4	Stubbington	Secondary Targets
Std Deviation 1.6%	PO6 4	Paulsgrove	Lower Primary Targets
	PO8 9	Horndean Kings	The Rest
	PO9 4	Barncroft	The Rest
	PO5 1	Nelson	Secondary Targets
	PO2 8		Secondary Targets
	PO9 2		Secondary Targets
The Rest	PO9 5	St Faith's	Secondary Targets
Last 8	PO13 9	Battins	Secondary Targets
Incidence	PO1 5	Lee East	The Rest
Average 6.9%	PO15 6	Fareham North-West	Upper Primary Targets
Std Deviation 1.8%	PO5 2	Horndean Hazleton and Blendworth	The Rest
	PO8 0	Hilsea	The Rest
	PO2 9		The Rest

Table 7-2: Male proposed screening targets

Table 7-3 combines the data from table 7-1 and table 7-2, to allow cross checking between genders to see which of the postcode sectors fall into the same screening category. It should be noted that the female screening areas relate to 59 postcode sectors and the male to 53 so some female sectors will not have a male equivalent.

Category (Female)	Target Sector (Female)	Female Screening Areas	Male Screening Areas
Upper Primary Targets	PO10 8	Wetbourne	Upper Primary Targets
Top 9	PO15 7	Whitely	**NO DATA**
Incidence	PO15 5	Fareham West	Upper Primary Targets
Average 18.8%	PO16 0	Fareham East	**NO DATA**
Std Deviation 2.2%	PO7 8	Stakes	**NO DATA**
	PO9 6	Rowlands Castle	**NO DATA**
	PO5 3	St Jude	Upper Primary Targets

Category (Female)	**Target Sector (Female)**	**Female Screening Areas**	**Male Screening Areas**
	PO1 1	Charles Dickens	Upper Primary Targets
	PO15 6	Fareham North-West	The Rest
	PO7 5		Secondary Targets
	PO5 2		The Rest
	PO9 2		The Rest
Lower Primary Targets	PO13 8	Purbrook	Lower Primary Targets
Second 21	PO16 8	St Faith's	**NO DATA**
Incidence	PO1 2	Grange	Upper Primary Targets
Average 15.1%	PO9 1	Portchester East	Upper Primary Targets
Std Deviation 0.8%	PO17 5	St Thomas	**NO DATA**
	PO7 7	Bedhampton	Upper Primary Targets
	PO14 1	Fareham North	Lower Primary Targets
	PO9 4	Fareham South	Secondary Targets
	PO3 5	Barncroft	Upper Primary Targets
	PO9 3	Copnor	Lower Primary Targets
	PO14 4	Titchfield	Upper Primary Targets
	PO3 6	Baffins	Upper Primary Targets
	PO1 4	Hayling East	Upper Primary Targets
	PO11 0	Fratton	Lower Primary Targets
	PO16 7		**NO DATA**
	PO2 7		Lower Primary Targets
	PO11 9		Lower Primary Targets
	PO5 4		Secondary Targets
	PO10 7	Emsworth	**NO DATA**
	PO6 3	Cosham	Upper Primary Targets
	PO14 2	Stubbington	Secondary Targets
Secondary Targets	PO9 5	Battins	The Rest
Third 17	PO12 4	Hardway	Upper Primary Targets
Incidence	PO2 9	Hilsea	The Rest
Average 13.0%	PO6 1	Drayton and Farlington	Secondary Targets
Std Deviation 0.7%	PO13 0	Bridgemary North	Upper Primary Targets
	PO12 1	Christchurch	Upper Primary Targets
	PO13 9	Lee East	The Rest
	PO12 3	Leesland	Lower Primary Targets
	PO6 2	Paulsgrove	Lower Primary Targets
	PO16 9	Nelson	**NO DATA**
	PO2 8	Denmead	Secondary Targets
	PO7 6	Central Southsea	**NO DATA**
	PO4 0	Cowplain	Lower Primary Targets
	PO8 8		Lower Primary Targets
	PO6 4		Secondary Targets
	PO8 9	Horndean Kings	Secondary Targets
The Rests	PO17 6	Boarhunt and Southwick	**NO DATA**
Last 12	PO8 0	Horndean Hazleton and Blendworth	The Rest
Incidence	PO4 8	Milton	Lower Primary Targets
Average 10.6%	PO5 1	Eastney and Craneswater	Secondary Targets
Std Deviation 0.8%	PO4 9	Hill Head	Lower Primary Targets
	PO1 3	Anglesey	Upper Primary Targets

Category (Female)	Target Sector (Female)	Female Screening Areas	Male Screening Areas
	PO14 3		Upper Primary Targets
	PO1 5		The Rest
	PO2 0		**NO DATA**
	PO12 2		Upper Primary Targets

Table 7-3: Comparison of female and male proposed screening targets

7.11.2 Mapping Screening Strategies

Figure 7-12 provides a summary of the four screening categories previously identified (Evenden, 2003). The screening categories are identified by colour and have been numbered 1 to 4 for clarity, representing Upper Primary Target through to tertiary screening targets.

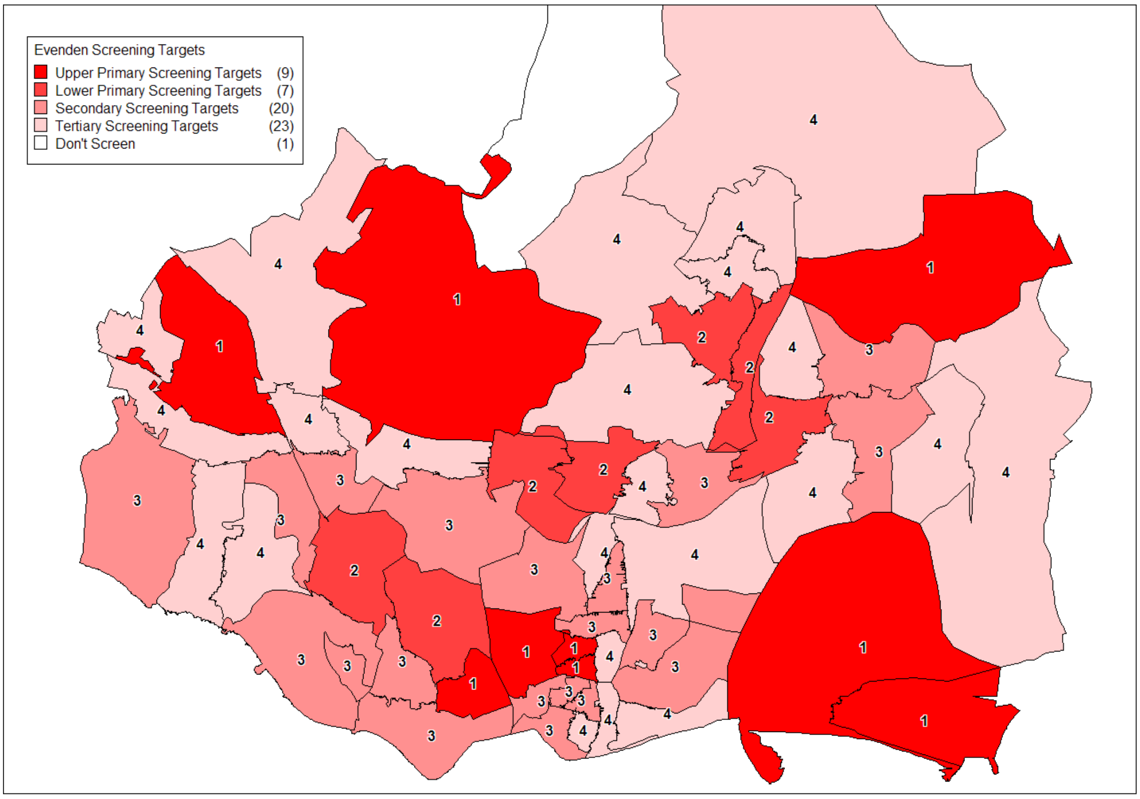

Figure 7-12: Overview of the screening areas previously identified by Evenden (2003)

Figure 7-13 and figure 7-14 provide map views of the screening categories for females and males respectively. The data displayed in these maps are based on table 7-1 and table 7-2. The maps clearly show a difference between the previously identified screening targets and also a difference between the gender screening targets.

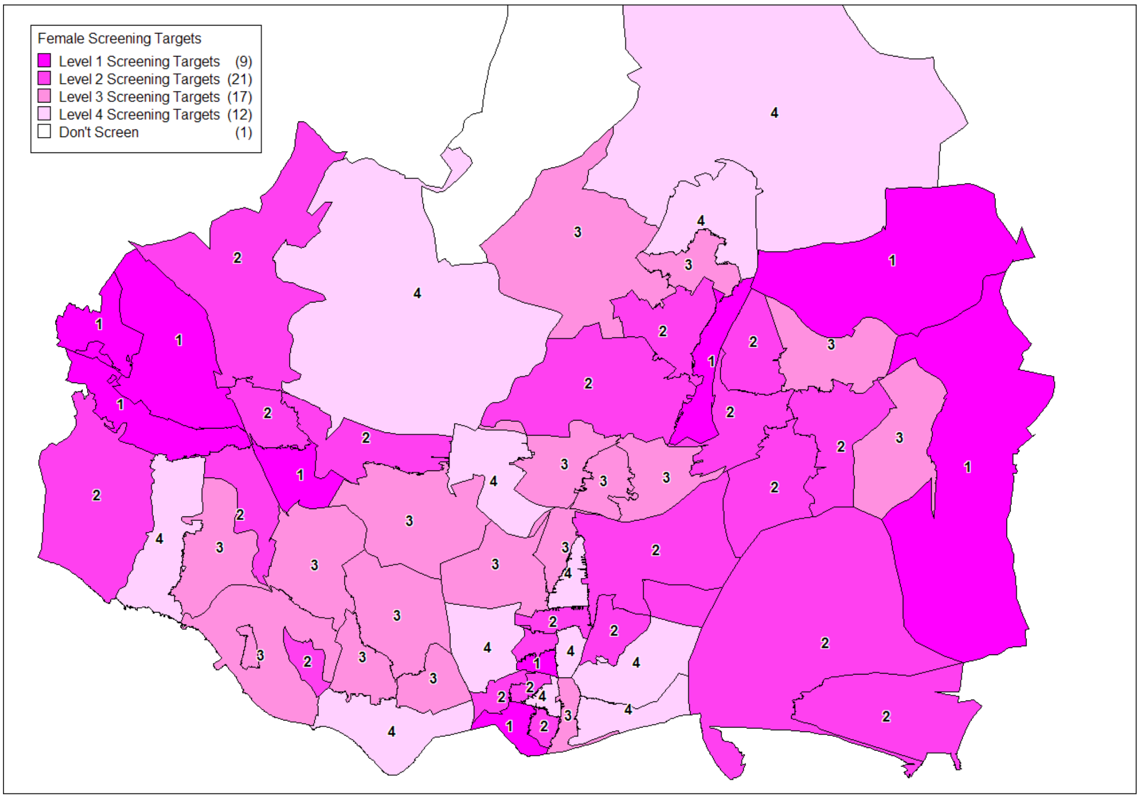

Figure 7-13: Overview of the female screening areas identified

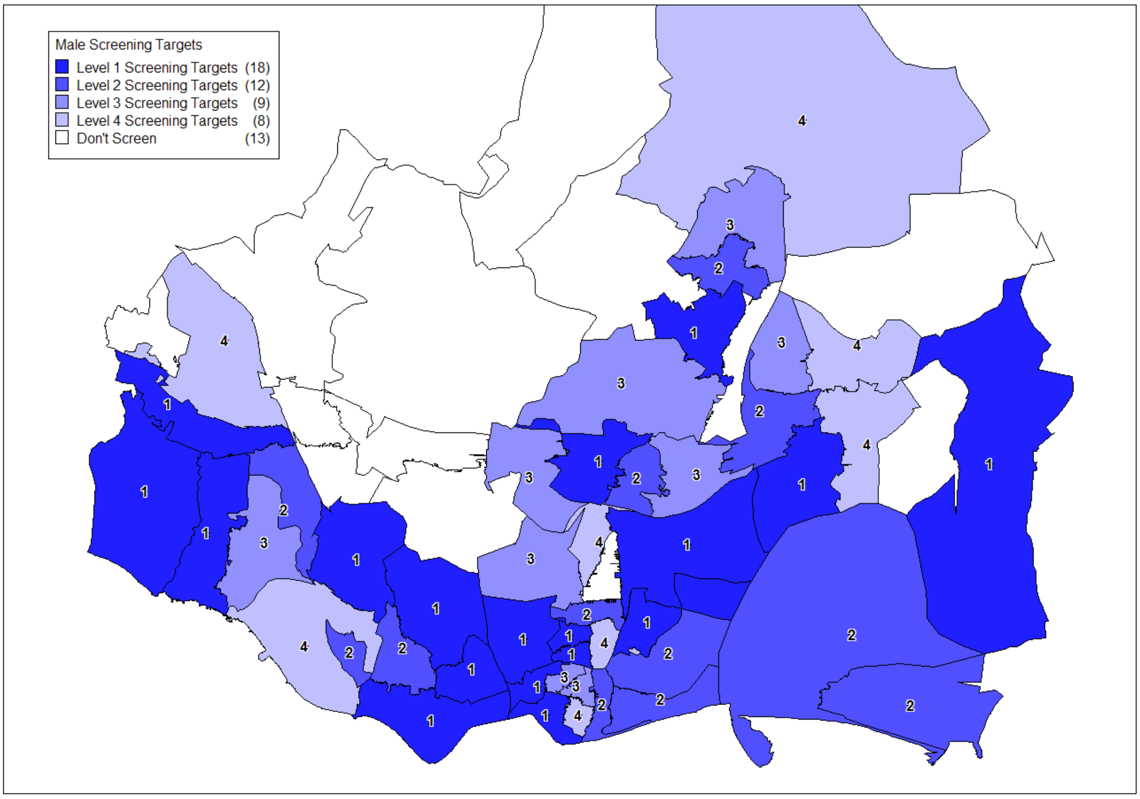

Figure 7-14: Overview of the male screening areas identified

7.12 Chapter Summary

The key findings of this analysis are:

- The Chlamydia screening coverage over the data collection period has been plotted onto maps of the screening area to clearly indicate the number of patents in the 13–26 year age group.
- Test result data including the number of tests, the number of positives and the number of other test results, have been plotted by gender. Clusters could be identified from these maps for each gender.
- By presenting incidence on maps, and identifying potential clusters of infections, screening areas, or areas that may benefit from targeted interventions have been identified.
- Using Evenden (2003) as a guide four categories or levels of screening/intervention locations have been identified. These levels differ by gender however some postcode sectors are at the same level of urgency, suggesting that they should be targeted.
- The maps clearly show that there are some differences between the female and male patients, which may be a result of the screening strategies currently in use.
- The Portsmouth and surrounding area may benefit from specific screening strategies or interventions rather than a blanket strategy of both genders.

8 Socioeconomic Analysis

8.1 Research Tasks Addressed

T2. What are the factors (e.g. socioeconomic and behavioural) that are associated with Chlamydia prevalence/incidence in an area?

T5. Can behavioural dynamics be adequately captured in a System Dynamics model of Chlamydia? Does the inclusion of behavioural factors make a difference in the evaluation of Chlamydia screening strategies?

8.2 Chapter Introduction

This chapter focuses on identification through statistical and data mining techniques the socioeconomic indicators that were associated with Chlamydia post code sector prevalence and incidence. The analyses applied to the data included: bivariate correlation and logistic regression analysis; and, data mining through the use of decision trees. A number of socioeconomic variables from multiple sources were examined, including CENSUS data obtained from the Casweb and Neighbourhood Statistic website. Due to the Chlamydia test data being in postcode sector geography, the socioeconomic indicators were converted from their source geography to postcode sector geography to enable analysis.

This chapter primarily addresses research task T2 in the identification of socioeconomic factors associated with Chlamydia. This chapter contributes to research task T5, through the identification of risk groups which are incorporated in the SD model.

8.3 Socioeconomic Datasets

The socioeconomic datasets used in the analysis are shown in table 8-1; additional information about the datasets is available in appendix C. A description of the datasets and their source are also provided, in the table. Many of these variables exhibited collinearity and the extent of the collinearity can also be found in appendix K. As many of the variables were collinear, logistic regression analysis was undertaken by gender, and is discussed in sections 8.4 and 8.5 for women and men respectively.

Data Set	Source	Description
Qualifications	Casweb - CS105	No qualfication through to higher degree
Accomodation Type	Casweb - CT005	Different types of unshared or shared accommodation
Tenure	Casweb - CT005	Different forms of ownership, rent or living rent free
Living Arrangements	Casweb - CT005	Different forms of cohabiting and living alone
Family Type	Casweb - CT005	Lone parent to married couple with parents through living alone
Economic Activity	Casweb - CT005	Active: Types of employment etc; Inactive: Retired etc
Country of Birth	Casweb - KS05	UK, EU or Other
Ethnic Group	Casweb - KS06	White, Mix, Asian, Black, Chinese
NSSEC	Casweb - KS014a	National Statistics Socio Economic Classification
Cars or Vans	Casweb - KS017	Number of cars/vans the household owns
Dependent Children	Casweb - UV06	Number and age group of dependent child(ren)
General Health	Casweb - UV020	Range from not good health to good health
Persons per Room	Casweb - UV058	Number of people per room
Occupancy	Casweb - UV059	scale to assess under-occupancy and over-crowding
Notifiable Offences*	Neighbourhood Statistics	Number of Key Criminal offences
Under 18 contraceptions	Neighbourhood Statistics	Estimated conception counts
Homelessness	Neighbourhood Statistics	Counts and percentages of the levels of homelessness
Same Sex Couples	Casweb - UV093	Number of same-sex couples identifying the other as partner
Deaths	Neighbourhood Statistics	Count of registered deaths
Age*	Casweb - UV04	Count by age
Total Population*	Casweb - UV04	Count of total population

Table 8-1: Socioeconomic datasets

8.4 Female Screening Data Regression Analysis

Stepwise linear regression was carried out to reduce the number of correlated variables previously mention in section 8.3 to a useful subset that best described infection prevalence for each gender. Selecting a range of candidate variables based on the correlation analysis gave a useful regression equation to describe or predict prevalence. Stepwise linear regression was carried out in SPSS (version no.17) based on those variables that were highly correlated with Chlamydia prevalence. The entry F value used was 0.10 and removal F value used was 0.15. The key variables found and there correlation coefficients were:

- NSSEC04 Ratio – Intermediate Occupations (–84.804)
- NSSEC03 Ratio – Lower Managerial and Professional Occupations (83.568)
- Ben – Ratio – Disability Living Allowance (109.673)
- NSSEC01 – large employers and higher managerial occupations (–0.013)
- Accom – Other type of establishment (0.005)
- Age – 100 plus (–0.427)
- Ethnic – Asian (–0.011)

The regression results are summarised in table 8-2 below. The R-squared value was 0.656, indicating that 65.6% of the variation was described by the above variables. The ANOVA, table 8-3 tests the acceptability of the model from a statistical perspective. The “Regression” row displays information about the variation accounted for by the model. The “Residual” row displays information about the variation that is not accounted for by the model. The significance value of the F statistic is less than 0.05, which means that the variation explained by the model is not due to chance.

R	R Square	Adjusted R Square	St Error of the Estimate
0.810	0.656	0.584	6.34341

Table 8-2: Female regression fit

	Sum of Squares	df	Mean Square	F	Sig
Regression	257.484	7	36.783	13.021	0.000
Residual	144.071	51	2.825		
Total	401.550	58			

Table 8-3: Female ANOVA

The coefficients of the variables included in the regression are shown in table 8-4.

Variable Name	Coefficients	Significance
Constant	8.762	0.002
NSSEC 04 Ratio - Intermediate Occupations	-84.804	0.000
NSSEC 03 Ratio - Lower Managerial and Professional Occupations	83.568	0.000
Ben - Ratio - Disability Living Allowance	109.673	0.058
NSSEC 01 - Large employers and higher managerial occupations	-0.013	0.000
Accom - Other type of establishment	0.005	0.000
Age - 100 plus	-0.427	0.005
Ethnic - Asian	-0.011	0.000

Table 8-4: Female regression coefficients

The regression equation has been plotted in figure 8-1 below. This seemed to explain the female Chlamydia prevalence variation reasonably well, capturing the central cluster of prevalence and the outliers.

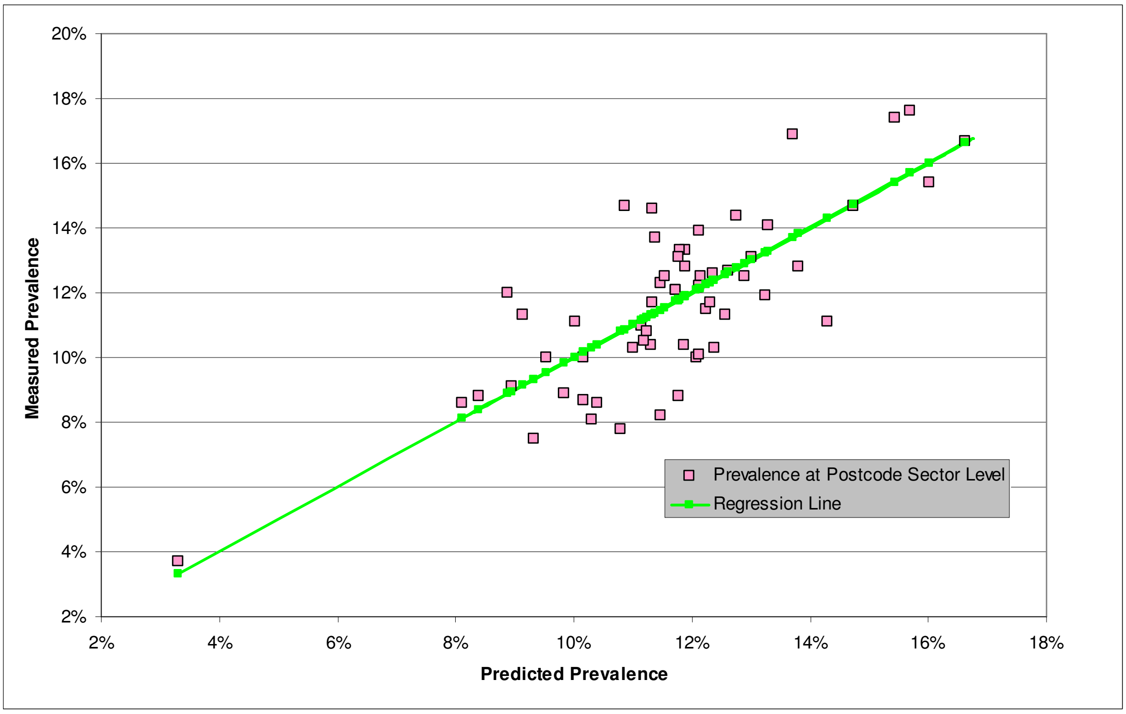

Figure 8-1: Female regression plot

A residual plot of the error term is provided in figure 8-2 and it is apparent that it is approximately normal.

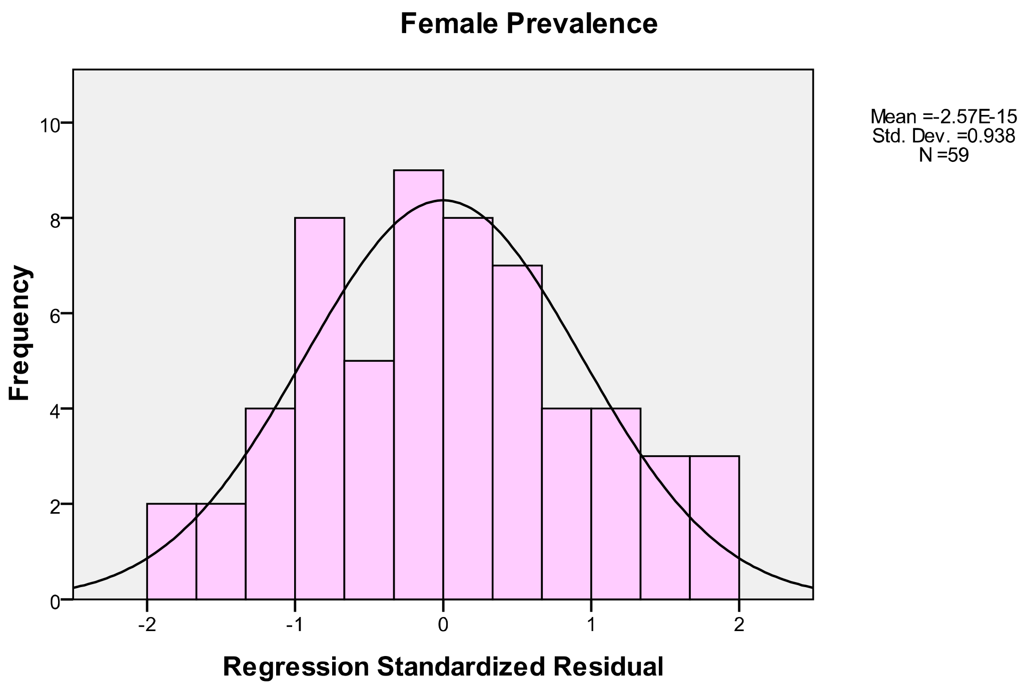

Figure 8-2: Female regression residuals

8.5 Male Screening Data Regression Analysis

Like the female regression analysis discussed in section 8.4, stepwise linear regression was carried out on the male data. Linear regression was carried out on the male variables that were identified in section 8.3 significantly correlated with Chlamydia prevalence. The key variables found and there correlation coefficients were:

- Accom – Ratio – Other type of establishment (101.063)
- Qualification – Ratio – Other (681.812)
- Birth – Ratio – EU (805.422)
- Car – Ratio – Three (–832.043)
- Accom – Ratio – Caravan, mobile or temporary structure (1247.068)
- Child – Ratio – One dependent child aged 5–11 (–2096.143)
- Age 90–99 (–0.196)
- Armed Forces – Armed Forces (0.023)
- Per – 1.5 persons per room (–1.097)

Regression analysis for the male data was more complicated than the female as many postcode sector prevalence levels for the male population were zero. The model as indicated by the R Square value in table 8–5 accounted for 65.6% of the variability.

R	R Square	Adjusted R Square	St Error of the Estimate
0.810	0.656	0.584	6.34341

Table 8–5: Male regression fit

The ANOVA of the regression analysis provided in table 8–6 suggests that the variation explained by the model is significant and not due to chance.

	Sum of Squares	df	Mean Square	F	Sig
Regression	3299.457	9	366.606	9.111	0.000
Residual	1730.271	43	40.239		
Total	5029.728	52			

Table 8–6: Male ANOVA

The coefficients of the male variables included in the regression are displayed in table 8–7.

Variable Name	Coefficients	Significance
Constant	19.090	0.310
Accom - Ratio - Other type of establishment	101.063	0.006
Qualification - Ratio - Other	681.812	0.001
Birth - Ratio - EU	805.422	0.001
Car - Ratio - Three	-832.043	0.000
Accom - Ratio - Caravan, mobile or temporary structure	1247.068	0.000
Child - Ratio - One dependent child aged 5-11	-2096.143	0.000
Age - 90-99	-0.196	0.000
Armed Forces - Armed Forces	0.023	0.002
Per - 1.5 persons per room	-1.097	0.000

Table 8-7: Male regression coefficients

The linear regression line is plotted in figure 8-3. and it can be seen that there are some limitations of the model, in that where the actual prevalence in the observed data is zero the model struggled to predict the correct prevalence with values ranging from -10% to 20%.This could be due to the shift in how male patients were tested in as much as previously they had been targeted like the female patients but there was then a shift to focus test on male patients that were contacts of positive female patients.

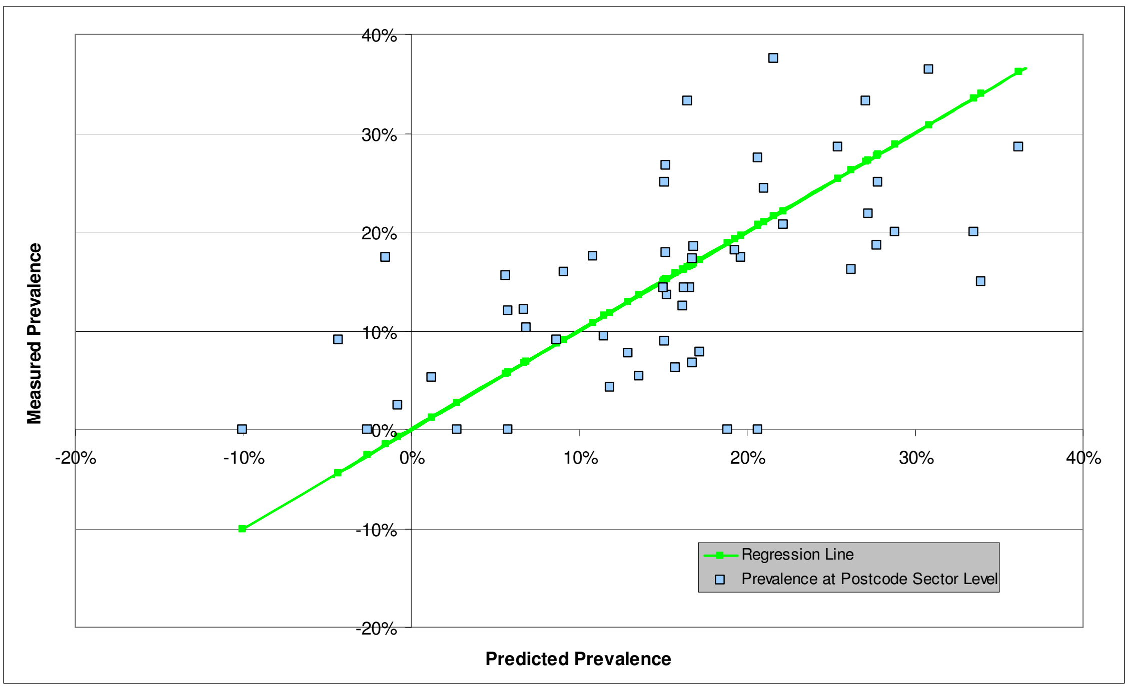

Figure 8-3: Male regression plot

Figure 8-4 indicates that the residuals are approximately normal.

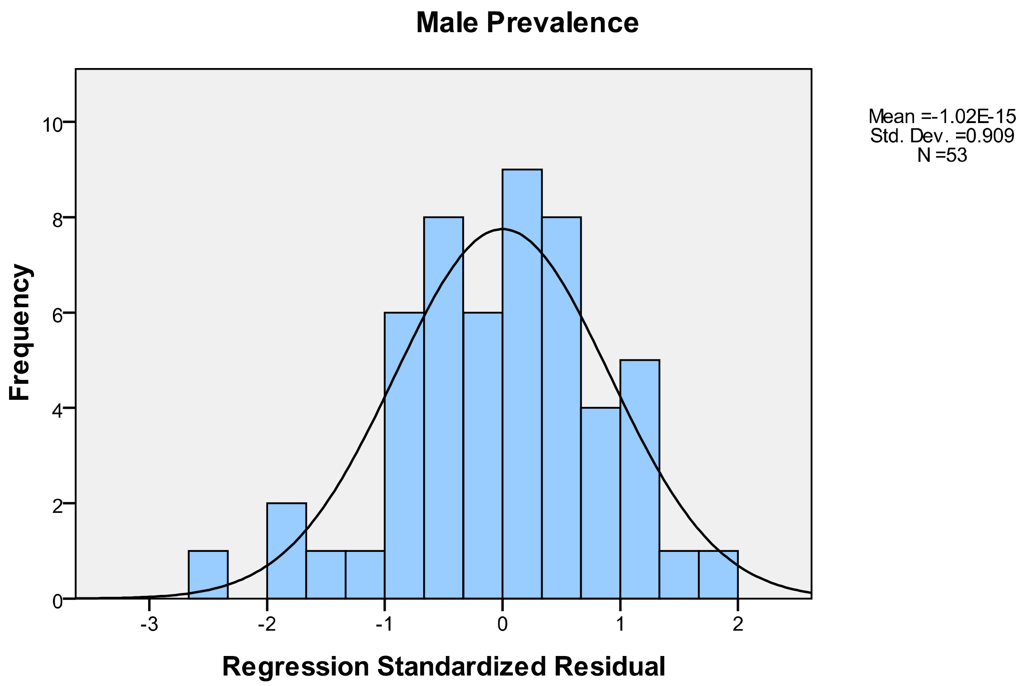

Figure 8-4: Male regression residuals

8.6 Limitations of Regression Analysis and Alternative Methods

Regression analysis was chosen as the main method of analysis, due to the author's familiarity with the technique and the types of variable made available through the data collection from the various data sources. The regression method informed the subsequent decision trees developed in section 8.7.

Regression analysis is not without its limitations. The limiting factors of the approach include (Norman and Streiner, 2000):

- Assumption of linearity, which can rarely be confirmed
- Identification of only relationships between variables, not identifying cause and effect
- Assumption that the residuals are distributed normally
- Inappropriate method to use when the variables exhibit non-linear relationships

Alternative data analysis methods could have been utilised including: Principal Component Analysis (PCA), Correspondence Analysis (CORA) and other Factor Analysis methods such as the latent class approach (Bartholomew et al, 2008). The aim of these methods is to reduce the number of variables from a potentially large set, to a more manageable number which still provides an accurate representation of the original data. In this research regression analysis was used to reduce the number of variables into a smaller subset of variables. PCA was not chosen as a number of the variables included in the analysis were categorical and PCA is used primarily with sets of continuous variables. CORA is similar to PCA although with an emphasis on categorical variables. The variables included in this research are a combination of categorical and continuous variables hence why regression was chosen to analyse them.

8.7 Screening Data Decision Trees

A decision tree is a tree-based classification model by which the model classifies cases into groups or predicts values of a dependent variable based on values of independent variables. Decision trees are used in this research to compliment the regression analysis.

Decision trees are used for (SPSS 17, 2008):

- ***Segmentation***. Identify persons who are likely to be members of a particular group.
- ***Stratification***. Assign cases into one of several categories, such as high-, medium-, and low-risk groups.
- ***Prediction***. Create rules and use them to predict future events, such as the likelihood that someone will default on a loan or the potential resale value of a vehicle or home.
- ***Data reduction and variable screening***. Select a useful subset of predictors from a large set of variables for use in building a formal parametric model.
- ***Interaction identification***. Identify relationships that pertain only to specific subgroups and specify these in a formal parametric model.
- ***Category merging and discretizing continuous variables***. Recode group predictor categories and continuous variables with minimal loss of information.

There are four main decision tree techniques: CRT, CHAID, Exclusive CHAID and QUEST and these will be described briefly in the next parts.

8.7.1 CRT or CART

The Classification And Regression Tree (CRT) growing method attempts to maximize within-node homogeneity. The extent to which a node does not represent a homogenous subset of cases is an indication of impurity.

8.7.2 CHAID and Exclusive CHAID

The Chi-squared Automatic Interaction Detection (CHAID) operates at each step by choosing the independent variable that has the strongest interaction with the dependent variable. Categories of each predictor are merged if they are not significantly different with respect to the dependent variable. Exhaustive CHAID is a modification of CHAID and examines all possible splits for each independent variable.

8.7.3 QUEST

The Quick, Unbiased, Efficient Statistical Tree (QUEST) is a method that is fast and avoids other methods' bias in favour of predictors with many categories. QUEST can be specified only if the dependent variable is nominal.

Sections 8.8 and 8.9 provide CRT decision trees based on the regression analysis carried out in sections 8.4 and 8.5 for female and male groups respectively.

8.8 Female Decision Tree

The variables highlighted by the regression analyses were used in the decision trees to ensure they were not overly complicated. Regression analysis was used to identify an independent and non-collinear set of variables.

The dependent variable was the Chlamydia prevalence by postcode sector and the independent variables were those identified by regression analysis. The decision tree for the female patients is illustrated in figure 8-5. The initial node indicates that the mean Chlamydia prevalence is 11.66%. The initial split is by the NSSEC04 – Ratio – Intermediate occupations as the first split and split the original 59 records to 58 and 1 postcode sectors with infection prevalence of 11.80% and 3.70% respectively. Node 10 exhibits the highest prevalence of 16.28%.

The tree continues to grow until all the cases within a node have the same value for the dependent variables. The tree growth can be limited manually by setting the maximum tree depth, or specifying the minimum number of cases required in each node before it splits. The default settings for tree depth in SPSS (5 levels for CART and 3 for CHAID) were used when creating the trees which resulted in the CRT trees displayed in figure 8-5 and figure 8-6. The minimum number of nodes for the parent and child nodes was reduced from the default values of 100 and 50 respectively as there were only 59 postcode sectors of interest. The minimum number of cases in the parent and child nodes was set to 1. Trees with a smaller number of cases increases the number of nodes produced, hence why the developed decision trees reach the maximum depth.

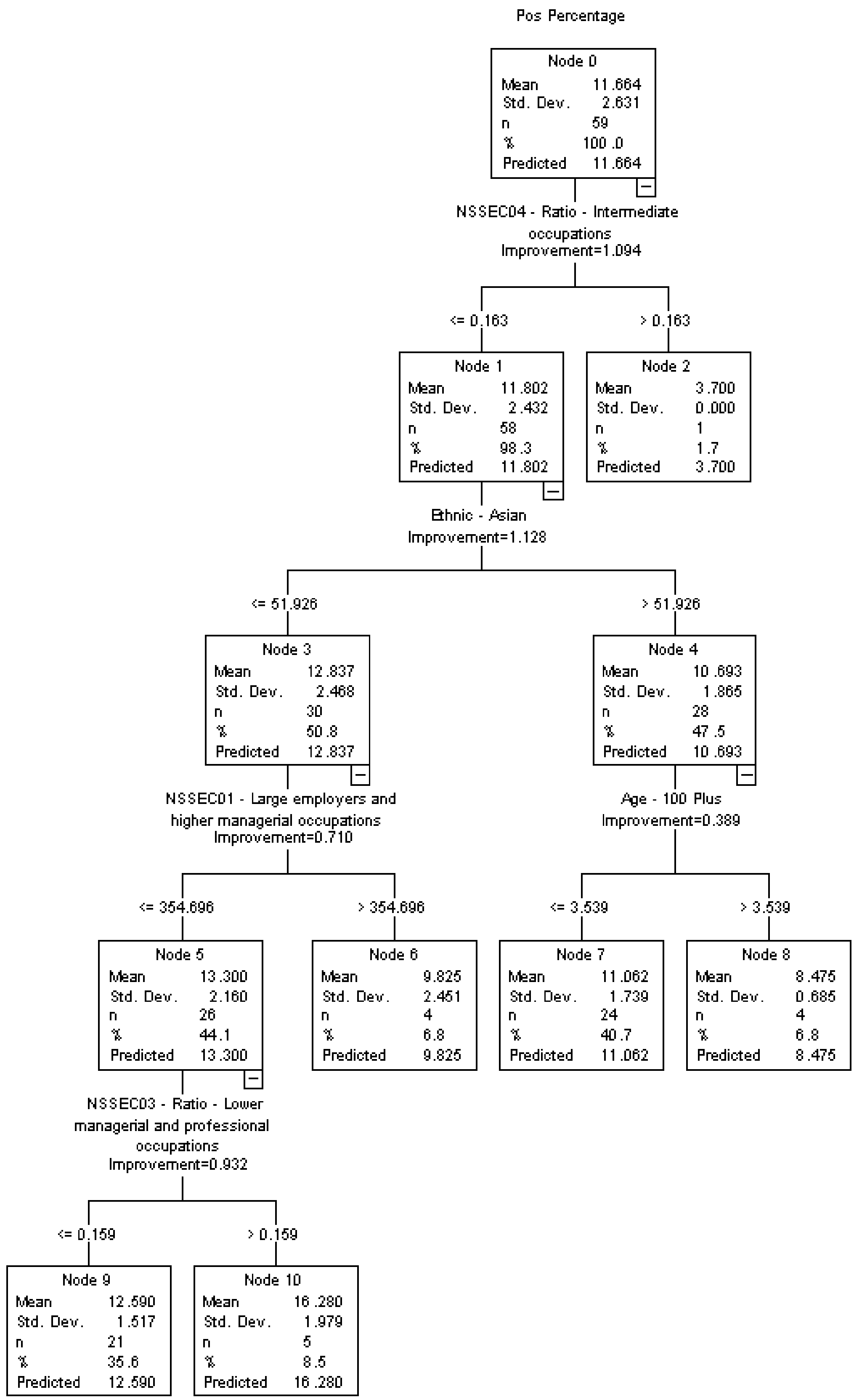

Figure 8-5: Female Decision Tree

8.9 Male Decision Tree

The decision tree for the male patients is illustrated in figure 8-6. The initial node indicates that the mean Chlamydia prevalence is 15.10%. The initial split is by Accom – Ratio – Other type of establishment as the first split and split the original 59 records to 40 and 13 postcode sectors with infection prevalence of 12.50% and 23.10% respectively. Node 11 exhibited the highest prevalence of 36.95%, relating to two postcode sectors. Node 7 exhibited the lowest prevalence with 12 postcode sectors and a mean of 4.56%.

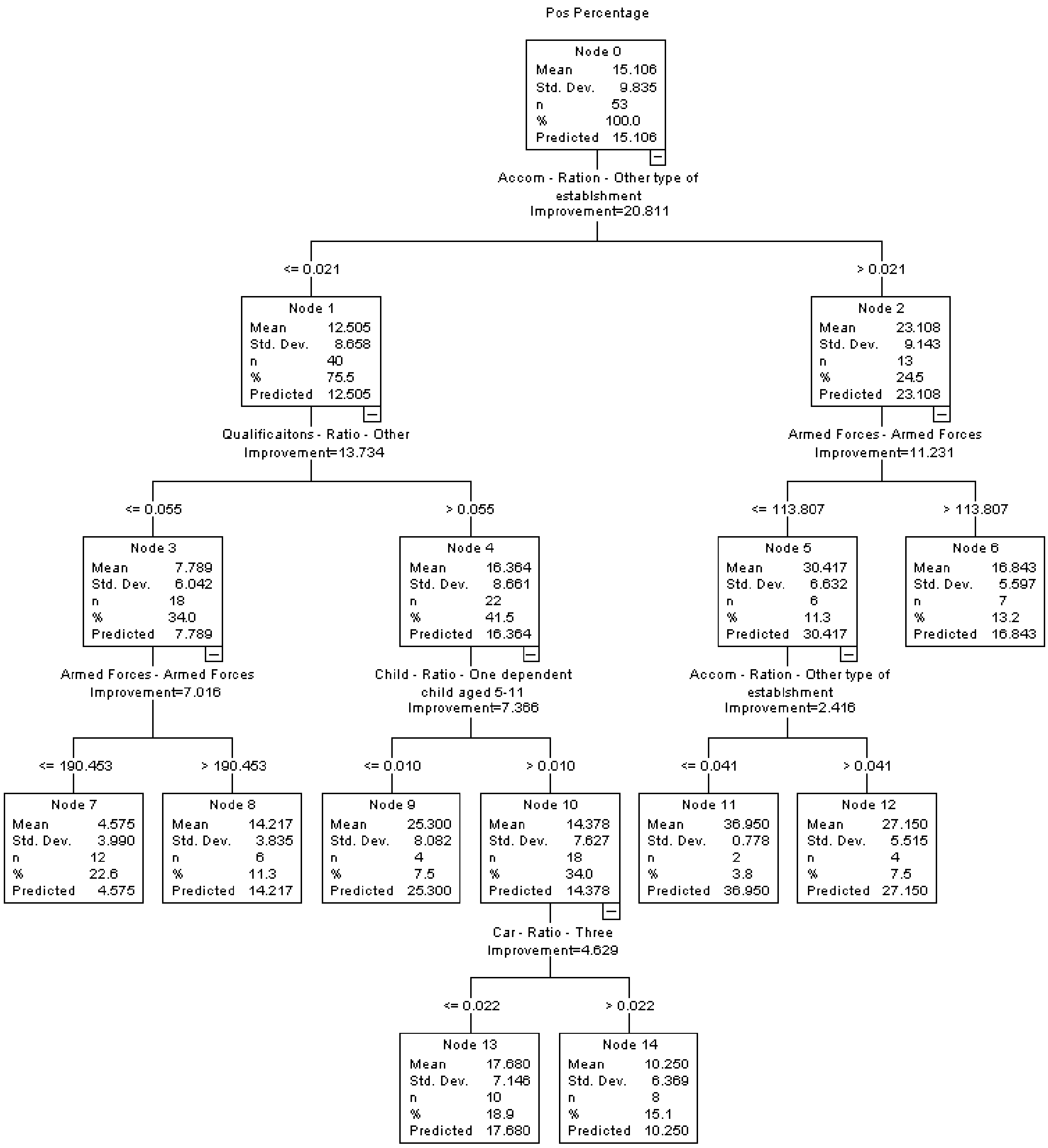

Figure 8-6: Male Decision Tree

8.10 Chapter Conclusions

Analyses were undertaken to ascertain which socioeconomic factors from the CENSUS related to the research area are associated with Chlamydia prevalence. Many socioeconomic factors when taken in isolation indicated a significant association with Chlamydia. Regression analysis highlighted the variables associated with Chlamydia levels in the research area.

There was a clear gender difference, in the identified variables, which is likely a result of the male Chlamydia result data relating to those men who have been identified through contact tracing of positive female partners.

8.11 Chapter Summary

This chapter has:

- Utilised the screening data discussed in chapter 6 and CENSUS data obtained and manipulated to postcode sector level, to be analysed.
- Several CENSUS variables were found to be correlated with postcode sector level Chlamydia prevalence, which exhibited gender differences.
- Due to many variables being correlated and a high level of collinearity, logistic regression analysis was undertaken to identify the key variables.
- Decision tree offered an effective tool for healthcare professionals to identify potential individuals to recommend for Chlamydia screening based on the available data.

9 Behavioural Analysis

9.1 Research Tasks Addressed

T2. What are the factors (e.g. socioeconomic and behavioural) that are associated with Chlamydia prevalence/incidence in an area?

T3. What is the difference in sexual behaviour, knowledge and attitudes between: attendees at the St Mary's GUM department and students from the University of Southampton?

T5. Can behavioural dynamics be adequately captured in a System Dynamics model of Chlamydia? Does the inclusion of behavioural factors make a difference in the evaluation of Chlamydia screening strategies?

9.2 Chapter Introduction

The purpose of this chapter was threefold: firstly, to determine the sexual knowledge, beliefs and attitudes of the local population; secondly, to identify the differences between individuals who attend the GUM department at St Mary's hospital with students from the University of Southampton; and, finally to identify behaviours associated with Chlamydia infection. The chapter is structured as follows. The data collection methods are discussed in section 9.3. The questionnaire results are summarised in sections 9.4 and 9.5. The differences in the data are examined by gender for the University and GUM groups in parts 9.4.1 and 9.4.2 respectively. The differences in the data were also examined by history of Chlamydia for the University and GUM groups in parts 9.5.1 and 9.5.2 respectively. Section 9.6 provides decision tree analysis of the variables identified in section 9.5.

This chapter focuses on providing possible answers for the research tasks: T2, T3 and T5. Due to the qualitative nature of the research tasks the explanations provided are open to interpretation.

9.3 Data Collection Methods

Due to the time constraints of the study the sensitivity of the subject area and the available budget the primary method of data collection was agreed to be questionnaire. The questionnaire development and the various versions of the questionnaire are discussed in the proceeding sections. In addition to the questionnaire data, results pertaining to participants' additional medical history could be obtained from the GUM system for the GUM group. Details about this additional data are discussed in part 9.3.3.

9.3.1 Questionnaire Development

In order to address the research questions two questionnaires were designed, a paper based questionnaire for participants from the GUM department and an electronic version for participants from the University. The questionnaires were designed to obtain various socioeconomic data and specific questions relating to the participant's sexual behaviour, sexual knowledge and sexual history.

Initial versions of the questionnaires were piloted with research student colleagues from the University of Southampton and other academic institutions as well as persons who the researcher knew outside of academia. Ideally the questionnaires should have been piloted with patients who visit the GUM department and general members of the public however ethical approval had not be obtained so this was not possible.

People under the age of 18 were identified as a key group of participants in the understanding of sexual health and behaviour. Obtaining ethical permission to ask patients under the age of 16 proved to be unattainable, therefore the 16-17 age group were chosen. This was because the 16-17 age group were deemed to be Gillick competent. A specific participant information sheet and consent form was developed for those participants under 18 – see appendix D.

The questionnaires went through 10 revisions following feedback from those who piloted the questionnaire and discussions with the Research Governance Office (RGO) at the University of Southampton and the Portsmouth NHS R&D Consortium. The final approved versions of the questionnaires can be found in appendix E. The GUM questionnaire contained 43 questions and the student questionnaire contained 44 questions. Both questionnaires contain questions that have multiple parts.

9.3.2 Sample sizes

The sample sizes calculated for the University and the GUM groups are shown in table 9-1.

Group	University	GUM >18	GUM 16-17
Female	189	188	153
Male	188	187	153
Total	377	375	306

Table 9-1: Calculated sample sizes

9.3.3 Additional Data

Additional data were retrieved from the GUM computer system for the GUM participants relating to their test results from the visit in which they completed the questionnaire. GUM participants were required to enter their clinic number on the questionnaire. The questionnaires were cross referenced with the computer system via the clinic number to maintain the anonymity of the patients. The data related to the various tests that GUM carry out for STIs including: Chlamydia, Gonorrhoea, HIV, Syphilis, Hepatitis B, and Hepatitis C.

9.3.4 Data Collection period

Following ethical approval, received on 16th of June 2008, questionnaires were printed off, and the online questionnaire made live. Permission was sought from the academic Schools from the University of Southampton. Each school had its own procedures relating to the research that can be carried out with their students. The procedures ranged from forwarding of the invitation letter to student email lists, to comprehensive additional ethical application, despite NHS ethical approval which trumps University level approval. The major contributing Schools were Social Science, Geography, and Ocean and Earth Science. Details about the University's contribution are discussed in sections 9.4 and 9.5. Attempts were made to start the data collection period simultaneously. Data were collected for the University participants between 17th September 2008 and 22nd February 2009 and the GUM participants between 28th September 2008 and 25th February 2009.

Due to the sensitive nature of the questionnaire it was difficult to obtain the calculated sample size. The numbers of questionnaires completed by the various groups are shown in table 9-2. It is apparent that the GUM 16-17 group fall well short of the calculated sample size. Further analysis and discussions in this chapter will be restricted to the University and GUM >18 groups.

Group	University	GUM >18	GUM 16-17
Female	180	174	13
Male	66	154	1
Total	246	328	16

Table 9-2: Actual sample

The low response rate for the GUM 16-17 group was a possibly a result of the sensitive subject the questionnaire addressed. Many individuals from this age group were often accompanied by parents and/or guardians who could have deterred them from participating in the research. The lower response rate of the male University group is most likely a result of the sensitive nature of the questionnaire. The length of the questionnaire could have also contributed to the low response rates for both groups.

As mentioned in part 9.3.1 each questionnaire contained over 40 questions. Tabular information for each question can be found in appendix L. To examine the potential differences within and between the groups and address the research tasks, the Chi square statistical test was chosen given the large number of variables to analyse and the available time. The analysis was conducted in SPSS version 17. The Chi square results are provided in sections 9.4 and 9.5. The tables presented in these sections use the short names for the questions. The meanings of the short name are provided in the accompanying text. A full list of short names for each question can be found in appendix F.

9.4 Gender Differences

The initial analysis explored the difference between the responses to the questionnaire with respect to gender. The questions identified as being significantly different between the genders at both the 95 and 99% levels by the Pearson Chi Square statistic are listed in table 9-3. This section relates to and elaborates on the table below.

Variable	Sig. (2 sided)
al_FrequencyAlcohol	0.000
AgeDifference	0.000
SexAct_Anal	0.000
ThreeMonParCat	0.000
contra_com	0.000
EmergencyContraception	0.001
NoContra_com	0.001
RelationshipStatus	0.002
agecat	0.002
risk_InternetSocial	0.004
risk_MarriedOtherPeople	0.010
qual_com	0.012
e_OtherSTI	0.017
res_LongInCity	0.019
dru_SexDrugsOther	0.027
risk_MarriedEachOther	0.030

Table 9-3: Sig. variables from Chi square by gender

Male participants overall drank more often than female participants (Al_FrequencyAlcohol). The Chi square statistic (p=0.000) suggests that this difference is significant. This finding is similar in many studies that suggest men drink alcohol more frequently than women (Radcliffe et al, 2001; Rogstad, 2004; Ross and Radcliffe, 2006)

The age difference between the participant and their last sexual partner (AgeDifference) question was broken into two younger age bands, an about the same age category and two older age bands. The wording of the question was not explicit and could be interpreted in two ways: the sexual partner's age in relation to the participant filling in the questionnaire e.g. person filling in questionnaire 20 and their sexual partner was 23 so therefore participant enters 3 years older; alternatively the question could be interpreted the other way, the participant's age in relation to the sexual partner's age in which case for the same example above the participant would enter 3 years younger. Interpretation of the results for this question need to be taken with caution, however they do agree with other studies suggesting that females sexual partners tend to be older and vice versa male sexual partners tend to be younger. The differences between the response being deemed significant (p=0.000) by the Chi square test.

Participants were asked if they have ever had anal sex that is if they have received or given anal (sexAct_Anal). 35.28% (121/343) of the female participants reported having anal compared with 53.49% (115/215) of the male. The higher percentage noted for males maybe a result of the inclusion of male homosexuals. The differences reported were deemed significant (p=0.000) by the Chi square test. No distinction was made between the receiving and giving of anal as was made for oral sex. This is a limitation when male homosexual relationships are examined as it cannot be determined and could potentially be important. Anal sex is an important factor with the spread of many STIs (Adams et al, 1998; Brandeau et al, 1993; Griffiths et al, 2006; Fulcher et al, 2005)

Participants were asked to state the number of sexual partners they had had in the last three months (ThreeMonParCat). Participants may have misinterpreted the question as how many sexual partners ever as there were a number of participants who stated over 10 although this could still be a valid three month total. To simplify the analysis 4 groups were created: 0, 1, 2 and 3 +. The male participants reported having a larger number of sexual partners 24.55% (54/220) reported having 3+ partners in the last 3 months compared to 11.05% (39/353) of the female participants reporting the equivalent. The male group were significantly more likely to have reported a greater number of partners (Chi square, p=0.000). This has proven to be the case before by Johnson et al (2001); Roberts et al (1990); Stover (2000); and, Griffiths et al (2000)

Participants were asked which method(s) of contraception they are currently using. As participants could use more than one method an additional variable was formed which reflected all the combinations of contraception used (Contra_com). Some methods were used in isolation, others in combination with one other method e.g. Condom and Pill. The key difference (Chi square, p=0.000) being that 42.62% (156/366) females used the pill, whereas 47.53% (106/223) of males used condoms. These are the most common form of contraception for each gender, but although the pill prevents pregnancy it does not reduce the spread of STIs (Johnson et al, 2001).

Emergency contraception was reported as being used by 58.38% (195/334) of the women and 40.65% (87/214) of the male participants reported that their partners had used emergency contraception. The differences between the genders was deemed significant (p=0.001) by the Chi square test. These results appeared to be surprising as a large proportion of the sample had used emergency contraception. This suggests that contraception was not available, or the individuals did not think about the consequences of unprotected sex, due to being "caught in the moment" under the influence of alcohol or drugs or merely careless. The reported male figure may be lower than that of women as the men may have been unaware that their sexual partner obtained emergency contraception.

Participants were asked the reason(s) why contraception wasn't used if they had ever had unprotected sex (NoContra_com). Participants were allowed to tick as many of the preselected answers as applied. The combinations of these answers were analysed rather than analysing the individual response categories. There were 39 combinations of the 7 responses available. The most common response for both genders was that to leave the question blank indicated that they either hadn't had unprotected sex or hadn't answered the question 44.81% (164/366) of the female group and 27.80% (62/223) of the male group. Other prominent answers were that "partner didn't want to" and "didn't think". The differences between the genders was deemed significant (Chi square, p=0.001). It should be noted that many of the combination had very low frequencies <5 making the Chi square test less reliable.

Four categories were defined to represent the current sexual relationship status of the participant (RelationshipStatus). 10.33% (22/213) of male participates reported being in a regular sexual relationship with one person but also having sex with another person(s) compared to 3.69% (13/352) of the female participants. Female participants were more likely to report that they were in a regular sexual relationship with just one person when compared to male participants 62.22% compared to 49.77%. These results suggest that female participants maintain one sexual relationship at a time and that males are more likely to have concurrent sexual partnerships. The differences in the sexual partnership results were deemed to be significantly different by the Chi Square analysis (p=0.002). Concurrent sexual partnerships are more likely to result in higher levels of STI infection as indicated by the screening data analysis of chapter 6. This however could be influenced by the manner in which male participants attend the GUM department, as one of the main routes is through contact tracing of positive female patients. This should not have influenced the male participants in the University sample; however as the GUM sample accounts for 70% (154/220) of the male participants it is likely to have had an effect.

The participants provided their dates of birth (DOB). From the DOBs 10 year age bands were tabulated from 10-19 to 50+ (Age bands). The age structure of the participants was as follows: 82.15% ([75+215]/353) of the female participants fell into the 10-19 and 20-29 age group compared with 70.91% ([31+125]/220) of the male participants to fall into the same age groups. The female group were significantly (Chi square, p=0.002) younger than the male group which reflects the existing knowledge that females tend to have older partners.

Social networking sites such as Facebook, MySpace, Bebo, and Twitter enable individuals to contact one another over the internet. Many of these sites offer dating applications which gain popularity. Participants were asked if they have ever met a sexual partner via a social internet site (RiskInternetSocial). 19.71% (41/208) of the male participants reported meeting a sexual partner on the internet compared with 10.71% (36/336) of the female participants. This difference was identified as significant (p=0.004) by the Chi square test. This area is relatively new and there has been little research into it especially in the Portsmouth and Southampton areas. The research conducted suggests further research is required in this area, with the use of meeting sexual partners over the internet increasing.

Another question used to ascertain a participant's knowledge about STIs was what is the risk of a married couple who have sex with others having an STI? (Risk_MarriedOtherPeople). Both genders agreed from the responses that this is more likely to increase the chances of one person in the couple becoming infected with an STI. The majority answered that the married couple would be "quite at risk" in this instance. The level of risk did vary significantly (Chi Square, p=0.010) between the genders with 16.28% (56/344) and 67.44% (232/344) of the females responding that the couple was "Greatly at risk" and "Quite a lot" at risk respectively. Compared with the male responses of 13.40% (28/209) and 60.29% (126/209) for the corresponding risk groups. Although both groups deemed this situation to be more risky once again the males view the situation as carrying less risk than the females. This could be due to a lack of knowledge on the males' part and/or a more cautious approach by the females.

Participants were presented with 8 categories of education ranging from currently at School to Postgraduate degree. As with previous questions discussed they could select multiple options, as such the unique combinations of qualifications were combined (Qual_com). The most common combination of qualifications for both groups was GCSEs grade A-C, A level and At University, 32.51% (119/366) of the female and 20.18% (45/223) of the male groups respectively. The second most common combination being GCSE grades A to C 11.20% (41/366) and 19.73% (44/223) for the female and male groups respectively. The difference between the qualification combinations was deemed significant (Chi square, p=0.012), however like the noContr_com it should be noted that many of the combinations contained a small number of participants.

The questionnaire had a series of questions which asked participants if they had ever had a number of STIs. A problem arose in that for the GUM patients their result from their visit to the department was linked to the questionnaire; therefore a number of patients had infections including Hepatitis B, Hepatitis C and MSU, which could have been answered as "Other" (E_OtherSTI) in the student questionnaire. Therefore analysis of this section needs to be undertaken with caution. 6.82% (15/220) of the males' participants reported having an "Other STI" compared to 1.98% of the female participants (7/353). This difference was deemed significant (Chi Square, p=0.017).Further explanation of this is difficult as to the uncertainty over what "other" infection they may have had.

The female distribution relating to how long they have lived in the city in which they completed the questionnaire (Res_LongInCity) indicated that females found to reside in the place they completed the questionnaire exhibited a shorter duration in comparison to the male population. 77.21% of the female population had lived in the city for <5 years, compared to 66.51%. This difference between responses was deemed by Chi Square analysis to be significant (p=0.019).

Of the 350 female participants 5 reported having sex with someone who takes drugs (Dru_SexDrugsOther) compared with 2 of the 212 male participants. The Chi square statistic (p=0.027) suggests that this difference is significant. Drugs in this instance relates to those who inject drugs. Is injected drug use associated more with males than females resulting in the reported numbers? The results to this question are dependent upon the length, amount of trust and level of communication in the relationship. It may have been the case that people may have been in very short relationship which could account for the number of “don’t know” answers to this question (14 female and 20 male), as there may not have been the opportunity to find out.

Participants were asked a number of questions to ascertain their knowledge about STIs. One question was what is the risk of those couples who are married and exclusively have sex with each other having an STI (Risk_MarriedEachOther)? The majority of participants stated not very much risk or none at all. However there was difference between how the male and females responded to this question, 48.84% (168/344) of females answered that there was not very much risk compared with 35.71% (75/210) males. Of those participants that answered that there was no risk at all 48.26% (166/344) were female and 60.48% (127/210) were male. These differences in responses were deemed significant (p=0.030) by the Chi square test. Married couples are susceptible to STIs if one of the couple had an infection before they were married, so there is risk. Males in general deemed this situation as having less risk than females.

9.4.1 Gender Differences for University Group

To distinguish if the variables that were identified as significant in the gender analysis section 9.4 remain significant when the group the participant comes from be that the GUM group or University group are taken into account. Additional Chi square analyses are undertaken for each group to determine the significant differences by gender for that group. The University group is analysed first below and the GUM group is analysed in part 9.4.2.

The additional Chi square analysis identified 3 variables as being significantly different by gender for the University group compared to the 16 variables initially identified in section 9.4. Only 1 variable of the original 16 (AgeDifference) remained significant when the University group was examined in isolation. The significant University variables are provided in table 9-4 and are discussed following the table.

Variable	Sig. (2 sided)
AgeEnterCat	0.026
AgeDifference	0.028
ConRea_MainReason	0.043

Table 9-4: Sig. variables from Chi square by gender and group – Uni group

The age the participant enters the country (AgeEnterCat) was significantly different (Chi square, p=0.026) between the genders for the University group. The AgeEnterCat variable was not identified as significant when the University and GUM groups were combined. A small number of the student sample answered this question 19.48% (30/154) of female and 22.72% (15/66) male participants. The female students who answered this question tended to enter the UK at an older age 83.33% (25/30) >=14 yrs compared to 66.66% (10/15) of males, which could potentially be the results of a cultural difference.

Female University participants reported that the age difference between them and their sexual partners were >=2 years older than them 29.81% ([29+19]/161). 62.11% (100/161) females reported having a sexual partner about the same age as themselves compared with 68.33% (41/60) of the male participants. The differences observed are significant (Chi square, p=0.028), these findings agree with those for the combined group reported in section 9.4.

The participants were asked if they used condoms to prevent pregnancy or to prevent infection, or both equal (ConRea_MainReason). There was a significant difference (Chi square, p=0.043) between the genders, with 58.70% (27/46) of males reporting that they use condoms solely to prevent pregnancy compared with 38.39% (43/112) of female participants. The proportion of participants for each gender who used condoms to prevent pregnancy and infection were also different with 39.29% (44/112) and 34.78% (16/46) for the female and male groups respectively. Males appear to be more concerned about pregnancy than infections.

9.4.2 Gender Differences for GUM Group

The specific GUM group Chi Square analysis identified 19 significant different responses between the genders, compared to the 16 variables identified when the samples were combined. 6 new variables were identified as relating specifically to the GUM group: vag_VaginalSex, AgeVaginal, living_com, e_HepB, wor_pregnancy and e_Warts. Of the16 originally identified variables: NoContra_com, qual_com and risk_MarriedEachOther, were not considered as significantly different between the genders for the GUM group.

Variable	Sig. (2 sided)
al_FrequencyAlcohol	0.000
AgeDifference	0.000
EmergencyContraception	0.000
SexAct_Anal	0.000
contra_com	0.000
res_LongInCity	0.001
AgeVaginal	0.001
dru_SexDrugsOther	0.003
risk_InternetSocial	0.003
agecat	0.004
ThreeMonParCat	0.004
wor_Pregnancy	0.017
RelationshipStatus	0.033
risk_MarriedOtherPeople	0.038

Table 9-5: Sig. variables from Chi square by gender and group -GUM group

The data suggested that males drink more frequently than females (Chi square, p=0.000). This is illustrated by 14.38% of males (22/153) reporting drinking on more than 5 days a week compared with 2.30% of the female (4/174)

The age difference between partners was suggested a significant difference between genders (Chi square, p=0.000), which was consistent with results found in the literature, with females reporting slightly older partners, 2-4 years older, 27.17% (47/173), and males slightly younger partners, 2-4 years younger, 30.52% (47/154).

A significant difference between genders was found of those who reported that they or their partner used emergency contraception (Chi square, p=0.000). A large proportion of the female respondents reported using emergency contraception 70% (119/170), which appears very large. 44.44% (64/144) of male respondents reported that their partner used emergency contraception which is again very high, although likely to be underreported due to those males who did not their sexual partner.

The survey found that 41.07% (69/174) of women reported having had anal sex ever compared with 62.67% (94/150) of men. The difference was found to be significant (Chi square, p=0.000), and is likely influenced by the male homosexual respondents.

Half of the male respondents reported using condoms during their last sexual contact (77/154), compared with 32.76% (57/174) of women which was found to be significant (Chi square, p=0.000). The reported figures may be attributed to female respondents having other forms of contraception available, which could possibly influence the male's choice of contraception.

The age of reported by respondents of first vaginal sex experience varied significantly between the genders (Chi square, p=0.001). The majority of female and male respondents reported having their first experience of vaginal sex in the 15-19 age bracket, 72.41% (126/174) for female and 65.58% (101/154). There was a tendency for some men to experience first vaginal sex later in 25+ age band 12.34% (19/154).

It is interesting that 97.13% (169/174) of the female respondents reported never having sex with someone who takes drugs compared to 87.67% (128/146) of men (Chi square, p=0.003). Women appeared to be more confident that their partner(s) have never taken drugs when compared to 10.96% (16/146) who did not know if their partner(s) had ever had drugs.

An interesting and relatively unexplored area is the relatively new use of social networking sites to find partners, such as freely available social networking sites, e.g. Facebook and Twitter, to specifically designed dating websites. The question was posed if a respondent had ever met a sexual partner through the internet. 25.52% (37/145) of male respondents reported meeting a sexual partner through the internet, compared to 12.35% (21/170) of females (Chi square, p=0.003)

The reported age bands of the respondents suggested that the male respondents were older than the female respondents. 78.74% (137/174) of the female respondents were aged between 10-29 years old, compared to 62.99% (97/154) of the male respondents (Chi square, p=0.004).

The number of reported sexual partners in the last 3 months for each gender was similar to the number reported in other studies, with male respondents reporting more sexual partners than their female counterparts (Chi square, p=0.004). 63.22% (110/174) of female respondents primarily reported having 1 sexual partner in the last 3 months, compared to 45.45% (70/154) of male respondents. 31.17% (48/154) of male respondents reported having 3 more partners compared to 16.09% (28/174) of the female respondents.

Females reported being more worried about becoming pregnant than males, worried about their partner becoming pregnant (Chi square, p=0.017). 52.07% (88/169) of females reported being not at all or a little worried about becoming pregnant compared with, 63.12% (89/141) of men.

Male respondents were more likely to report taking place in concurrent relationships 14.29% (21/147) reported being in a regular sexual relationship but also having sex with another person(s), compared to females, 5.75% (10/174) (Chi square, p=0.033). The majority of respondents: 60.92% (106/174) and 48.30% (71/147) for females and males respectively reported being in a regular sexual relationship with a single person.

The survey contained questions to obtain respondents views on various scenarios and their associated risks. One question posed was: what is the risk of a married couple who have sex with others having an STI? Male respondents reported this scenarios as being less risky than their female counterparts (Chi square, p=0.038).

9.5 Chlamydia History Differences

Section 9.4 examined the response from the questionnaire to identify any gender differences. Further analysis was undertaken in parts 9.4.1 and 9.4.2 to investigate the difference if any the group the patient came from, either the GUM or University, made. Table 9-6 illustrates the responses from the questionnaire that were significantly associated with reporting ever having Chlamydia. Like section 9.4 the analysis presented in section 9.5 is further investigated by respondents group in parts 9.5.1 and 9.5.2.

Variable	**Sig. (2 sided)**
al_Drunk	0.000
ConRea_HIV_STIs	0.000
ConRea_MainReason	0.000
EmergencyContraception	0.000
risk_Personal	0.000
wor_HIV1	0.000
wor_STIs	0.000
SexAct_Anal	0.001
ThreeMonParCat	0.001
dru_SexDrugsYourself	0.002
res_LongInCity	0.003
SexAct_OralReceived	0.005
SexAct_OralGiven	0.007
cig_Smoke	0.008
AgeDifference	0.008

Variable	Sig. (2 sided)
NoSib	0.010
AgeVaginal	0.011
agecat	0.012
al_AmountAlcohol	0.017

Table 9-6: Sig. variables from Chi square by Chlamydia history

Of those who had ever reported having Chlamydia 94.96% (113/119) had had sex whilst drunk in their life (Chi square, p=0.000). 75.00% (339/452) of those who reported never having Chlamydia, did report having sex at some point in their life whilst drunk.

68.91% (82/199) of respondents who had ever had Chlamydia reported using condoms to protect against STIs compared to 49.34% (224/454) of those who had never had Chlamydia (Chi square, p=0.000). This questionnaire fails to take into account the temporal aspects of contraception use. The respondents may have had Chlamydia early in their life and subsequently changed their contraceptive beliefs and use.

An interesting result from the questionnaire was that of those who had ever had Chlamydia reported that condoms were mainly used to prevent infection32.53% (27/83) or to prevent infection and pregnancy 51.81% (43/83) compared to 18.73% (53/282) and 40.43% (114/282) from the group who had never reported having Chlamydia (Chi square, p=0.000). In addition the group who had reported no previous Chlamydia infection reported use of condoms primarily for the prevention of pregnancy 33.69% (98/282) compared with 9.64% (8/83) of the previously infected group.

Results from the questionnaire suggested that those people who had previously had Chlamydia were more likely, or their partners were more likely, to have used emergency contraception. 69.83% (81/116) of those who had reported ever being infected with Chlamydia reported using emergency contraception, compared to 47.86% (201/420) of those reporting no previous infection (Chi square, p=0.000).

The group of respondents who have had Chlamydia reported greater personal risks to themselves 29.57% (34/115) compared to the group who had never been infected with Chlamydia 15.00% (66/440) (Chi square, p=0.000). What is interesting though about reported personal risk is the similarity between both groups who reported that they were “not very much risk” 44.09% (194/440) and 44.35% (51/115) of the previously not infected and infected groups respectively. Those respondents who had ever had

Chlamydia reported that they were more worried about becoming infected with HIV. 20.69% (24/116) of this group were extremely worried when compared with the 10.31% (46/446) previously non infected group (Chi square, p=0.000). If the quite worried to extremely worried responses are combined then 47.41% (55/116) of those previously infected are worried compared with 30.94% (138/446) of the previously not infected group.

Those who had reported being previously infected with Chlamydia were more likely to respond being quite to extremely worried about becoming infected with another STI 62.93% (73/116) compared with 39.10 (174/445) (Chi square, p=0.000). Also of interest are those who report not being worried about becoming infected with an STI, 25.39% (113/445) of those who had never had Chlamydia reported not being worried about STIs compared with 8.62% (10/116) of the previously infected group.

There was a significant difference found (Chi square, p=0.001) between the two groups and if they have ever had anal sex. 56.41% (66/117) of the group who had ever had Chlamydia reported ever having sex compared with 38.55% (170/441) of the never had Chlamydia group.

The group who reported previous Chlamydia infection reported a greater number of sexual partners in the last 3 months: 41.18% (49/119) reported more than 2 sex partners compared with, 26.65% (121/454) from the never had Chlamydia group (Chi square, p=0.001). 61.23% of the never had Chlamydia group reported having 1 sexual partner compared to 55.46% of the ever had Chlamydia group.

Those from the ever had Chlamydia group were more likely to report to have had sex under the influence of drugs 29.66% (35/118) compared to the never had Chlamydia group 16.37% (73/446) (Chi square, p=0.002).

Those respondents from the ever had Chlamydia group were more likely to have resided in the city all of their life's 27.59% (32/116) when compared with 18.79% (84/447) of the never had Chlamydia group (Chi square, p=0.003). There is a lot of movement in and out of Portsmouth and Southampton due to their naval and student populations.

The responses from the two groups suggested that a wide range of sexual activities took place. The given and receiving of oral sex were key elements of the questionnaire. The ever had Chlamydia group reported that 99.15% (116/117) had ever received oral sex compared with 91.87% (407/443) of the never had Chlamydia group (Chi square, p=0.005). These results were similar with the oral given results with the ever had

Chlamydia group reporting 98.29% (115/117) had given oral sex compared with 90.21% (396/439) of the never had Chlamydia group (Chi square, p=0.007).

Those from the had Chlamydia group were more likely to currently smoke cigarettes 50.42% (60/119) compared with 36.87% of the never had Chlamydia group (Chi square, p=0.008).

The results suggest a wider age range between partners, between the two groups. The never had Chlamydia group reported having partners about the same age, 52.45% (225/429) compared to 40.34% (48/119) (Chi square, p=0.008). The had Chlamydia group suggested that partners tended to be younger than the index respondent of 2 years or greater, 29.41% (35/119) compared to 18.18% (78/429).

An interesting finding was that the "had Chlamydia" group were more likely to report being an only child 92.4% (110/119) compared to 79.52% (361/454) of the never had Chlamydia (Chi square, p=0.010).

There was a noticeable difference between the ages of first vaginal sex between the two groups. The had Chlamydia group tended to have vaginal sex at an earlier age 21.01% (25/119) fell into the 10-14 age bracket compared with 11.01% (50/454) of the never had Chlamydia group. (Chi square, p=0.011)

The age structure was significantly different between the two groups (Chi square, p=0.012). What is interesting is that 78.99% (94/119) of the group who had ever had Chlamydia on completion of the questionnaire fell into the 10-29 age group. The questionnaire failed to ascertain the age a respondent reported having a STI which is a limitation of this research. However given the size of the questionnaire and what it was trying to accomplish this could be addressed in future research.

There was a marked difference between the two groups and the amount of alcohol they would consume on the occasions that they would drink alcohol (Chi square, p=0.017). The had Chlamydia group were more likely to drink more when they drank with 21.85% (26/119) reporting drinking more than 6 drinks when they drank, compared with 12.00% (51/425) of the never had Chlamydia group. The never had Chlamydia group tended to drink one or two drinks when they drank 46.12% (196/425) whereas the ever had Chlamydia group reported drinking one or two drinks 33.61% (40/119) of the time.

9.5.1 Chlamydia History Differences for University Group

Section 9.5 demonstrated the significant factors that differentiated between those who reported ever having and those never having Chlamydia. This part as well as part 9.5.2 distinguishes the significant factors when the group of the respondent: GUM and University, is taken into account. Table 9-7 illustrates that only two of the original 19 identified factors was still considered significant when the University respondents were examined in isolation. An additional factor was identified as being significant when taken in isolation that being whether the respondent has ever had sex with someone who takes drugs.

Variable	Sig. (2 sided)
EmergencyContraception	0.000
SexAct_Anal	0.000
dru_SexDrugsOther	0.008

Table 9-7: Sig. variables from Chi square by Chlamydia history by group - Uni group

Of the University respondents from the ever had Chlamydia group, 87.50% (14/16) reported ever having or their partner using emergency contraception, compared with 41.26% (85/206) of the never had Chlamydia group (Chi square, $p=0.000$). These results should be treated with caution given the small size of the ever had Chlamydia group. 70.59% (12/17) of those from the ever had Chlamydia group reported ever having anal sex compared to 27.35% (61/223) of the never had Chlamydia group (Chi square, $p=0.000$). And 11.76% (2/17) of the ever had Chlamydia group reported ever having sex with someone who takes drugs when compared with 0.89% (2/225) of the never had Chlamydia group (Chi square, $p=0.008$).

9.5.2 Chlamydia History Differences for GUM Group

Similar to part 9.5.1 this part examines the key factors identified from the questionnaire that are associated with ever testing positive for Chlamydia. The key factors that remained significant for the GUM group are shown in table 9-8. Of the 19 factors previously discussed in section 9.5, nine remained significant when the GUM group was investigated in isolation.

Variable	Sig. (2 sided)
al_Drunk	0.004
ConRea_HIV_STIs	0.005
risk_Personal	0.010
e_Gonorrhoea	0.011
wor_HIV1	0.019
e_OtherSTI	0.019
wor_STIs	0.026
dru_SexDrugsYourself	0.036
EmergencyContraception	0.037

Table 9-8: Sig. variables from Chi square by Chlamydia history by group – GUM group

Even though both groups reported a high incidence of ever having sex whilst being drunk there was still a significant difference identified. 96.08% (98/102) of the GUM group who had ever had Chlamydia had ever had sex drunk compared to 85.27% (191/224) of the never had Chlamydia group (Chi square, p=0.004).

What is again interesting is that 71.57% (73/102) of the GUM had ever had Chlamydia group reported using condoms to protect against STIs when compared with 54.87% (124/226) of the never had Chlamydia group (Chi square, p=0.005)

The GUM ever had Chlamydia group considered themselves more at risk when compared to the GUM never had Chlamydia group. 34.69% (34/98) of the ever had Chlamydia group considered themselves either quite or greatly at risk of having an STI, compared with 24.06% (51/212) of the never had Chlamydia group (Chi square, p=0.010).

The GUM ever had Chlamydia group were more likely to have ever had Gonorrhoea compared with the never had Chlamydia group (Chi square, p=0.011). 7.84% of the ever had Chlamydia group reported ever having Gonorrhoea whereas, 1.77% (4/226) of the never having Chlamydia group reported ever having Gonorrhoea.

Those from the ever had Chlamydia group were more worried about potential HIV infection when compared with the never had Chlamydia group. 90.91% (90/99) of the ever had Chlamydia group were worried when compared with 74.77% (163/218) of the never had Chlamydia group (Chi square, p=0.019). This could possibly be a consequence of the ever had Chlamydia group's likely exposure to STI treatment and counselling, therefore raising their awareness about the risks of STIs in particular HIV.

The same pattern was identified as previously mentioned above regarding HIV to other STIs. The ever had Chlamydia group was more worried about becoming infected with another STI than the never had Chlamydia group, 95.96% (95/99) compared to 86.70% (189/218) (Chi square, p=0.025).

What is interesting it that the never had Chlamydia group reported a higher level of having another STI, 7.96% (18/226) when compared with the ever had Chlamydia group 0.98% (1/102) (Chi square, p=0.019). This difference is likely to equate to why the never had Chlamydia group were in the GUM department in the first place.

Those from the GUM ever had Chlamydia group were more likely than their never had Chlamydia counterparts to have ever had sex under the influence of drugs, 31.68% (32/101) compared to 20.64% (45/218) (Chi square, p=0.036).

Emergency contraception use by the respondent or the partner of the respondent was more likely in the ever had Chlamydia group, 67.00% (67/100), than the never had Chlamydia group 54.21% (116/214) (Chi square, p=0.037).

9.6 Decision Trees for Chlamydia Classification

The analysis undertaken in sections 9.4 and 9.5 were useful in identifying which factors are more associated with certain target conditions, e.g. identifying gender differences in the responses and identifying the factors associated with ever testing positive for Chlamydia. Regression analysis similar to that conducted in sections 8.4 and 8.5 would be useful to identify the key factors and the influence of the variables identified by the regression. Regression analysis however is not the easiest form of analysis for healthcare professionals to understand. Therefore, decision tree analysis was used to identify the combination of variables that would inform healthcare professionals of whom to offer Chlamydia screening to.

Various decision tree models were constructed (CRT, CHAID, Exhaustive CHAID and QUEST) and applied to the University and the GUM filtered responses to construct appropriate trees. Table 9-9 and table 9-10 illustrate how accurate the decision trees were in the identification of those who had Chlamydia and those who did not. In the construction of the trees the data was randomly split into a training and test set. The rules used to construct the decision tree were obtained from the training set, and then the accuracy of the model was tested on the screening set. The University decision tree accuracy results are shown in table 9-9. What is immediately clear is that there are two decision tree methods that have both been identified as being 70.20% correct when applied to the test set. The trees that were constructed from the CRT and the CHAID method are discussed in parts 9.6.2 and 9.6.3 respectively.

		CRT			CHAID		
		No	Yes	% Correct	No	Yes	% Correct
Training	No	82	27	75.20%	82	27	75.20%
	Yes	2	10	83.30%	2	10	73.30%
	Overall %	69.40%	30.60%	76.00%	69.40%	30.60%	76.00%
Test	No	84	35	70.60%	84	35	70.60%
	Yes	2	3	60.00%	2	3	60.00%
	Overall %	69.40%	30.60%	70.20%	69.40%	30.60%	70.20%

Table 9-9: University decision tree evaluation

The CHAID decision tree was determined to be the best tree to use to assess the GUM data. The accuracy of the CHAID decision tree is shown in table 9-10. What is interesting is that this decision tree is considerably less accurate overall than the University decision trees shown in table 9-9. The overall accuracy of the GUM tree is 52.80%.

		CHAID		
		No	Yes	% Correct
Training	No	54	60	47.40%
	Yes	9	42	82.40%
	Overall %	38.20%	61.80%	58.20%
Test	No	48	64	42.90%
	Yes	13	38	74.50%
	Overall %	37.40%	62.60%	52.80%

Table 9-10: GUM decision tree evaluation

9.6.1 Classification and Regression Tree (CRT) University Decision Tree

The CRT decision tree provides a tool to assist a healthcare professional's assess whether a person has Chlamydia based on a number of questions. These questions place people into categories (likely to have Chlamydia or not) based on historical data of previous patients. The CRT decision developed is displayed in figure 9-1.

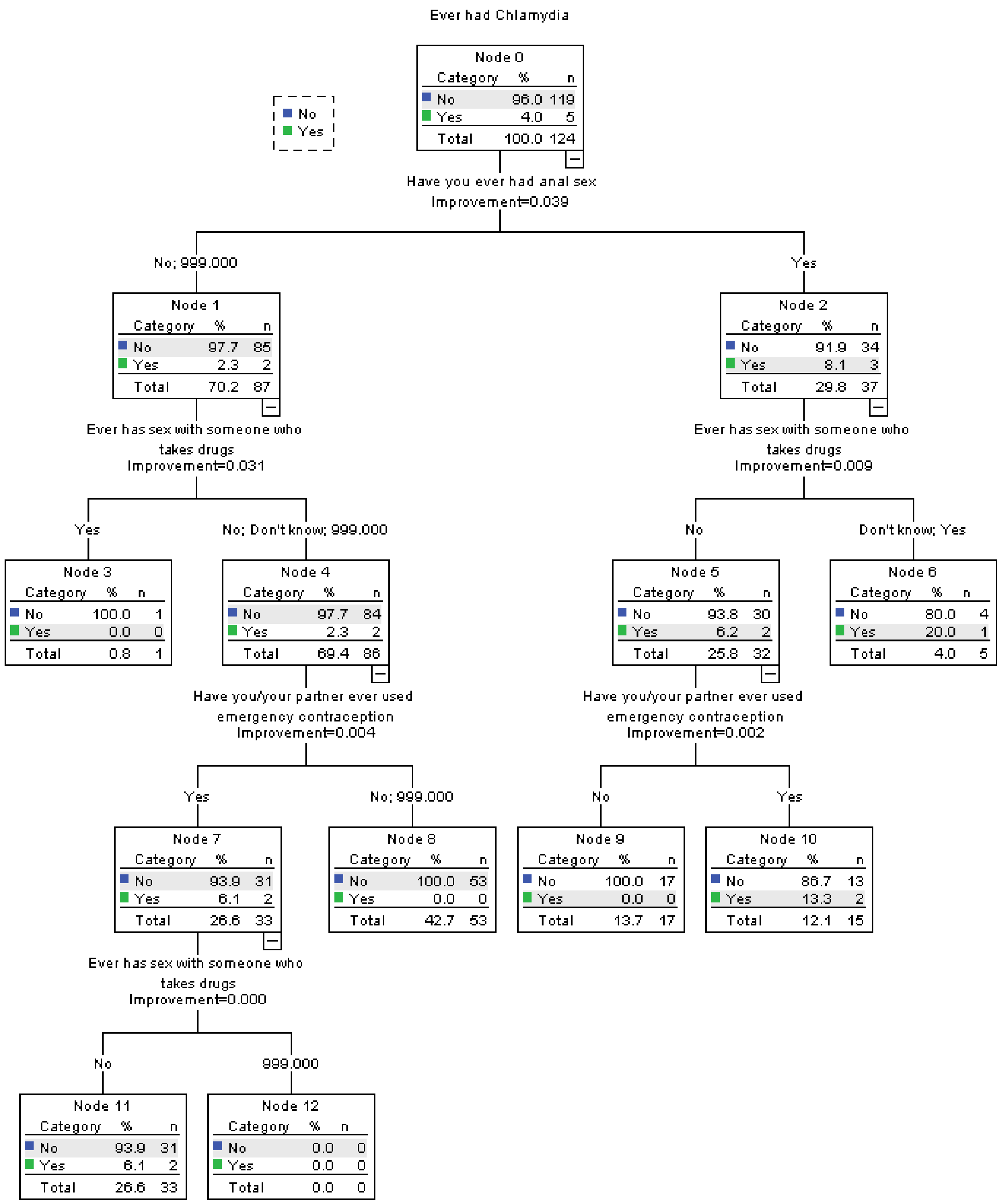

Figure 9-1: University CRT decision tree

9.6.2 Chi-squared Automatic Interaction Detection (CHAID) University Decision Tree

The developed CHAID tree illustrated in figure 9-2 has the same accuracy as the CRT tree but is easier to follow as it contains fewer nodes and branches. Given the choice between the two, people may be likely to use this tree. The key questions used to identify possible Chlamydia infection are: Have you ever had anal sex, and have you ever had sex with someone who uses drugs.

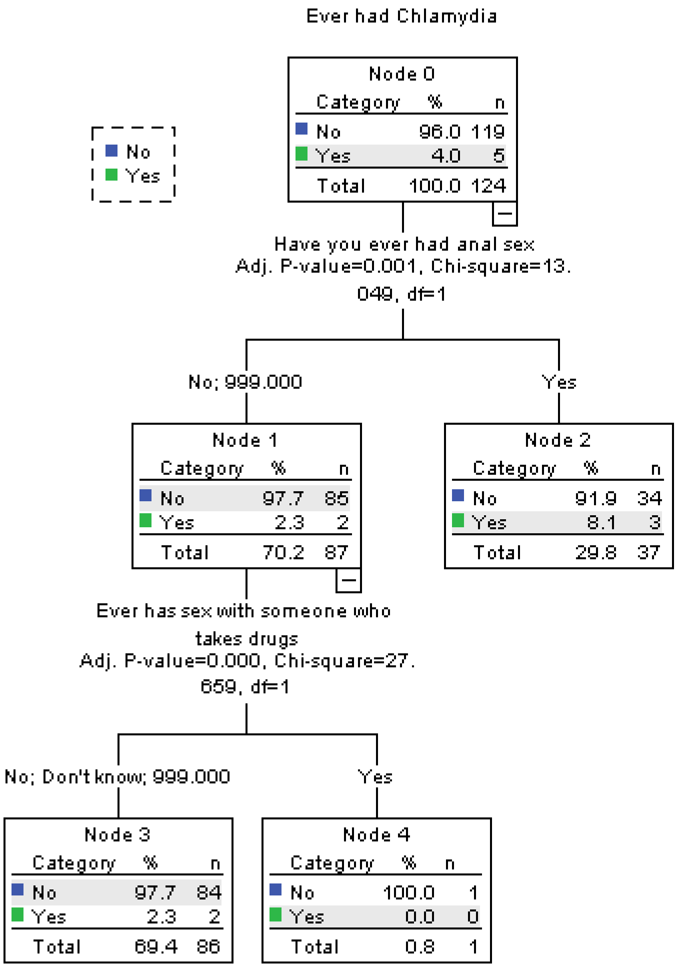

Figure 9-2: University CHAID decision tree

9.6.3 Chi-squared Automatic Interaction Detection (CHAID) GUM Decision Tree

The most accurate decision tree when analysing the GUM only data was a CHAID tree which consisted of four questions and is illustrated in figure 9-3. What is interesting in this tree is that if people have used condoms to protect against STI they are identified as being more likely to have had or have Chlamydia which may be thought of as counterintuitive.

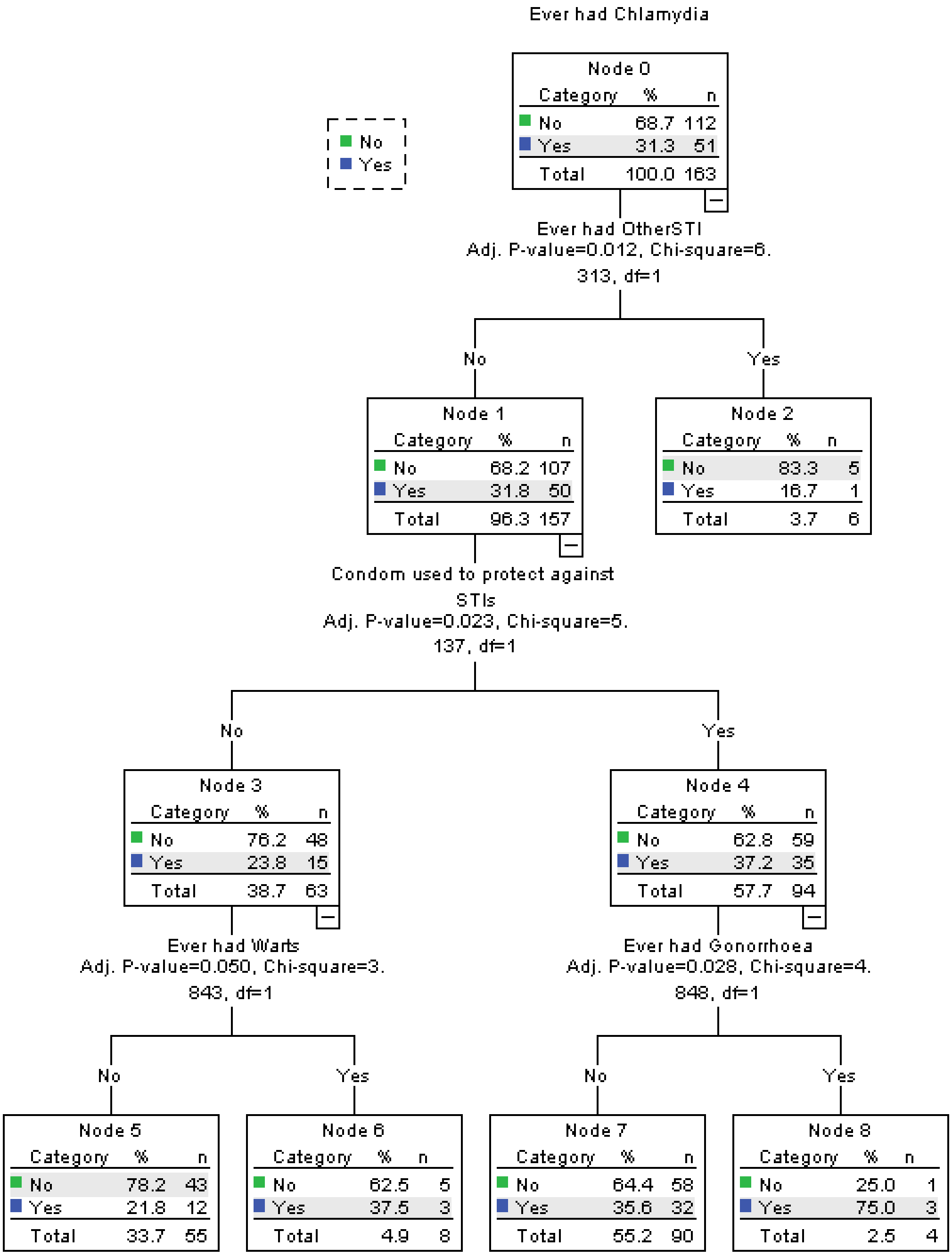

Figure 9-3: GUM CHAID decision tree

9.7 Chapter Conclusions

This chapter analysed the responses from the questionnaire carried out by patients who attended the GUM department at St Mary's Hospital Portsmouth and students from the University of Southampton. The analysis explored gender and Chlamydia history differences overall and specifically for the two groups of respondents.

The primary purpose of the analysis was to identify behavioural risk factors. The identified factors and the socioeconomic factors identified in chapter 8 and the literature are used to define high and low risk sexual behaviour groups. Theses sexual behaviour groups incorporated in the developed SD model discussed in chapter 11. The factors that were identified from the questionnaire as being associated with individuals with a greater risk of Chlamydia infection (the high risk group) are shown in table 9-11 below. The low risk group are the opposite of the factors stated below.

High Risk Group Behaviours
Self-perception of being at risk
Have anal sex
2 or more sexual partners in the last three months
Have sex under the influence of drugs or alcohol
Earlier sexual debut
They or their partner has ever used emergency contraception
Currently smoke

Table 9-11: Risk factors associated with Chlamydia

9.8 Chapter Summary

This chapter:

- Provided a rationale for the questionnaire.
- Discussed the development of the questionnaire.
- Results from the questionnaire were discussed in relation to many perspectives.
- The differences between GUM and University respondents were highlighted.
- Risk groups were identified that could be used in the SD model developed in chapter 11.

10 Discrete Event Simulation Genito-Urinary Medicine Model

10.1 Research Tasks Addressed

T4. Can DES be used to model a GUM department to assess scenarios that the stakeholders are interested in?

T6. Can the developed DES and SD models be successfully integrated? Is the combination of DES and SD models in this healthcare context beneficial?

10.2 Chapter Introduction

This chapter describes the development of a DES model of the GUM department at St Mary's Hospital Portsmouth. The model development is briefly discussed, including: the data requirements, the key features of the model, the results available from the model and the verification and validation of the model. The base model is then discussed and compared with a suggested improved model. Experimental design, results and sensitivity analysis are included which informed the choice of the improved model. The chapter concludes with key points and findings from the model development before a summary of the chapter is provided.

This chapter primarily addresses research task T4, and indirectly T6 as the developed DES model represents half of the composite model.

10.3 Method

Simulation and in particular DES is used in many industries to allow alternative configurations of systems to be evaluate. As stated in the literature (see part 4.4.2) there are few DES models of GUM departments or sexual health clinics, and as such this model has been developed, in collaboration with the GUM department at St Mary's. The remainder of section 10.3 summarises the key points in the model's development.

10.3.1 Simul8

The commercial DES software Simul8 (www.simul8.com) was chosen to construct the model due to the author's familiarity with its functionality. The Simul8 Corporation offers PhD students access to the professional version of the software, with all the functionality which was required for the model produced. Other DES software is available both open source: Tortuga (http://code.google.com/p/tortugades), Facsimile (www.facsim.org) and commercial: Anylogic (www.xjtech.com), Arena (www.arenasimulation.com) and WITNESS (www.lanner.com/en/witness/cfm). Alternatively the model could have been constructed using a programming language.

10.3.2 Activity Cycle Diagram

The activity cycle diagram (ACD) was used as a starting point in the development of the DES model. Figure 10-1 is the ACD of the walk in process of the GUM department. This ACD uses colours to represent when and what resources are required e.g. Staff. The yellow and green boxes represent reception and medical staff respectively. The blue arrows represent the flow of patients. Patients (after the initial reception tasks) do not have to pass through the medical processes in order. The black lines represent the flow of paperwork and the red lines represent the flow of lab specimens. This development of the ACD was an iterative process involving the stakeholders.

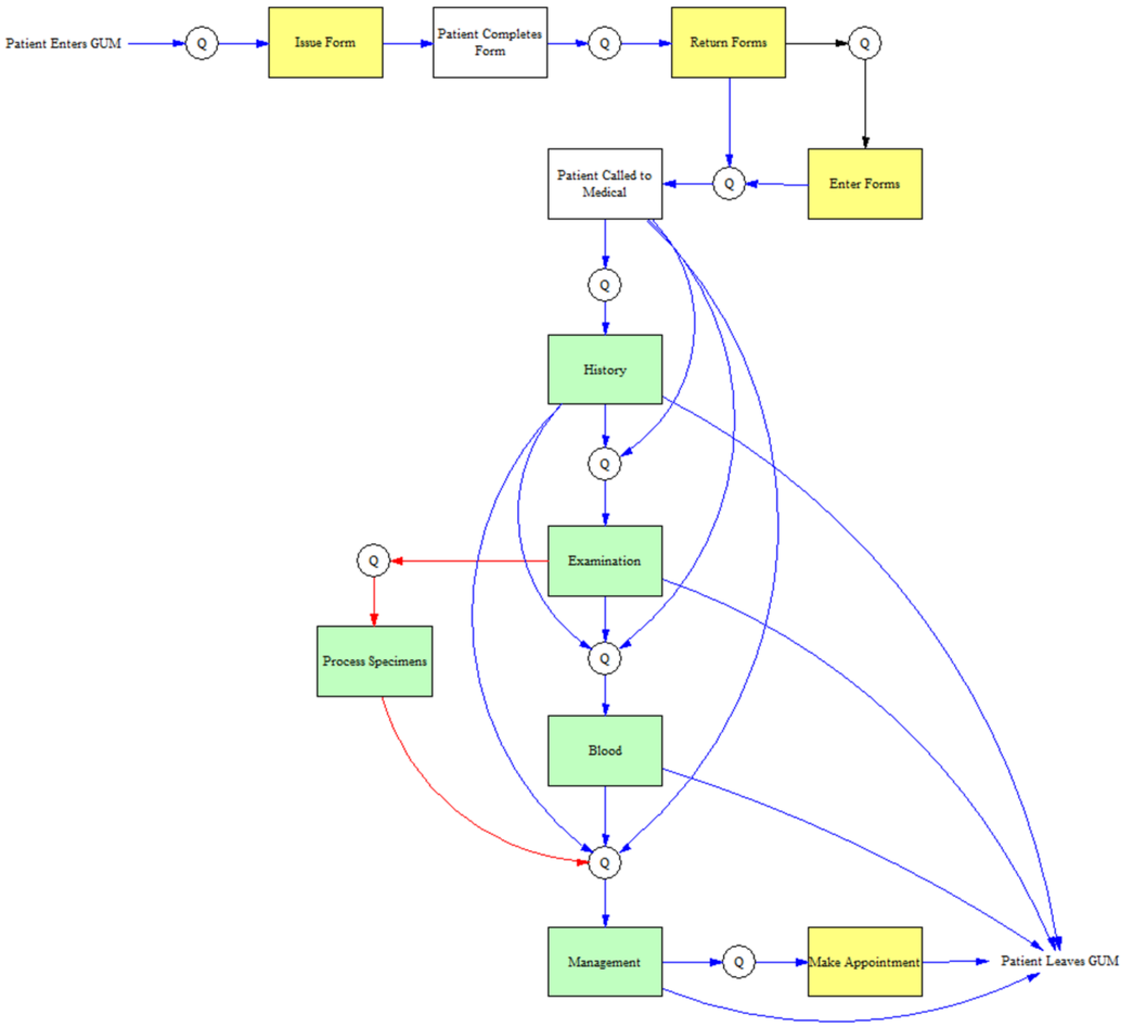

Figure 10-1: Activity flow diagram

10.3.3 Data Collection

Many data were available but not necessarily in the right form to be used to construct the model. Data had to be manually collected for some parts of the model. Table 10-1 provides a summary of the data required in the model and how they were collected. Where data were manually collected this was carried out by both the author and also staff from the GUM department. Several data sources were obtained through the analysis of the screening data discussed in chapter 6 and this has been highlighted in table 10-1.

Category	Data Required	Data Source
Arrival	Patient Arrival Profiles	Chlamydia Screening and Geoclinic systems (**chapter 6**) and also manual data collection during wc 14/07/2008
	Phone Arrival Profiles	Manual data collection took place wc 14/07/2008 for reception and 21/07/2008 for lab calls
	Opening Times	Current opening times
Patient Characteristics	Type of Patient New, Followup or Old New	Chlamydia Screening and Geoclinic system (**chapter 6**)
	Gender of Patient	Chlamydia Screening and Geoclinic system (**chapter 6**)
	Probability profile for the STIs being investigated	Chlamydia Screening system, Geoclinic system (**chapter 6**) and KC60 returns
	Medical Processes the patient will require	Manual data collection took place wc 21/07/2008
GUM Capacity	Waiting Capacity: Seated and Standing	Capacity of clinic checked during model building meetings
	Medical Waiting Capacity	Capacity of clinic checked during model building meetings
Medical Processes	Examination Process Duration	Manual data collection wc 21/07/2008
	History Process Duration	Manual data collection wc 21/07/2008
	Blood Process Duration	Manual data collection wc 21/07/2008
	Lab Process Duration	Manual data collection wc 21/07/2008
	Management Duration	Manual data collection wc 21/07/2008
	Medical Staff Shift Patterns	Obtained copy of staff rota
Reception Processes	Issue of paperwork Duration	Manual data collection wc 14/07/2008
	Patient completion of paperwork Duration	Manual data collection wc 14/07/2008
	Paperwork entered into the System Duration	Manual data collection wc 14/07/2008
	Make appointment Duration	Manual data collection wc 14/07/2008
	Reception Staff Shift Patterns	Obtained copy of staff rota
Other Processes	Reception Phone Call Duration	Manual data collection wc 14/07/2008
	Lab Phone Call Duration	Manual data collection wc 21/07/2008

Table 10-1: Data collection for DES

The instruments used to collect the data can be found in appendix G. Where members of staff from GUM were asked to collect data manually, several staff members were included and there was a broad consensus in the processing times collected by the members of staff. Due to the sensitive nature of the conditions the GUM department handles, the privacy of the patients had to be respected. Therefore these data were recorded by GUM staff. Where collected data could not be fitted to known distributions, user defined distributions were produced. These were created from the collected data using the “probability profile” function of Simul8, enabling any distribution to be generated through the assigning of values and probabilities to any number of columns in a histogram.

Data were also sourced from: the GUM internal computer systems; the Health Protection Agency (HPA); the National Chlamydia Screening Programme (NCSP) and the Department of Health (DH) to estimate probabilities of developing the STIs of interest. The conditions of interest were: Chlamydia, Gonorrhoea, Genital Warts, Non Specific Urethritis (NSU), Genital Herpes, Syphilis and HIV/AIDS.

10.3.4 Key Features of the Model

A selection of screenshots from the GUM model, found in appendix M, with a brief explanation of the functionality and its relationship to the ACD are provided in this part. Figure 10-2 is the entire GUM model. Each of the highlighted sections in this figure will be briefly discussed.

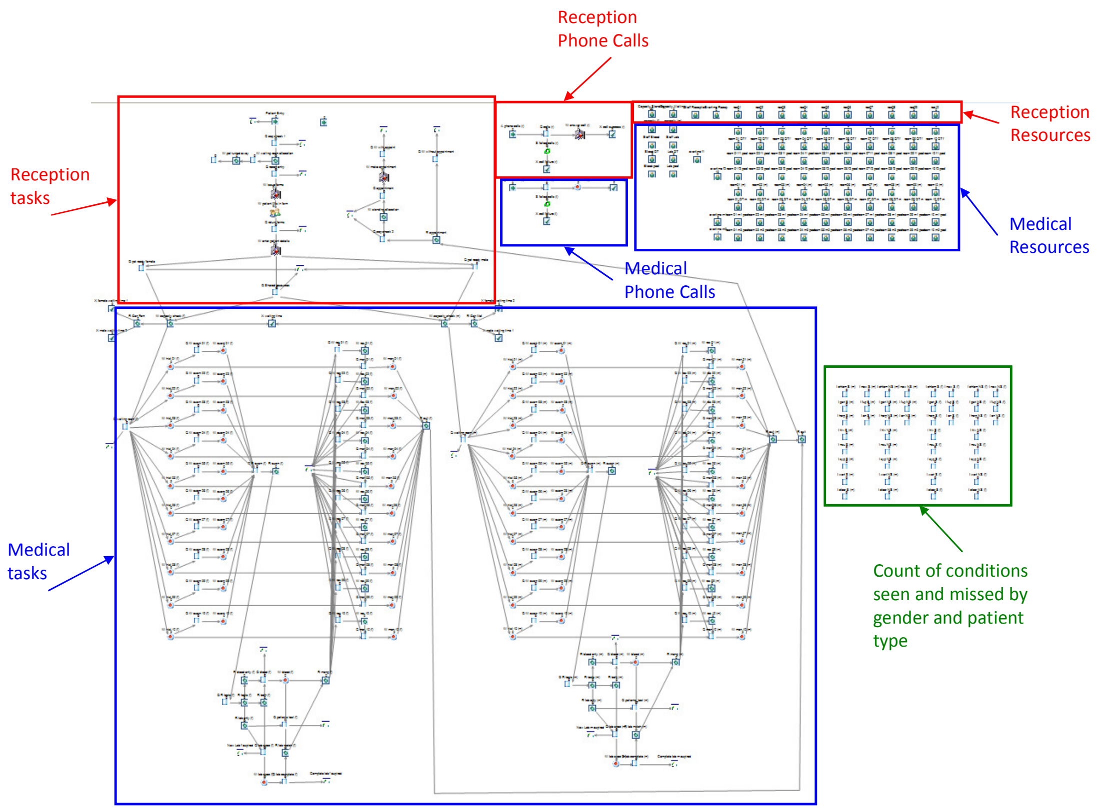

Figure 10-2: The complete model

Figure 10-3 displays the reception processes which are highlighted in the red box of figure 10-2, which is associated with the yellow and white boxes from the ACD in figure 10-1. The portion on the left of the model relates to incoming patients, and the section on the right relates to patients leaving the system after completing the medical processes. The model uses graphics to identify those tasks which require the reception and medical room/staff resources. The reception processes requiring receptionists are represented by an office cubicle and the medical processes requiring medical staff are represented by a red cross. Where the default Simul8 icons have been used these are for routing purposes or applying some decision rule or logic to the patient.

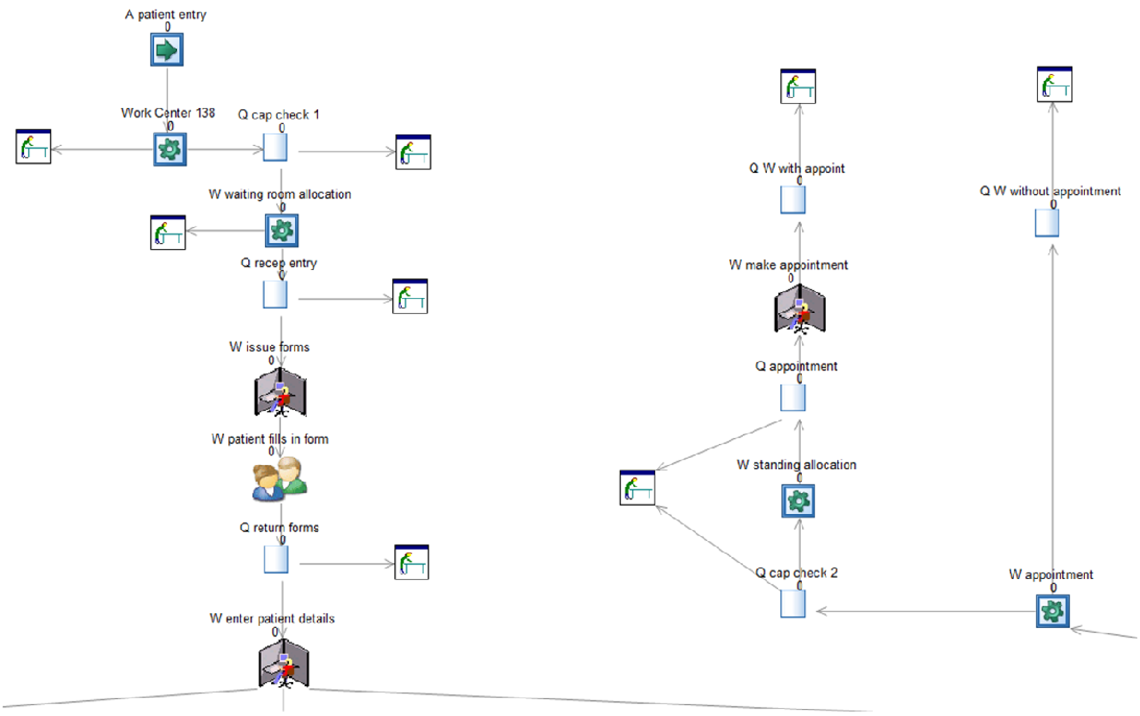

Figure 10-3: Reception tasks

Figure 10-4 is a cross section of the medical processes from the blue medical task box from figure 10-2 which captures: the history, examination and management medical processes from the ACD.

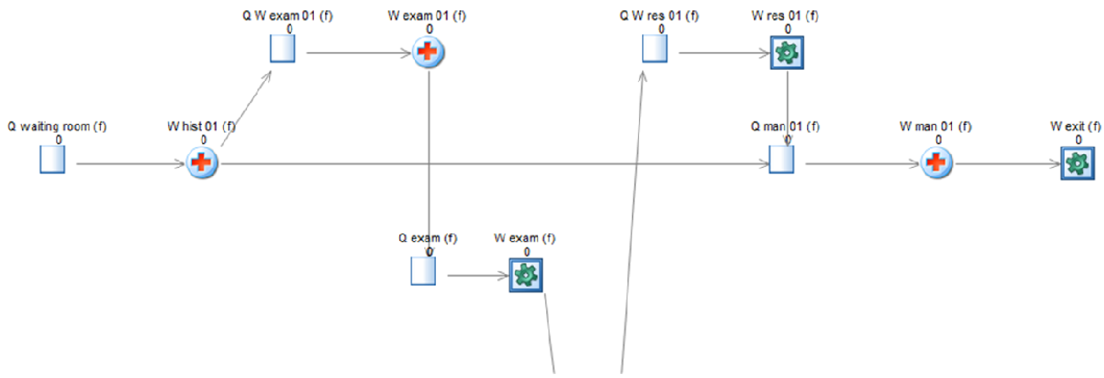

Figure 10-4: Main medical tasks

Figure 10-5 relates to the medical processes from the blue medical task box from figure 10-2 which are not captured in figure 10-4: the blood and lab processes. Both the main medical processes and the lab and blood processes are replicated in the model to allow for gender segregation which is currently how the GUM department operates. The lab and blood staff are shared and this is achieved in the model by sharing the same resources for the lab and blood work centres for the each gender.

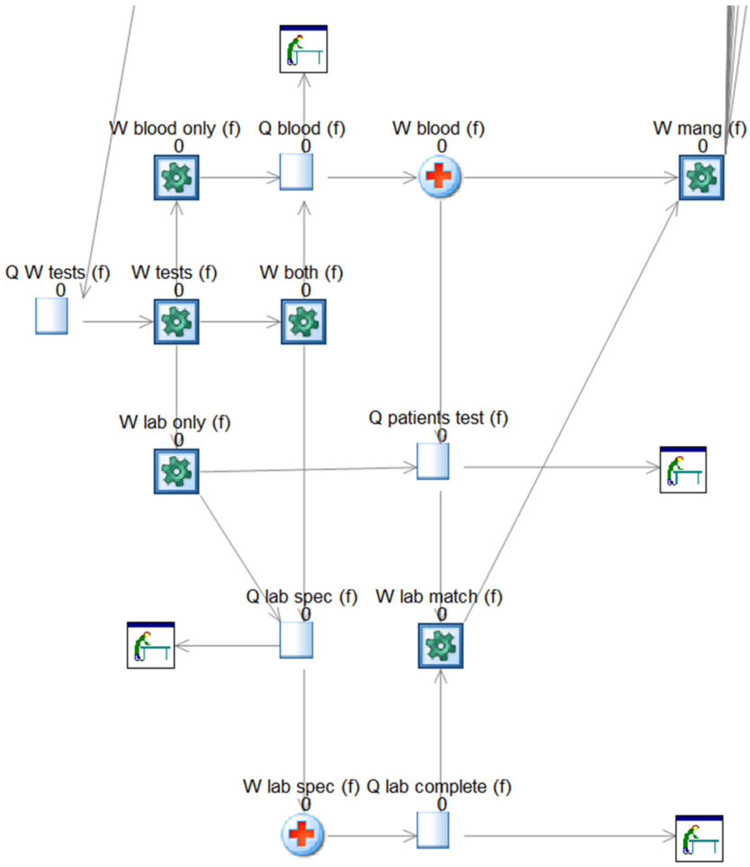

Figure 10-5: Blood and lab tests

Figure 10-6 represents the phone calls that arrive in the department requiring attention from either a reception or medical member of staff. It was important to include these processes in the model as they reduce the amount of time available for direct contact with patients in the department. The priority of phone calls over patients can be adjusted to allow experimentation providing figures of how many calls are answered successfully or missed.

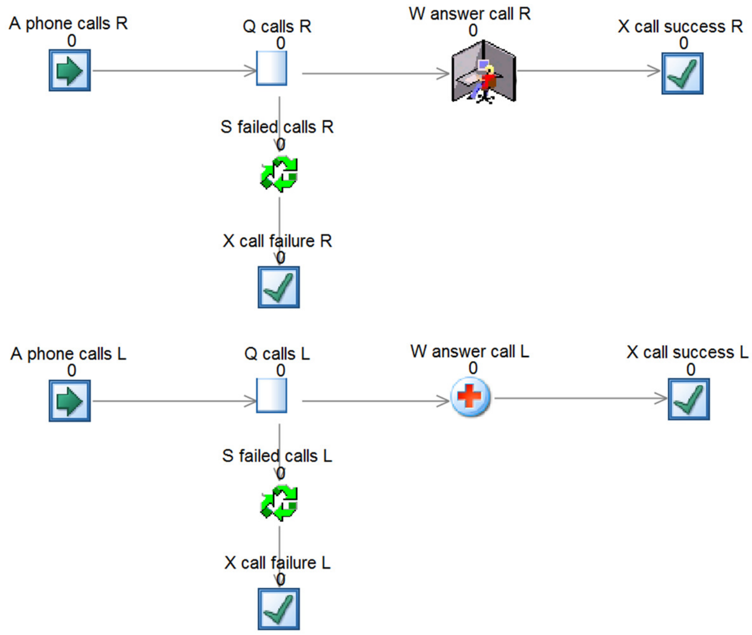

Figure 10-6: Phone calls for reception and the lab

Figure 10-7 relates to the resources that are used in the model which are the constraints that affect a patient's flow through the system. The coloured boxes are not present in the model but have been added to figure 10-7 to group the resources by purpose. The resources contained within the green box represent the reception staff (10 reception staff), the capacity of the waiting room and overtime resources (when the system works over capacity). The pink box represents the medical staff associated with the female patients and a variety of overtime options. The blue box is the male equivalent of the pink box. The red box represents the resources associated with the blood test and processing of lab specimens which do not distinguish by gender.

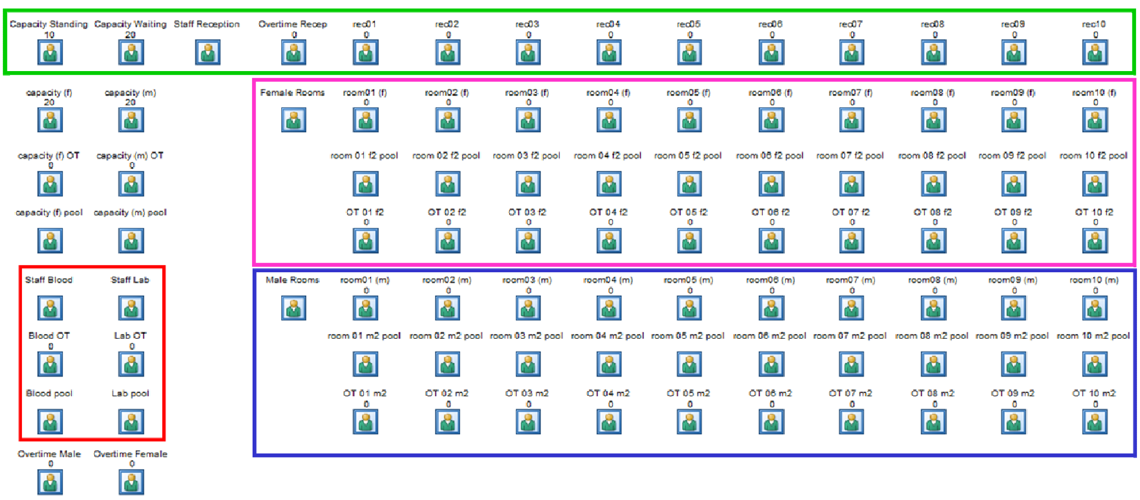

Figure 10-7: Resources

Patients are assigned attributes on entry to the system, discussed in greater detail in part 10.3.6 relating to labels. The STIs that they have are known at this point. If they leave the system before they have reached the management stage of the medical process then they are considered to have not been seen. The number of STIs missed are known (within the model, although obviously not in real life) and are recorded. Figure 10-8 represents the model objects that store information about the conditions seen and missed.

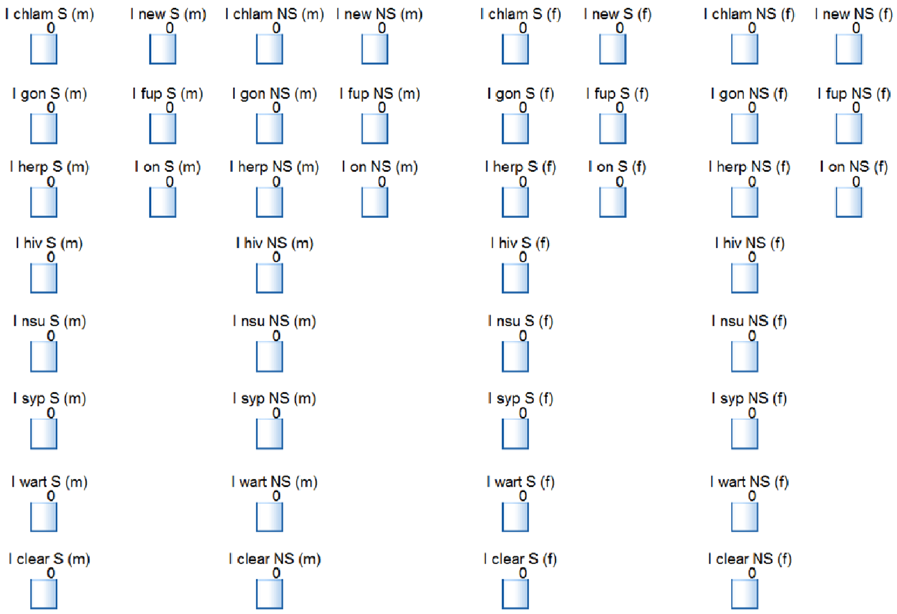

Figure 10-8: Queues used to collect specific results

10.3.5 Results Available from the Model

The model is very detailed and 170 results are available, with confidence limits. The results can be categorised into 11 groups with the number in brackets representing the total number of results in each group: Arrivals (2), Conditions Missed (16), Conditions Seen (16), Overtime (2), Patients Missed (16), Patients Seen (6), Patients Point of Exit (30), Phone Calls (4), Resources (36), Time at Point of Exit (18), Waiting Time (24). The full list of results can be found in appendix R. The number of results collected may appear to be excessive, but some configurations may need all these results to evaluate the merits of a specific design. For example, a specific configuration may process a large amount of patients and may be viewed as a success if patient throughput was the key performance indicator, but the waiting time of these patients as well as the resource utilisation may be excessive. Therefore multiple performance indicators are important when evaluating each proposed configuration to allow trade-offs to be made.

10.3.6 Labels and Information Variables

The labels and information variables in Simul8 are vital. They help capture the complexity of the system that the standard graphical Simul8 objects cannot. This enables the real data to be easily incorporated and the results from the model to be obtained.

The model consists of 33 labels to capture patient attributes. The labels can be broken down into seven groups: Patient Type and ID, Conditions, Medical distributions, Phone distributions, Routing, Reception distributions and Waiting time. For a full list and description of the labels see appendix H. There are three distinct patient types: new (N), follow up (FUP) and old new (ON). Each patient has a unique ID enabling the lab results from those patients who provide specimens to be tied up with each patient. There are eight labels, representing the seven conditions under investigation plus one to represent those patients who were all clear or had another condition. The probability for infection for each of these conditions is specified by gender and can also be specified by patient type.

There are three groups of labels which contain the distribution parameters or distribution name of the process durations: medical, reception and phone durations are modelled this way. These are known as label based distributions. The medical process duration i.e. history, examination, blood and lab tests and management can be dependent on the gender of the patient and the patient type. There are six labels in the model, five of which are label based distributions for the five medical processes. Rather than assign distributions to the objects in the model that represent the medical processes, the distributions are assigned to the patient and when the patient reaches each medical stage the corresponding distribution is read by the simulation object from the patient's label. Phone call durations follow a similar process to patients. Each type of call is assigned a label to represent the distribution used for sampling its duration. The reception tasks durations follow the same principle relating to the issuing of forms, completing of forms, entering the details and making appointment durations by gender and where specified by patient type.

The group of routing labels is important, ensuring patients follow the correct pathways through the system. The model contains eight routing labels. These labels determine the gender of the patient the routing of the patient through the system and the routing of specimens through the system. Simul8 allows a "shelf life" or a maximum waiting time that an item or in this case a patient is willing to wait before they will leave the system. A group of three labels were used to represent patients' maximum waiting time in the reception areas and the medical areas. As the medical and reception task are not a single process, the shelf life values are stored in labels and are updated as the patient moves through the system.

The model includes 140 variables in addition to the default Simul8 variable. The 140 variables can be differentiated into two broad categories: number variables and spreadsheet variables. There are 24 numeric variables and 116 internal Simul8 spreadsheets. For a full list of variables used in the model and a brief description of their functionality see appendix Q. The non-default number variables can be classified into three groups: control (9), count (7) and time (8) where the number in brackets is the number of variables in that group. The non-default internal spreadsheets can be classified into eight groups: arrivals (2), control (3), duration medical (41), duration reception (33), overtime (26), patient attributes (3), results (1) and shifts (7). The combination of labels and the internal variables makes the Simul8 model flexible enough to capture the processes that occur at an individual patient level. The functionality of the model is enhanced when the labels and variables are used in conjunction with Visual Logic (VL), Simul8's internal Simulation language and VBA which is discussed in part 10.3.7.

10.3.7 Interface, VBA and Visual Logic

It is uncommon for healthcare professionals to be trained in simulation techniques, although they were actively engaged in the model creation process for both the DES GUM model and the SD Screening model (see Chapter 11). To enable users to effectively operate the models a simple user interface was constructed. This part relates to the user interface as it pertains to the GUM model however a single user interface was constructed to operate the two models: DES, SD and also the combined composite option. The interface can be found in appendix O. The aspects of the interface associated with the SD model and the composite model will be discussed in part 11.3.5 and 12.4 respectively. The user interface was constructed in Microsoft Excel for two reasons: firstly, most people are familiar with office and windows based software; and secondly, the use of the VBA to enable communication between Simul8 and VENSIM through Excel.

In total including the VENSIM and Composite elements the Excel user interface contains 158 sheets. With respect to the GUM model 141 sheets of the user interface are used. Table 10-2 provides a summary of the GUM interface broken into seven broad groups, with a brief description of their purpose. The 141 GUM model sheets have been classified into these seven groups: Run Model (9), Arrival Profiles (6), Patient Variables (9), Resources (3), Task Duration (78), Staff and Room Shift Patterns (42) and Results

(10), where the number in brackets represents the number of sheets from the interface associated with that particular group.

Name	Purpose	Achieved by
Run Model	To run the Simul8 model from within	VBA: To open and run Simul8 model Visual Logic: To ascertain the run length and start time
Arrival Profiles	Set the patient, and different phone call arrival profiles by hour of day and day of the week	Visual Logic: To import from Interface and to set the parameter of the model
Patient Variables	Set processes patients receive by patient type and associated probabilities patient having STIs	Visual Logic: To import from Interface and to set the parameter of the model
Resources	Set the non staff resources - waiting capacity	Visual Logic: To import from Interface and to set the parameter of the model
Task Duration	Set the Reception and Medical process durations by patient gender and type	Visual Logic: To import from Interface and to set the parameter of the model
Staff and Room Shift Patterns	Set Reception staff and Medical staff shift patterns	Visual Logic: To import from Interface and to set the parameter of the model
Results	Retrieve Simul8 model results and present them in Excel	Visual Logic: To collate and export the results from Simul8 model to the Interface

Table 10-2: Summary of Excel user interface

Figure 10-9 provides screenshots from the user interface to illustrate its design and functionality. The screen on the left is an input screen for the GUM model. The parts of the model that the user can manipulate are highlighted in green and the user can only navigate between these cells. The yellow button is for navigation between other screens of the interface. The screen on the right is an example of an output screen. In this case the user can simply view the results or navigate to a different sheet. For a more detailed description of the user interface see the user manual in appendix I.

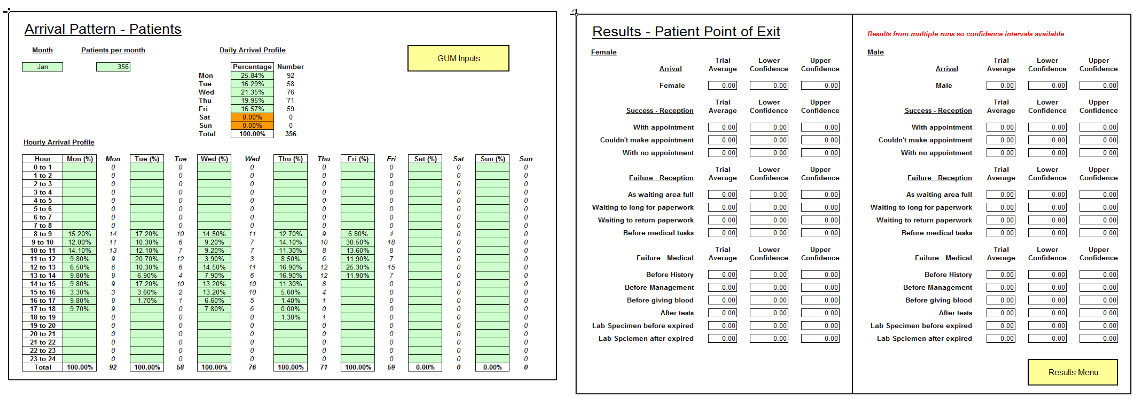

Figure 10-9: Sample screenshots from the user interface

The VL is primarily used to read information from Microsoft Excel. Because VL was only used to import data, relatively few lines of VBA code (145) were required to enable communication between the interface and Simul8. Over 10,000 lines of VL code were used in the model for a variety of purposes including the importing and exporting of data, decision rules and logic relating to turning patients away for example. For a full list and summary of the function of the VL used in the model see appendix S.

10.3.8 Model Validation and Verification

Model verification refers to how accurately the constructed and coded model matches the agreed specification of the system under investigation. Model validation is concerned with the accuracy of the model compared with the real-life system in terms of the outputs, whether patients go through the system in the correct order, etc.

There are many methods and tests to assess validation and verification (V&V) Pidd (2004), Law (2007), Robinson (2004) and Sargent (2008) which are crucial in developing confidence and trust in the model for the modeller and the stakeholder(s).

The flow diagram was of the GUM departments "walk in" process was transformed into an ACD shown in figure 10-1, which was signed off by the stakeholders. At each stage of the model construction small sample models of the various stages were developed, i.e. the processes patients and reception staff follow at reception; the processes that patients and medical staff follow on the medical side of the department. These were discussed with stakeholders before being incorporated in the overall model. It was this continued discussion with stakeholders which kept them actively engaged in the model building process, allowing the verification of the model to occur continuously during its development.

Figure 10-10 is an example of how the model was verified with the GUM staff. A version of the final model discussed in part 10.3.4 was re-structured and placed onto a floor plan layout of the department. The routes between the simulation objects were amended to reflect the routes that patients could take through the department. This visualisation along with the ability to differentiate between the female and male patients (pink and blue dots respectively) and the routes the resources took (Reception and Medical Staff) enabled staff to question the model, e.g. if a patient or resource went an unexpected route.

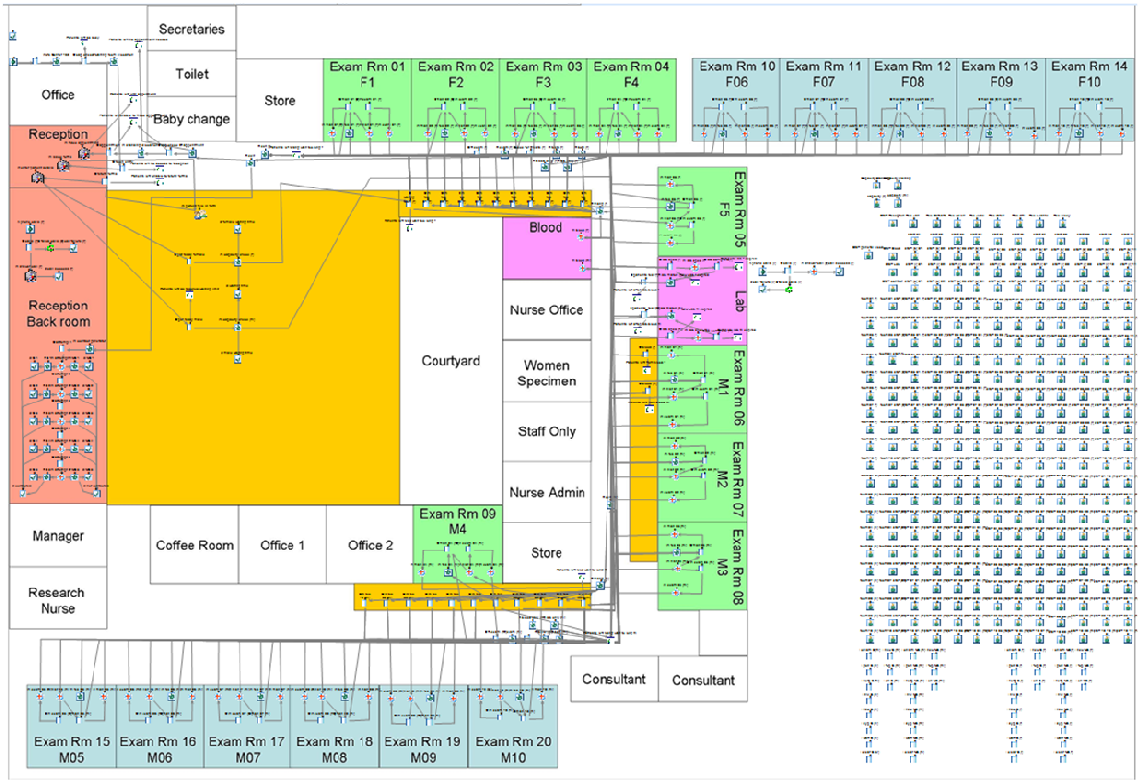

Figure 10-10: Model superimposed on GUM department layout

Models in OR as in most disciplines simplify the world to capture the key factors that influence the system, the principle of Parsimony (Pidd, 2004). Thus validation and verification can be very difficult, due to subtle influences of the system which have been ignored for modelling purposes yet (unknown to the system owners and the model builder) could have serious influences on the real system.

In terms of validation there are many possible tests that can be carried out. Very few models, if any, could be considered completely valid. One of the best ways to validate a computer simulation model is to not try to prove the model is correct but to try to prove that it is incorrect. The more tests which are passed the greater buy in there will be in the model (Robinson, 2004). The model validation tests used included: operational validity and extreme condition tests to check that the outputs from the model behaved as predicted or could have been expected to behave; data validity (the data were thoroughly checked for inaccuracies, see chapter 6) in terms of the data collected manually by staff in the department and by the author; and finally, the model results were compared with historical results. The base results are shown in section 10.5 alongside the historical results where available. All of the VL used in the model was checked to ensure each routine was functioning correctly. The model itself was built iteratively with the input of both clinical and operational research collaborators. A meeting was held with the entire GUM department at which GUM staff expressed their comments, views and questions about the model.

10.4 How data are assigned to patients

Various data sources were used to understand (see part 10.3.3): the process times, the probabilities of being infected with conditions; and, the arrival profile of patients to the GUM department. This section provides an example of how the labels (see part 10.3.6 and appendix H) associated with a particular type of patient, namely a new male patient (the term “new” will be discussed below) are assigned values and distributions, making reference to a selection of the distributions produced from the data collected. In the majority of cases the distributions were user-defined empirical distributions based on the actual data obtained, rather than fitted parametric distributions. The complete set of distributions produced can be found in appendix R.

Data were collected relating to the arrival profile, and type of patients who visit the department. Patients could be new patients, follow up patients or what are referred in the department as old/new patients, i.e. those who have visited the department previously but are now returning for a new reason. Figure 10-11 displays the arrival pattern by day of the week distribution. There are further distributions which break down arrivals by hour of the day and this can vary (and does in the experiments discussed in sections 10.5 and 10.6) by day of the week.

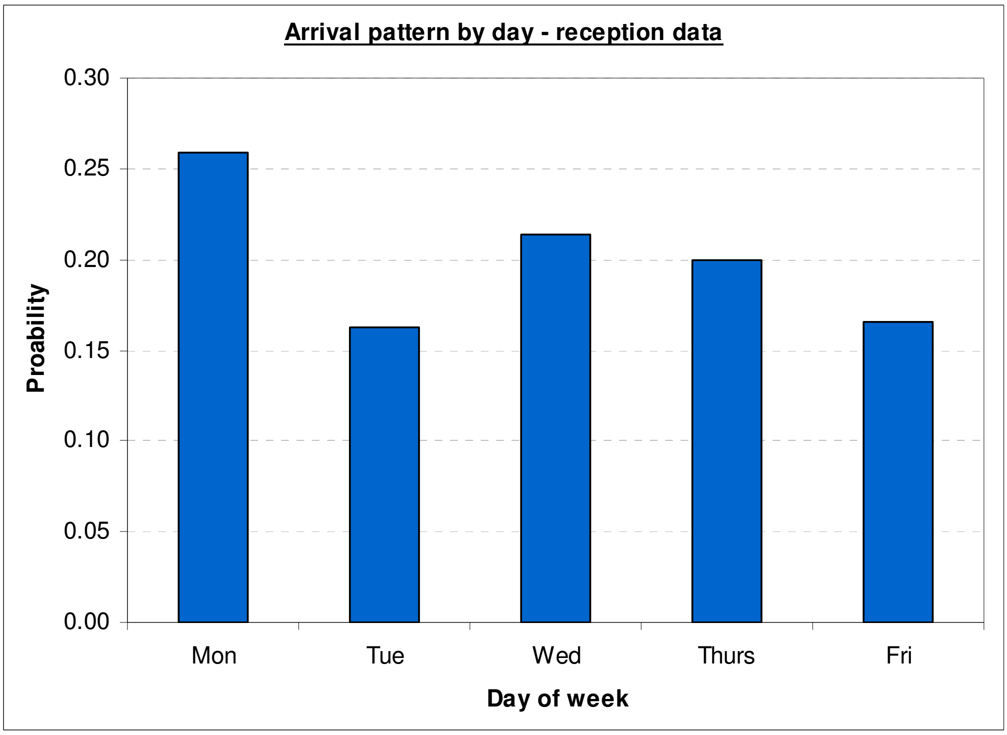

Figure 10-11: Arrival profile by day of the week

As mentioned this example will focus on male new patients. Figure 10-12 illustrates the patient type by gender distribution, indicating that new patients are the most common type, which reflects the walk-in nature of GUM. Therefore in this example the label for patient type would be set to be new. This is important as the gender and patient type influence subsequent distributions and values assigned to other labels.

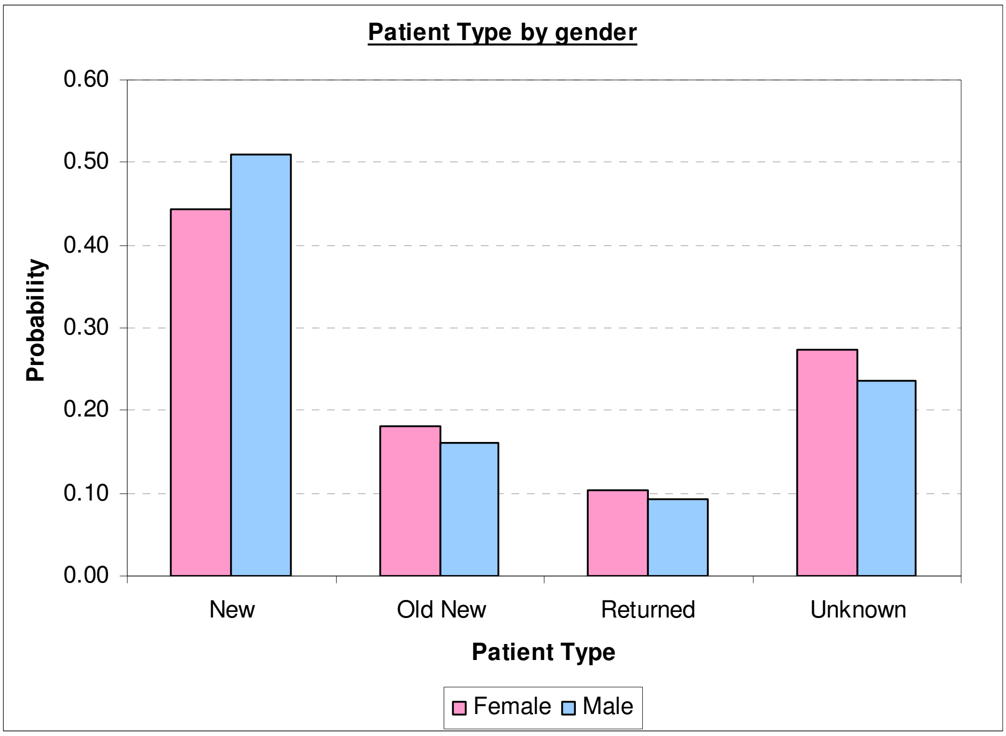

Figure 10-12: Patient type and gender distribution

The model focuses on seven conditions: Chlamydia, Gonorrhoea, Genital Herpes, Genital Warts, NSU and Syphilis. If a patient does not have one of these conditions they are assumed to be all clear. These seven conditions cover the majority of conditions that the department handles. There may be a small number of other conditions that will be missed as the patient is classed as all clear. The assignment of whether a patient has one or more of these conditions follows the process that will be discussed here in reference to Chlamydia. The process is the same for the other six conditions although different distributions would be sampled from. Figure 10-13 is the Chlamydia probability distribution for new male patients. It is possible to go down to this level of detail or to use a more general level of infection if the user wishes, i.e. all male patients. Each condition has a yes/no type label and if they are all negative then the eighth label “all clear” is marked as yes.

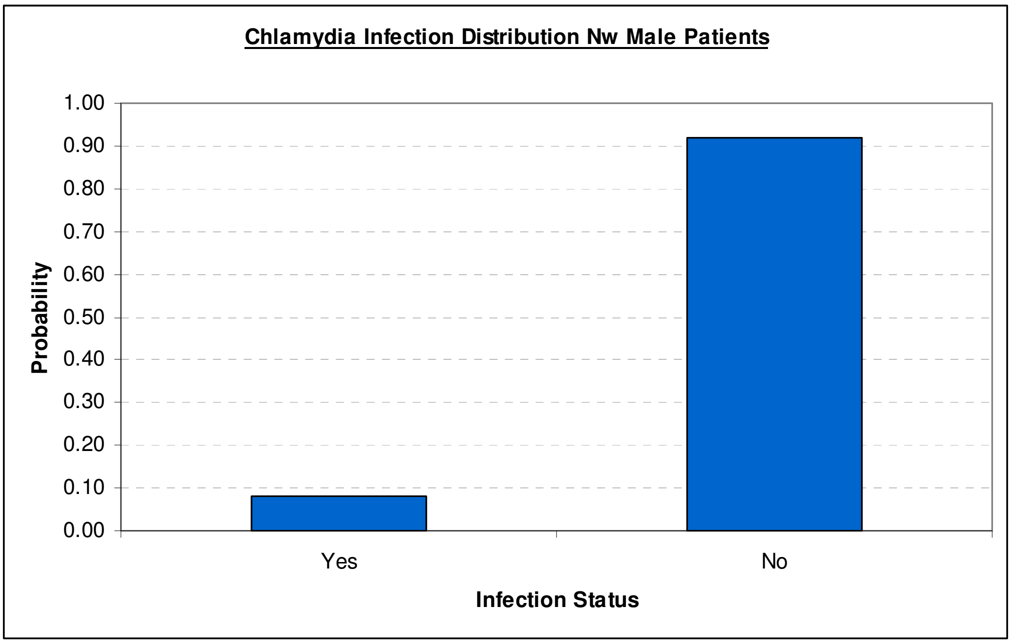

Figure 10-13: Chlamydia infection probability for new male patients

The time that the patient spends at different stages in the system is determined by distributions which are assigned according to the patient's labels, known in Simul8 as "label based distributions". The label based distributions are then sampled from when the patient reaches the relevant point in the department. This method is used for the reception and medical tasks.

The main reception tasks are: the issuing of paperwork; the completion of this paperwork by the patient; the time taken to enter patient details on the system following the completion of this paperwork; and, the making of follow up appointment(s). The duration of each of the discussed tasks is captured by a label based distribution. Figure 10-14 is the empirical distribution representing the time required to enter the new male patient's details onto the system. The actual time to enter the details is influenced by the number of reception staff available; if there are not enough reception staff available then this process will obviously take longer as in addition to the process time the patients will have to queue until a member of reception staff is available. The same process is followed for the other reception tasks previously mentioned, each with its own label based distribution.

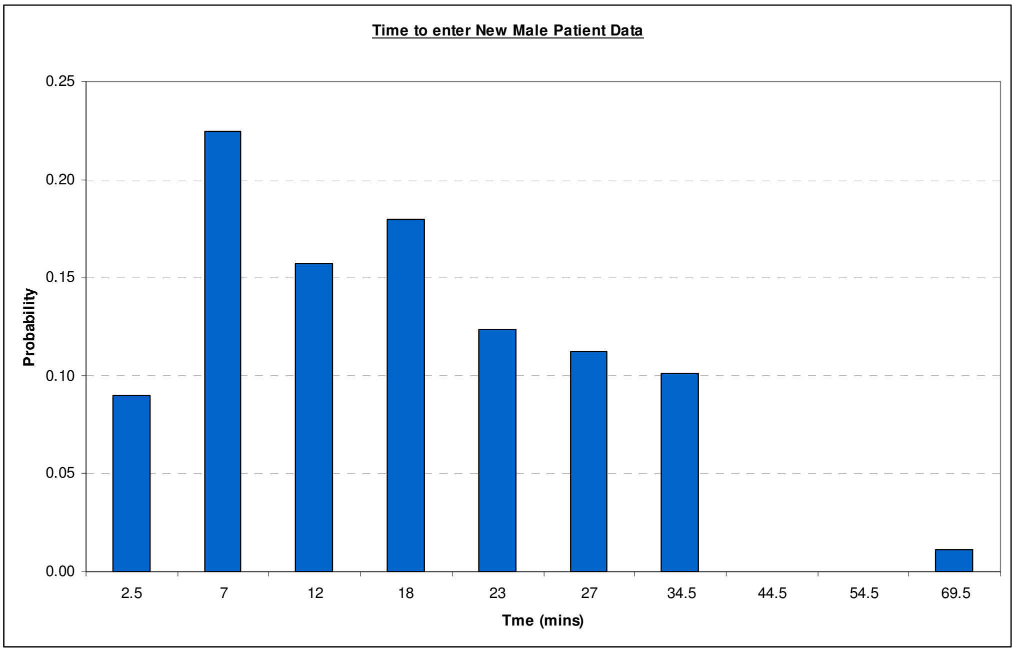

Figure 10-14: Time to enter male patient details to the system distribution

The medical processes are captured in the same manner as the reception processes previously described. A patient can go through up to five medical processes: providing a history, being examined, providing a blood sample, waiting for an in-house specimen to be processed, and receiving advice and treatment (management). These processes are all captured by label based distributions assigned to the patient. Figure 10-15 is the distribution for the history-taking process, for all male patients. It should be noted that patient-specific distributions can be combined with more generic distributions if so wished. The other medical processes are assigned label based distributions in a similar fashion.

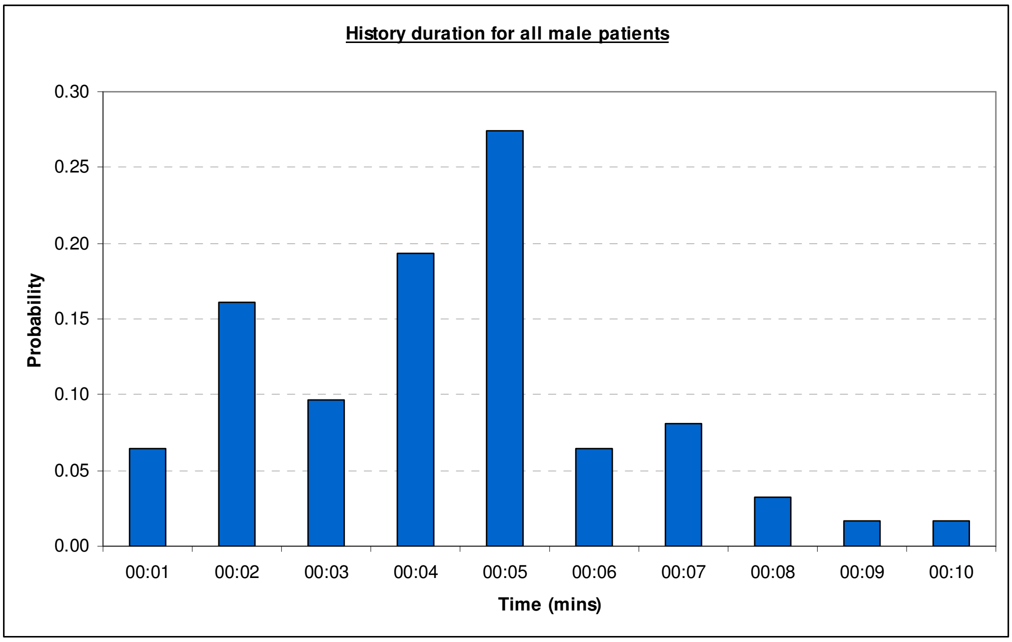

Figure 10-15: History duration distribution for male patients

Other labels are assigned values following the same approach, for example the labels to determine if a patient requires a blood test, a lab test or both, and whether or not the patient makes an appointment for another visit before leaving the department.

10.5 Base Model and Suggested Improvement

The base model draws from a number of data sources, as shown in table 10-1. The base model utilised: actual arrival figures, staff schedules, opening hours and patient pathways. Section 10.5 is organised to display the base case results alongside a suggested improved GUM configuration. Section 10.6 identifies how the key processes in the model which resulted in the greatest improvement in performance indicators were identified. This influenced the suggested improved model configuration.

Many results in the model were used to validate the model against historical data. There are also many results available from the model which are currently not collected in the real system, but are of interest to the stakeholders. Table 10-3 illustrates how the GUM model was validated against historical data by comparing the number of patients seen and those who were not seen. The difference column in the two tables indicates how far away from the real system the model is. The model is turning away more people than in reality and is therefore seeing fewer patients. However, this is due to the “turned away” decision rule which is discussed further in section 10.6. The base model assumes that this rule will be strictly adhered to, when in reality this is a human system so: a) staff may decide to try to fit a few extra patients in at the end of the session; and, b) patients may choose to try their luck and stay in the system longer. The base model was approved by the department stakeholders as being sufficiently accurate.

Seen	Historical	Base Model	Difference	Difference (%)
Female	853.00	844.80	8.20	0.96
Male	788.00	772.60	15.40	1.95
Total Patients	1,641.00	1,617.40	23.60	1.44

Not Seen	Historical	Base Model	Difference	Difference (%)
Turned Away	127.00	109.75	17.25	13.58
Walked Out	187.00	218.70	-31.70	-16.95
Total Not Seen	314.00	328.45	-14.45	-4.60

Table 10-3: Comparison with historical figures

The following tables compare the base model results with a suggested improved scenario. The base and improved model parameters can be found in appendix T. Only a selection of the all the possible results are displayed for clarity with the full results available from appendix T. To summarise the key difference the “Improved” model has five FTE: reception staff, female and male medical rooms, whereas the base uses actual system schedules, which are fragmented for each of the three resources mentioned, based mainly on staff availability and budget constraints.

Table 10-4 illustrates the resource utilisation (% of shift time working) results. The improved model demonstrated a reduced room utilisation rate compared to the base system which is to be expected as it uses a greater number of resources. The base scenario had three female and male rooms which did not operate at full capacity, whereas the improved model had five female and male rooms. The utilisation results for the 4th and 5th rooms (female and male) are therefore listed as not applicable in the base case.

Results	Base Average	Base CI	Improved Average	Improved CI
Waiting Room Capacity - Utilisation	9.79	(9.42-10.15)	8.42	(8.28-8.56)
Capacity Standing	0.45	(0.44-0.47)	0.34	(0.33-0.35)
Reception Staff - Utilisation	55.63	(54.94-56.33)	42.47	(42.02-42.93)
Female Medcial Waiting Area - Utilisation	4.34	(4.24-4.44)	3.41	(3.35-3.48)
Male Medical Waiting Area - Utilisation	6.36	(6.11-6.61)	3.87	(3.81-3.93)
Blood Staff - Utilisation	5.03	(4.85-5.21)	1.08	(1.04-1.12)
Lab Staff - Utilisation	8.95	(8.68-9.22)	1.85	(1.80-1.90)
Female Room 01 - Utilisation	11.71	(11.43-11.99)	6.04	(5.92-6.16)
Female Room 02 - Utilisation	15.66	(15.25-16.07)	7.26	(7.03-7.49)
Female Room 03 - Utilisation	14.61	(14.14-15.07)	7.17	(6.98-7.35)
Female Room 04 - Utilisation	na	na	4.03	(3.95-4.12)
Female Room 05 - Utilisation	na	na	7.23	(7.04-7.41)
Male Room 01 - Utilisation	27.36	(26.79-27.93)	8.28	(8.05-8.51)
Male Room 02 - Utilisation	21.36	(20.81-21.91)	8.30	(8.12-8.48)
Male Room 03 - Utilisation	20.06	(19.40-20.71)	8.25	(8.11-8.39)
Male Room 04 - Utilisation	na	na	7.58	(7.38-7.78)
Male Room 05 - Utilisation	na	na	8.27	(8.12-8.41)

Table 10-4: Utilisation results

The improved model resulted in more patients being seen and therefore more conditions being identified, when compared to the base model as illustrated in table 10-5.

Results	Base Average	Base CI	Improved Average	Improved CI
Female Patients Seen - Chlamydia	58.50	(55.14-61.86)	67.30	(63.92-70.68)
Female Patients Seen - Gonnorhea	3.55	(2.33-4.77)	4.15	(2.94-5.36)
Female Patients Seen - Herpes	23.70	(21.66-25.74)	27.65	(25.34-29.96)
Female Patients Seen - HIV	0.80	(0.44-1.16)	0.95	(0.53-1.37)
Female Patients Seen - NSU	23.35	(20.65-26.05)	26.20	(23.42-28.98)
Female Patients Seen - Syphillis	0.50	(0.08-0.92)	0.70	(0.30-1.10)
Female Patients Seen - Warts	41.95	(39.21-44.69)	49.45	(46.58-52.32)
Female Patients Seen - All Clear	671.75	(660.50-683.00)	767.65	(756.08-779.22)
Male Patients Seen - Chlamydia	62.50	(59.13-65.87)	72.40	(68.41-76.39)
Male Patients Seen - Gonnorhea	8.40	(6.79-10.01)	9.50	(7.61-11.39)
Male Patients Seen - Herpes	16.55	(14.18-18.92)	19.10	(16.41-21.79)
Male Patients Seen - HIV	1.35	(0.94-1.76)	1.40	(0.96-1.84)
Male Patients Seen - NSU	66.55	(62.52-70.58)	74.80	(70.57-79.03)
Male Patients Seen - Syphillis	1.85	(1.32-2.38)	2.35	(1.65-3.05)
Male Patients Seen - Warts	57.30	(54.00-60.60)	66.90	(63.67-70.13)
Male Patients Seen - All Clear	602.55	(592.18-612.92)	687.10	(674.49-699.71)

Table 10-5: Number of patients seen

The opposite is true for the "conditions missed". As previously mentioned, the conditions that a patient has are known within the model and if patients leave the system at any point the model records which if any of the STIs they had. By improving the configuration of the department from the base case to the improved case, fewer conditions are missed, as illustrated in table 10-6.

Results	Base Average	Base CI	Improved Average	Improved CI
Female Patients Not Seen - Chlamydia	12.20	(10.53-13.87)	3.40	(2.46-4.34)
Female Patients Not Seen - Gonnorhea	1.00	(0.66-1.34)	0.40	(0.12-0.68)
Female Patients Not Seen - Herpes	5.75	(4.83-6.67)	1.80	(1.26-2.34)
Female Patients Not Seen - HIV	0.15	(0.00-0.32)	0.00	(0.00-0.00)
Female Patients Not Seen - NSU	4.00	(3.20-4.80)	1.15	(0.66-1.64)
Female Patients Not Seen - Syphillis	0.20	(0.01-0.39)	0.00	(0.00-0.00)
Female Patients Not Seen - Warts	9.50	(7.85-11.15)	2.00	(1.39-2.61)
Female Patients Not Seen - All Clear	134.30	(127.70-140.90)	38.40	(34.76-42.04)
Male Patients Not Seen - Chlamydia	14.15	(11.78-16.52)	4.25	(3.30-5.20)
Male Patients Not Seen - Gonnorhea	1.70	(0.81-2.59)	0.60	(0.22-0.98)
Male Patients Not Seen - Herpes	3.80	(2.82-4.78)	1.25	(0.68-1.82)
Male Patients Not Seen - HIV	0.15	(0.00-0.32)	0.10	(0.00-0.24)
Male Patients Not Seen - NSU	12.35	(10.84-13.86)	4.10	(3.23-4.97)
Male Patients Not Seen - Syphillis	0.85	(0.36-1.34)	0.35	(0.12-0.58)
Male Patients Not Seen - Warts	12.45	(10.91-13.99)	2.85	(2.32-3.38)
Male Patients Not Seen - All Clear	127.50	(122.22-132.78)	42.95	(40.34-45.56)

Table 10-6: Number of patients not seen

The throughput of patients is a key performance indicator in the model. Table 10-7 provides details of the patient point of exit by gender. From the table we can see that more patients are seen who either make an appointment or do not require an appointment in the improved model. Also the number of patients who left the department unable to make an appointment has decreased. Fewer patients are turned away as the department has the capacity to accept more patients and the reception caused departures (relating to paperwork processing) have also reduced.

Results	Base Average	Base CI	Improved Average	Improved CI
Female Patients Not Seen - Chlamydia	12.20	(10.53-13.87)	3.40	(2.46-4.34)
Female Patients Not Seen - Gonnorhea	1.00	(0.66-1.34)	0.40	(0.12-0.68)
Female Patients Not Seen - Herpes	5.75	(4.83-6.67)	1.80	(1.26-2.34)
Female Patients Not Seen - HIV	0.15	(0.00-0.32)	0.00	(0.00-0.00)
Female Patients Not Seen - NSU	4.00	(3.20-4.80)	1.15	(0.66-1.64)
Female Patients Not Seen - Syphillis	0.20	(0.01-0.39)	0.00	(0.00-0.00)
Female Patients Not Seen - Warts	9.50	(7.85-11.15)	2.00	(1.39-2.61)
Female Patients Not Seen - All Clear	134.30	(127.70-140.90)	38.40	(34.76-42.04)
Male Patients Not Seen - Chlamydia	14.15	(11.78-16.52)	4.25	(3.30-5.20)
Male Patients Not Seen - Gonnorhea	1.70	(0.81-2.59)	0.60	(0.22-0.98)
Male Patients Not Seen - Herpes	3.80	(2.82-4.78)	1.25	(0.68-1.82)
Male Patients Not Seen - HIV	0.15	(0.00-0.32)	0.10	(0.00-0.24)
Male Patients Not Seen - NSU	12.35	(10.84-13.86)	4.10	(3.23-4.97)
Male Patients Not Seen - Syphillis	0.85	(0.36-1.34)	0.35	(0.12-0.58)
Male Patients Not Seen - Warts	12.45	(10.91-13.99)	2.85	(2.32-3.38)
Male Patients Not Seen - All Clear	127.50	(122.22-132.78)	42.95	(40.34-45.56)

Table 10-7: Patient's point of exit

It is worth noting that the improved scenario is one of many potential scenarios that the department could investigate before possible implementation. It needs to be stressed that this form of simulation will not give the "optimal" solution in its current form. It could give several solutions which are better than the current situation, but often there is a trade-off between competing factors, i.e. budget and number of staff, staff availability and opening hours. The model was developed primarily to elicit debate and provide information to support decision makers rather than make specific recommendations.

10.6 Experiments and Sensitivity Analysis

The design of the GUM model enables an incredibly large number of "what if" scenarios to be investigated. A suggested scenario is provided in section 10.5 as an improved configuration of the department. One of the purposes of the model is to allow the healthcare professionals the ability to explore the scenarios that they wish to at a time that suits them. To stimulate debate about which factors/variables are important in this system a fractional factorial experimental design consisting of 32 experiments was devised in collaboration with stakeholders, to examine the key factors to manipulate in the initial "what if" experiments. The results of the initial experimentation are discussed in part 10.6.1.

Following this initial experimentation a further 73 experiments were run to investigate various aspects of the department in greater detail independently, including capacity of medical rooms and reception area, available staff and the number of reception staff. Detailed results for the 32 fractional factorial experiments and the 73 experiments can be found in appendix T. The remaining parts of section 10.6 provide a summary of the results from the 73 additional experiments grouped by variable.

10.6.1 Fractional Factorial Design

The GUM model is a representation of the walk-in processes that patients follow when entering the department. The GUM model also includes other activities which draw resources such as reception and medical staff away from the treatment of patients. The model is therefore highly complex, and there are thousands of parameters that could potentially be changed and their effect and interaction on the system explored. Rather than investigate each of these variables as well as the interactions with the other variables, a fractional factorial design was devised (Law, 2007) in collaboration with stakeholders. The factors and performance measures in table 10-8 were identified as key variables to investigate. The factors are in the table on the left represented by the x values and the performance measures of interest are shown in the table on the right represented by the y values. The number of patients turned away, the number of the patients not making it past the medical stages; y1 was identified by the stakeholders as the key performance indicator.

Factor	Low (-1)	Standard (0)	High (1)
x1 = rooms (f)	1	5	10
x2 = rooms (m)	1	5	10
x3 = Blood	1	5	10
x4 = Lab	1	5	10
x5 = Recep	1	5	10
x6 = Waiting	20	40	60
x7 = Capacity (f)	2	5	20
x8 = Capacity (m)	2	5	20

Performance Measures
y1 = patients turned away
y2 = patient throughput
y3 = waiting time
yn = Other variables defined by GUM

Table 10-8: Factors and performance measures

The fractional factorial design including the factor (x) values of the 32 experiments can be found in appendix T. Figure 10-16 summarises the results from these experiments. The key performance indicator the number of patients not seen is plotted for each experiment. Patients who cannot be seen can exit the system at many possible points. These exit points have been grouped to: those patients who are turned away before being able to enter the system and those patients who leave as they have exceeded their reception waiting time and medical waiting time limit respectively.

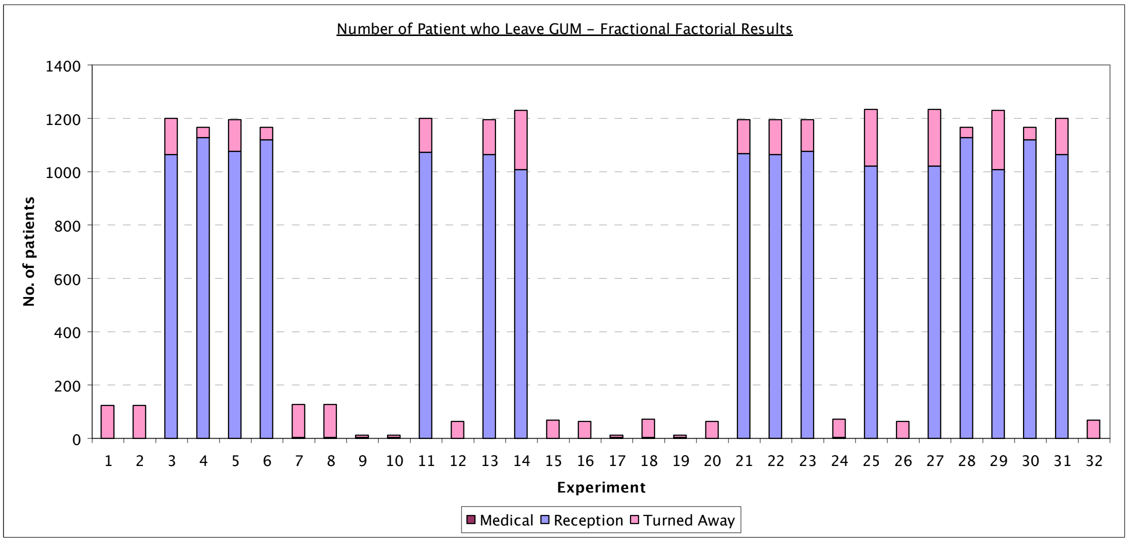

Figure 10-16: Fractional factorial results

Figure 10-16 identifies several experiments which are superior to others resulting in fewer patients not seen. E.g. Experiments: 1, 2, 7, 8, 9, 10, 15 and 16 etc. In each of these experiments the number of reception staff was set at the maximum value, which suggested that having enough reception staff in place is vital given the current design of the walk in processes.

10.6.2 Medical Rooms and Medical Staff

Medical rooms in the model are assumed to only be able to operate when a healthcare professional is available to perform the treatment; therefore one resource is used to represent both the room and the person. In the system medical staff are assigned to rooms and there is no sharing of staff, e.g. if you were seen by staff member “A” during the initial medical stages you would be seen by staff member “A” during the later stages.

These 10 experiments examine the effect of increasing the number of medical rooms for both female and male patients simultaneously. Figure 10-17 illustrates the effect of the number of rooms available on the number of patients not seen. The figure suggests that fewer people are turned away as the number of medical rooms increase, and it is the turned away mechanism which has the largest contribution to the number of patients not seen. The graph also suggests that the number of people who leave the reception due to reaching waiting time limits remains relatively constant which was to be expected given that the number of reception staff is fixed at the maximum level for the 10 experiments.

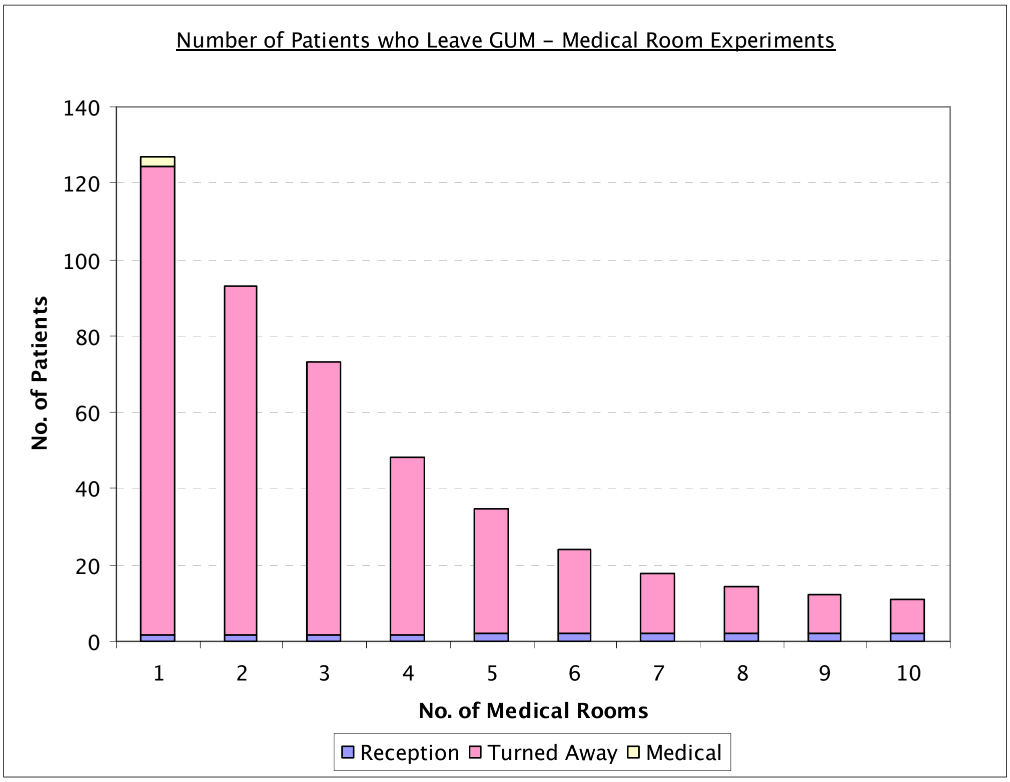

Figure 10-17: Number of medical rooms vs. patient left

Figure 10-18 provides information on the number of conditions which are missed. The more people who are not seen the more conditions are missed. Some patients may have more than one condition and some patients may have none of the conditions under consideration and therefore will appear to be all clear, which are not included on the graph.

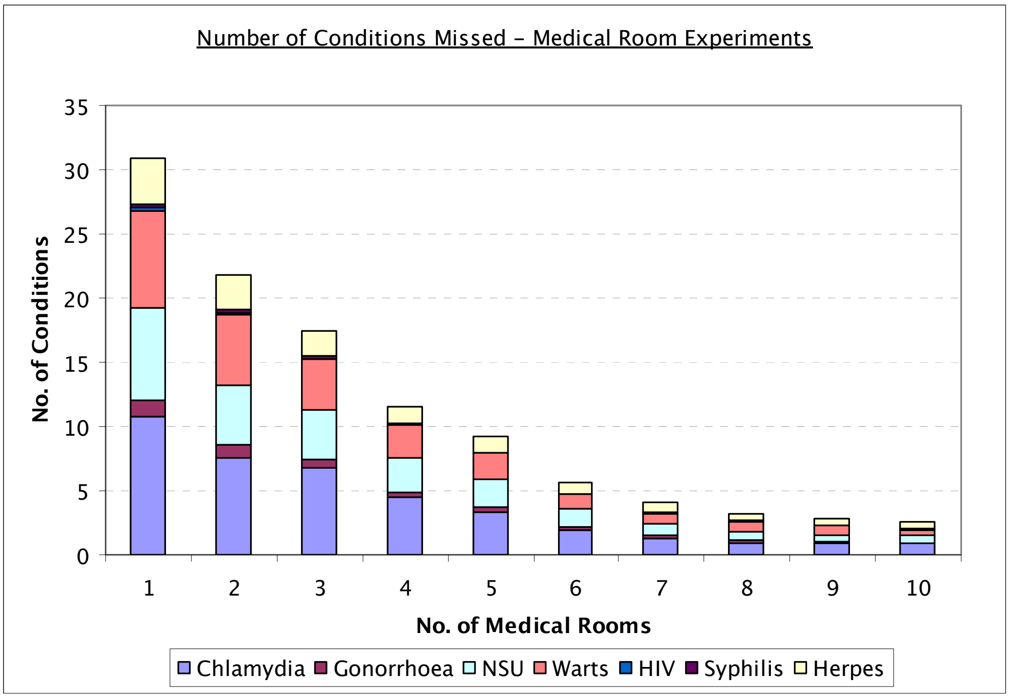

Figure 10-18: Number of medical rooms vs. conditions missed

Figure 10-19 illustrates the average waiting time broken down by gender. This is the waiting time in the reception area of the department. The department has two areas for waiting the normal seated waiting area at reception and the gender specific medical waiting areas associated along the female and male sides of the department. The waiting time in figure 10-19 is the waiting time at the reception side of the department. It remains relatively constant due to the number of reception staff remaining constant throughout the experiments. The patients are then drawn into the medical waiting areas following completion of the reception paperwork. The initial values for the medical waiting areas are high and increase as the number of medical rooms increase.

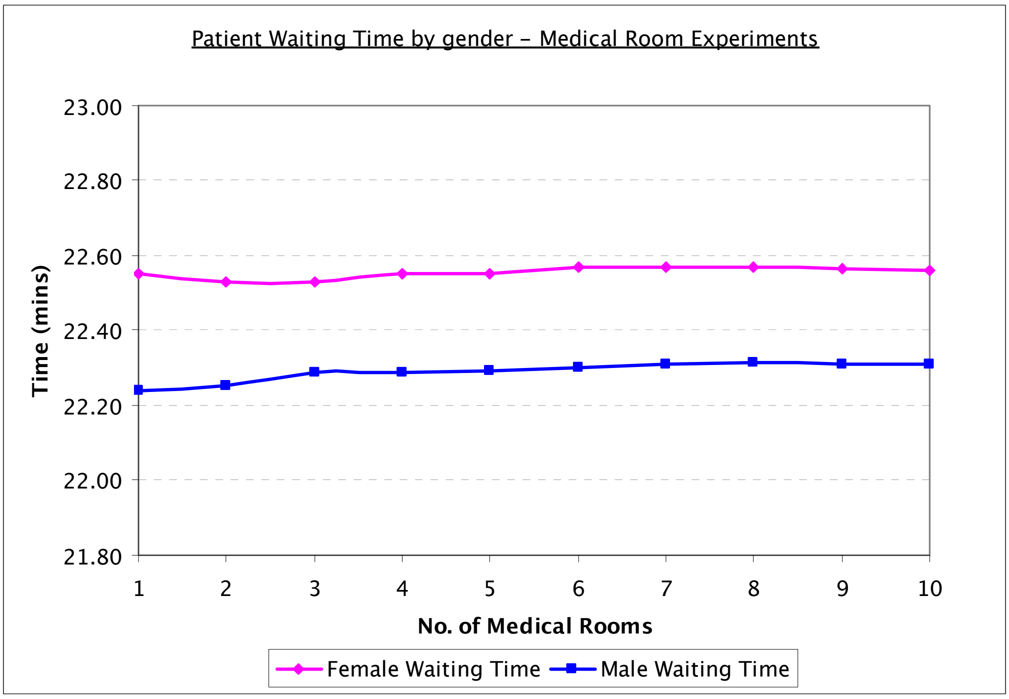

Figure 10-19: Number of medical rooms vs. patient's waiting time

Figure 10-20 provides the utilisation results for selected resources in the model. The utilisation in this instance refers to how much time the resources spends working (treating patients, or dealing with patients). The results are as to be expected number of rooms increase the utilisation decreases.

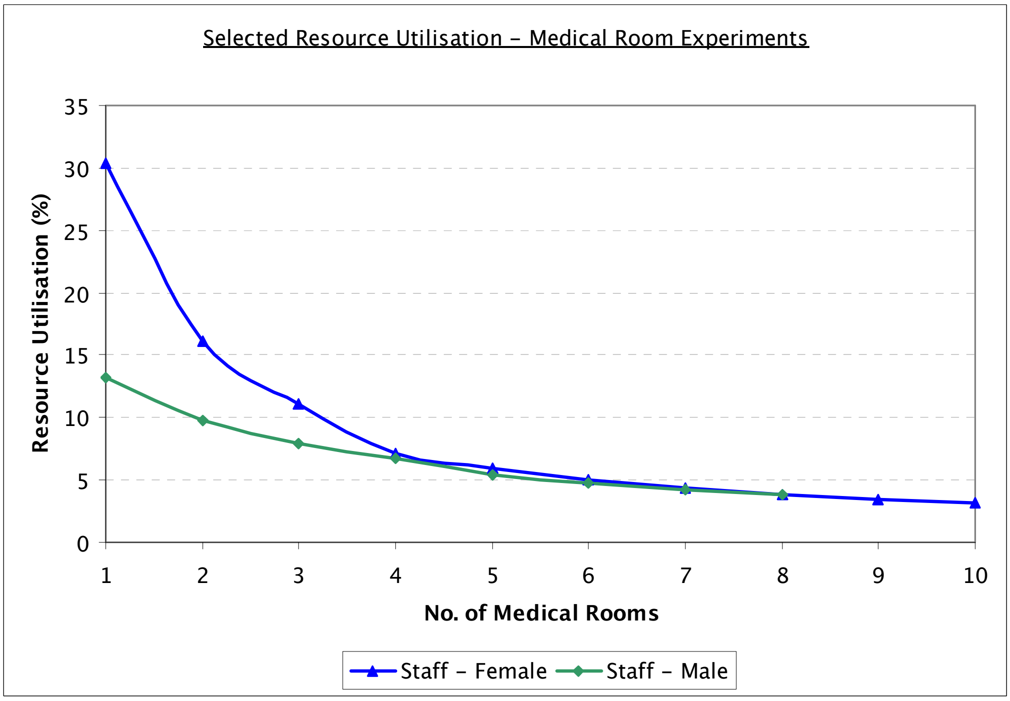

Figure 10-20: Number of medical rooms vs. resource utilisation

Figure 10-21 illustrates the average total time a patient spends in the department who successfully makes it past the management medical stage. The average total time remains fairly constant until the rooms increase to 9 and 10. This could be due to bottlenecks in the system which resulted in patients being turned away at the reception side of the department due to the decision rule that the department operates. With the increase in the number of medical rooms fewer patients are now turned away. This increases the number of patients in the system which then prolongs the patients' waiting time in the waiting areas (medical and reception) which increases patient's total time in the system.

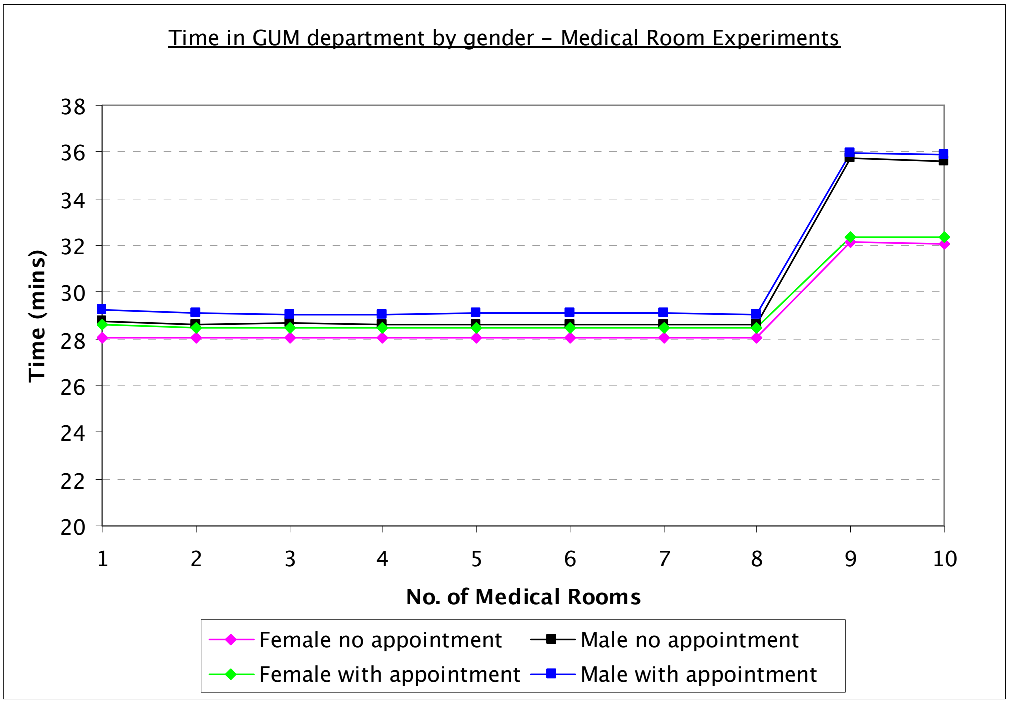

Figure 10-21: Number of medical rooms vs. patient's time in department

10.6.3 Reception Staff

These experiments examined the number of reception staff available. Figure 10-22 demonstrates that the number of patients seen increases as the number of reception staff increases. The number of patients turned away remains relatively stable and is based on the number of medical rooms available. The model suggests a trade-off needs to be made between the number of reception staff employed and the number of patients who leave reception as a result of exceeding their waiting time limits.

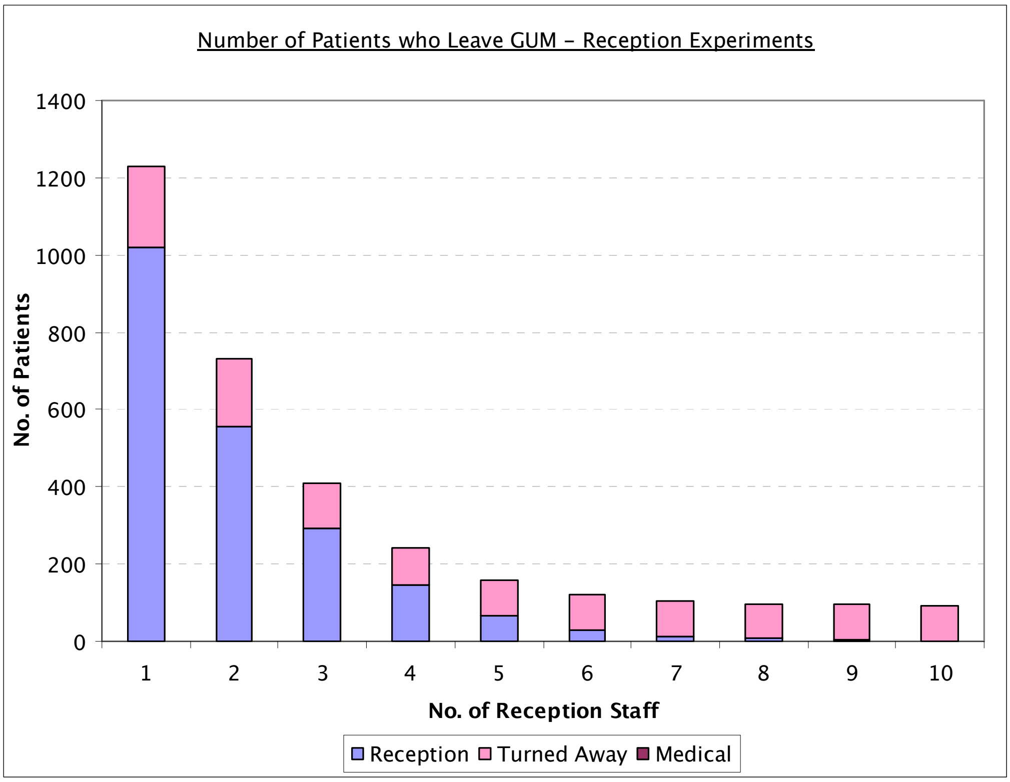

Figure 10-22: Number of receptionists vs. patients left

Figure 10-23 indicates that patients waiting time is also reduced by employing more reception staff. This is primarily due to the time taken to enter the patient's details, before they are able to be called into the medical side of the department. Patient's waiting time reduces substantially up to 5 reception staff and thereafter additional staff only slightly reduces the patient's waiting time.

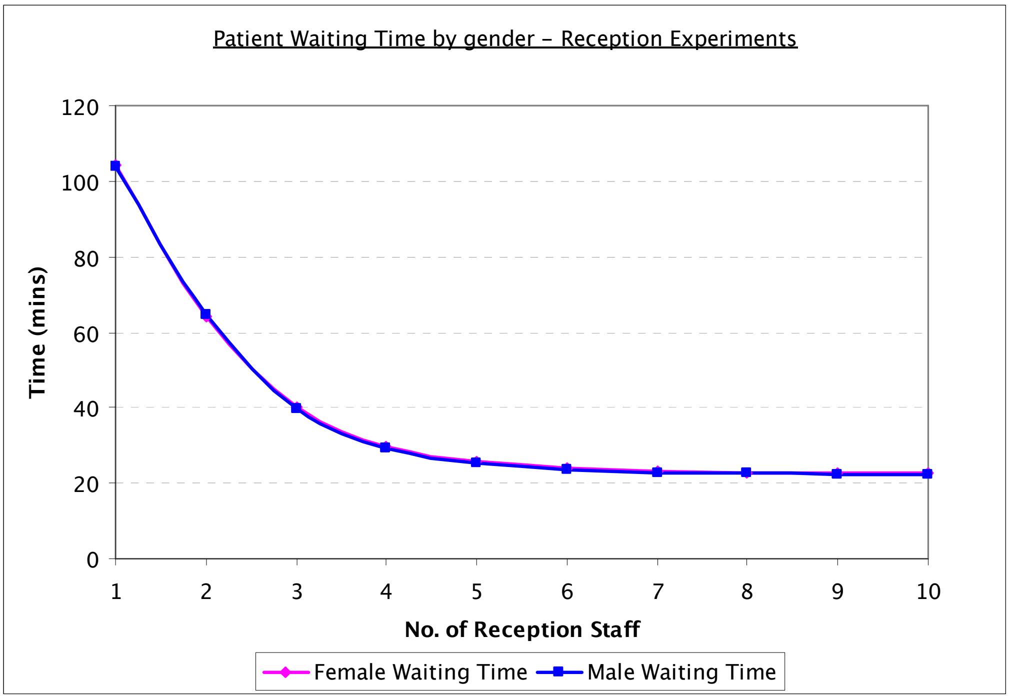

Figure 10-23: Number of receptionists vs. patient's waiting time

Figure 10-24 represents the resource utilisation of selected resources within the system. The "Staff – Reception" utilisation decreases as the number of staff increases, as expected. What is interesting is that the "Staff – Female" and "Staff – Male" do not reach steady state until the reception staff level reaches 4. This is presumably related to those patients who leave reception who have exceeded their waiting limit during the period from 1 to 4 where the reception area could be viewed as being understaffed. It is important to note that although the utilisation of the reception staff and the other staff may seem low, this needs to be offset against the throughput of patients see figure 10-22.

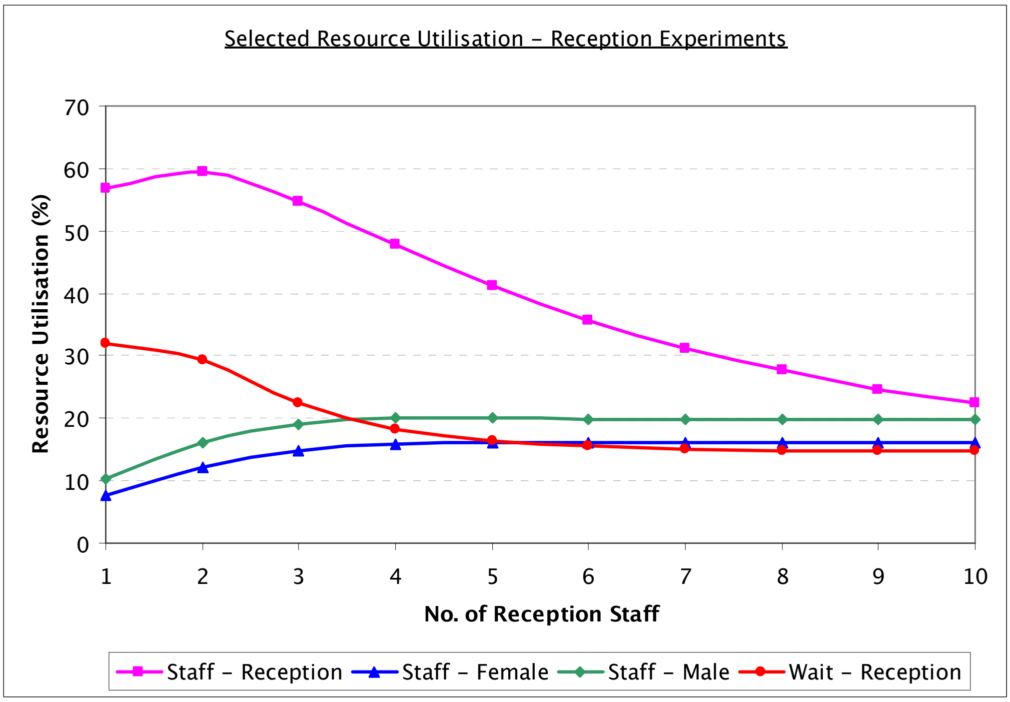

Figure 10-24: Number of receptionists vs. resource utilisation

Figure 10-25 clearly shows that by increasing the number of reception staff available that you decrease the patient's total time in the system.

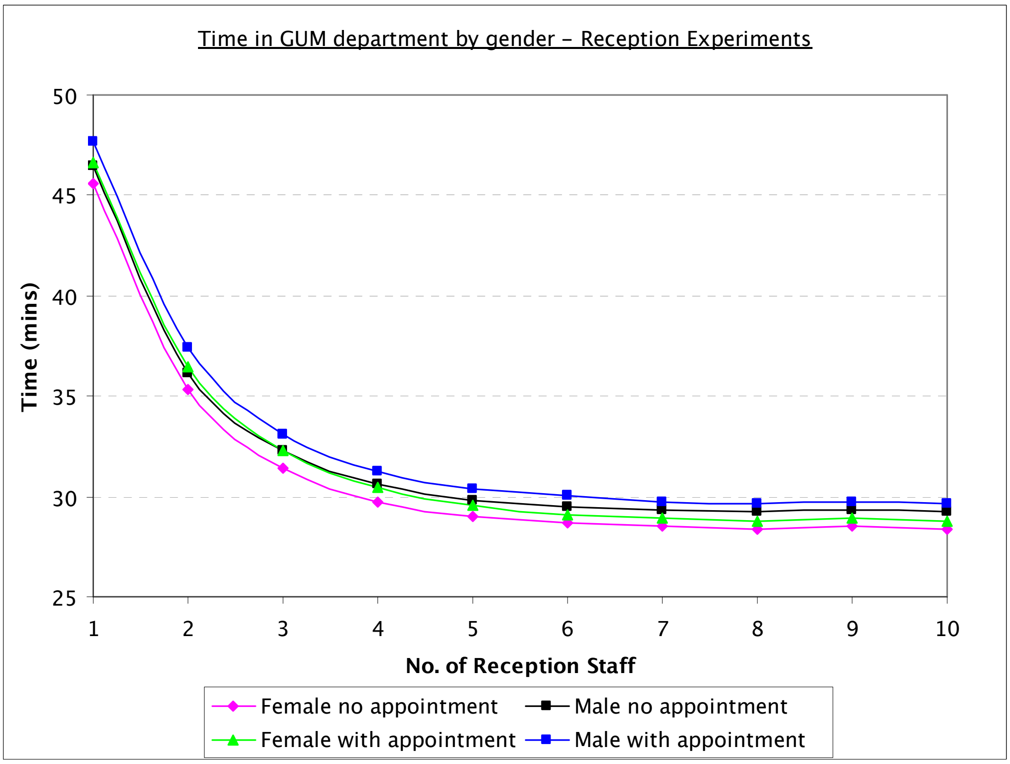

Figure 10-25: Number of receptionists vs. patient's time in department

10.6.4 Compliance

The department operates a decision rule to predict how long a patient may need to wait given the current status of the department, i.e. the number of people in the department and the resources available. The decision rule is quick to implement. They assign an average time that it will take to treat a patient, e.g. 15 minutes, they know the estimated waiting time for a person when they enter the department as they know the number of people in the system and they know the number of staff that they have they can therefore work out if the patient's estimated time will be run over the departments opening hours and/or staff working hours and then advise the patient to come back another day if necessary. Compliance in this context means the probability of a patient accepting the reception staff's advice to come back another day, with "0" representing non-compliance and staying in the department until they leave due to breaching one of their timing constraints and "1" representing compliance of staff advice and leaves the system to try again another day.

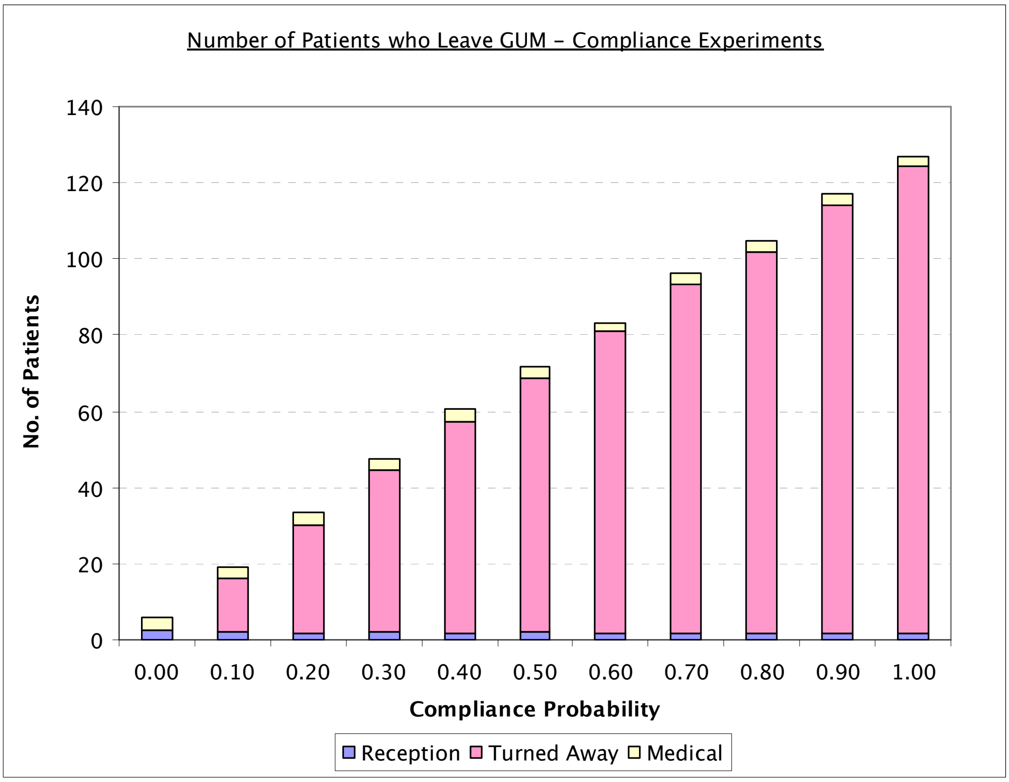

Figure 10-26: Compliance rate vs. patients left

Figure 10-26 illustrates the number of patients who were not seen. When the compliance level increases towards 1 the number of patients who are turned away also increases. When compliance is zero no patients are turned away. There are relatively constant medical and reception exit figures as the value for these parameters are fixed. One explanation why, if the decision rule was ignored that the department would be able to treat all the majority of the patients is that the true number of arrivals may not have been recorded on the GUM systems. They may only have recorded those patients who proceeded through the department and not those who arrived and were subsequently turned away.

Figure 10-27 shows that the selected resource utilisation remains relatively stable over the 11 experiments. The graph suggests that the medical capacity would be capable of dealing with the additional demand which was previously turned away.

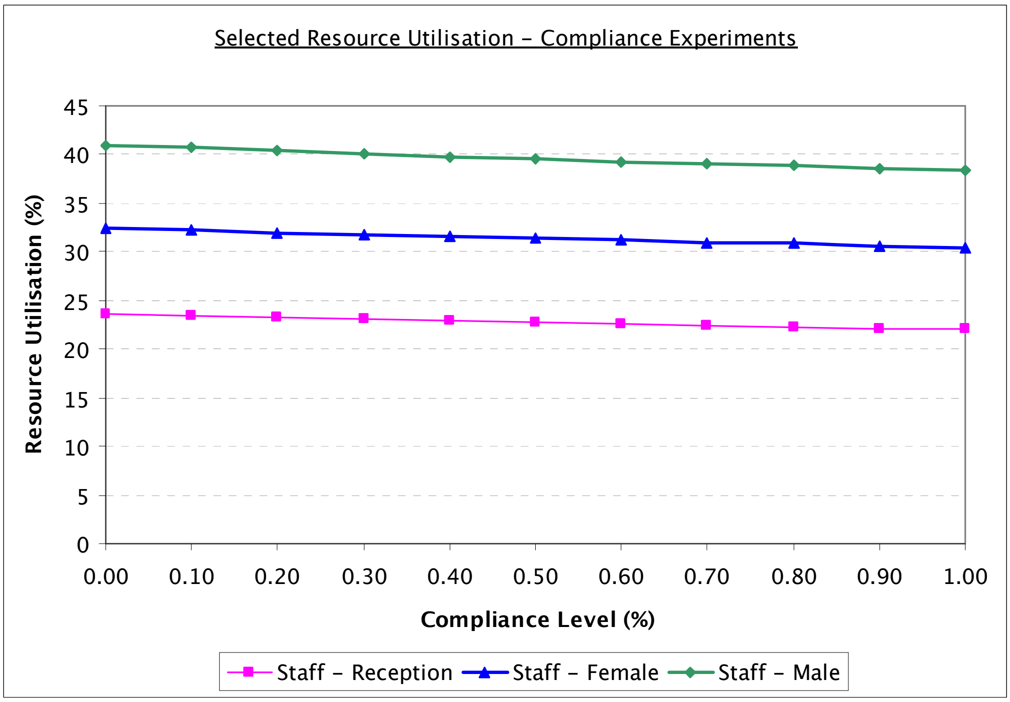

Figure 10-27: Compliance rate vs. resource utilisation

Figure 10-28 illustrates the average total time that patients spend in the system. What is clear is that females spend less time in the department than males although only a few minutes on average. This is due to the distributions used to sample task durations for the genders. Many of the data collected identified the male tasks as taking slightly longer e.g. management of male patients the final stage of the medical process can take much longer than females primarily as it is difficult to contact male patients through the health system so once there, greater effort may be made to provide health guidance.

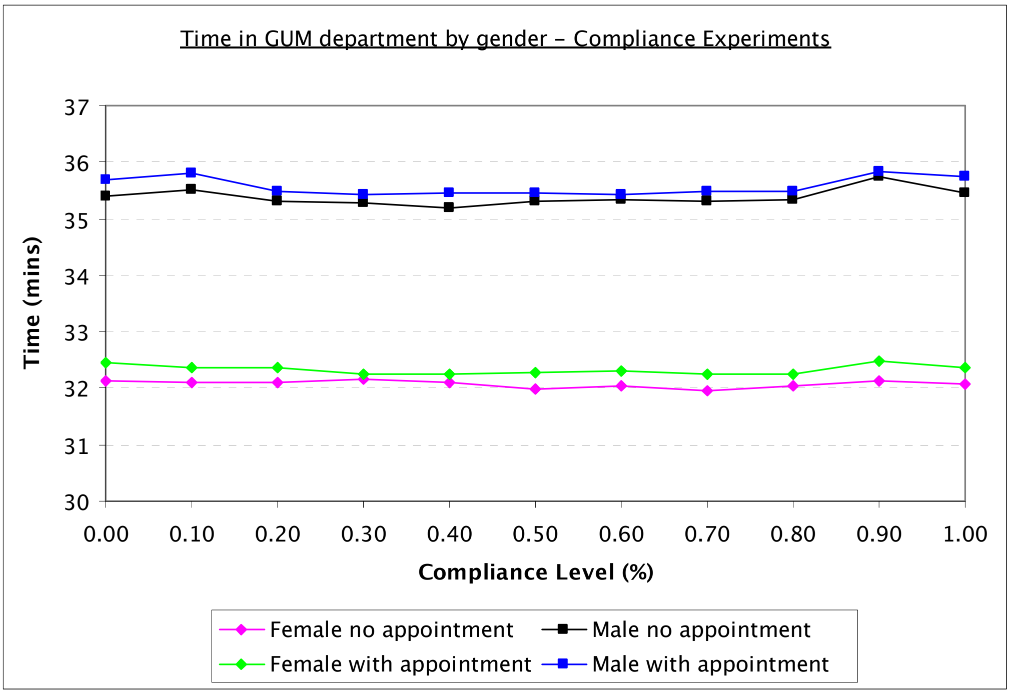

Figure 10-28: Compliance rate vs. patient's time in department

10.6.5 Treatment Time

Treatment time in this context refers to the average time that the healthcare professionals use when implementing their decision rule to accept patients or prompt patients to return another day. Currently the department assumes that on average a patient will require 15 minutes of medical treatment which is a reasonable assumption. This set of experiments examines 5 different average times and their effect.

Figure 10-29 illustrates the number of patients who were not seen. The graph indicates that as the average time to treat patients increases more patients are turned away and vice versa. The decision rule is an important mechanism for controlling the work load of the department, however the results as in the previous part on compliance suggest that more patients could be treated who are currently being turned away. Many patients can be treated in under the estimated waiting time however a few outliers would require a longer treatment time. These outliers result in patients potentially being turned away unnecessarily.

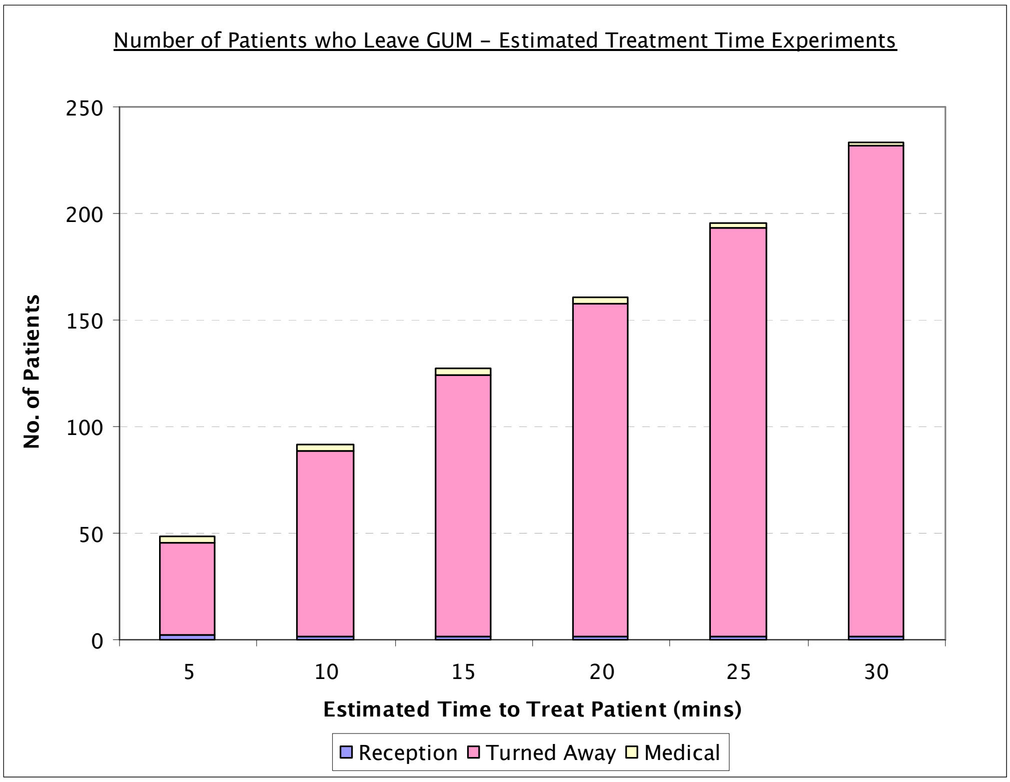

Figure 10-29: Estimated treatment time vs. patients left

Figure 10-30 illustrates the utilisation of selected resources from the model. The utilisation of the resources gradually decreases as the estimated time to treat patients' increases. This is due to more patients being turned away and therefore not utilising the resources see the compliance explanation in part 10.6.4.

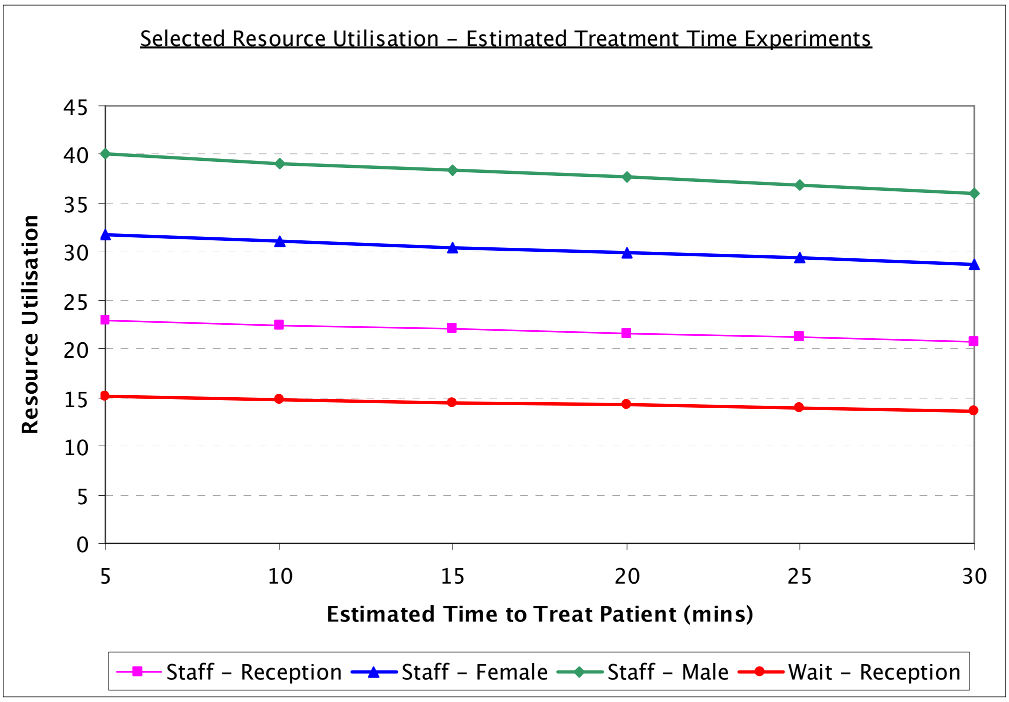

Figure 10-30: Estimated treatment time vs. resource utilisation

Figure 10-31 illustrates the average total time in the department. In line with the resources figure 10-30 there is a reduction as the estimated treatment time increases, in this case the total time in the system decreases by a few minutes on average for females and males. This is due as previously mentioned to more patients being turned away. With more patients being turned away the waiting time for those in the treatment time in the department has reduced.

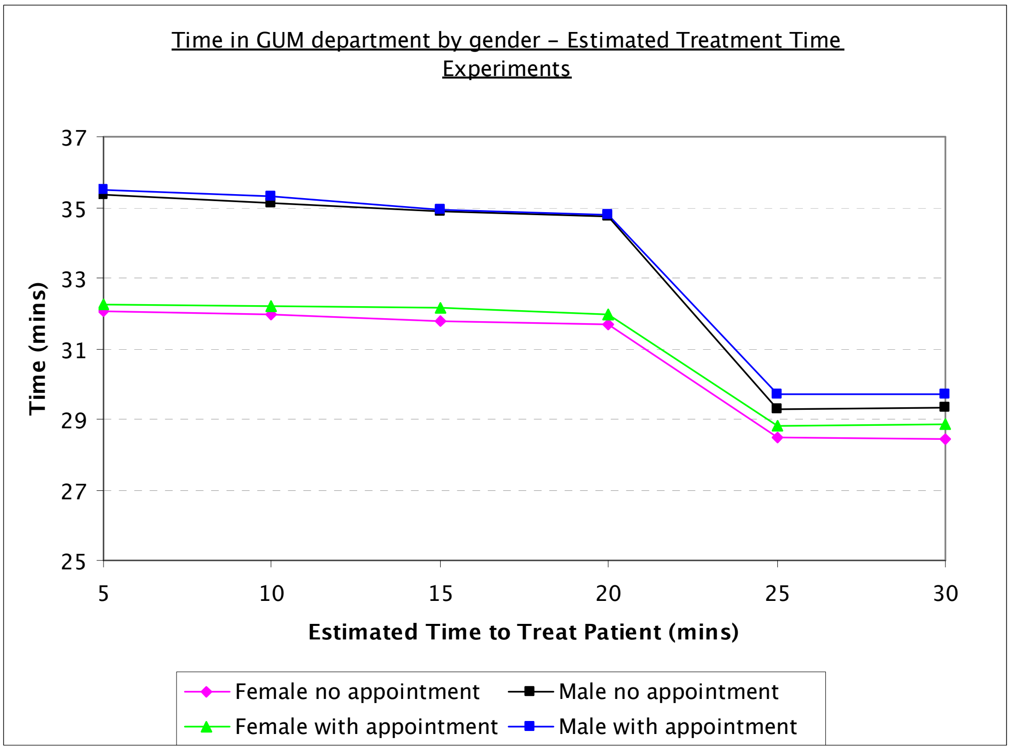

Figure 10-31: Estimated treatment time vs. patient's time in department

10.6.6 Shared Medical Resources vs. Segregation by Gender

The department currently operates a shared single waiting area at reception and then two medical waiting areas which are gender specific. This is due to the sensitive nature of the conditions patients present with at the department and also due to how busy the department can get. If patients were asked to return to the main reception waiting area between medical processes they could find their seat taken by a new walk in patient or one who was previously standing.

The department does share resources when the department is busy however this part compares the distinct approaches: the segregated approach and the shared approach and not a combination of the two although this could be investigated if required.

The aggregated number of patients not seen (turned away, waiting limit reached in reception and medical) for the shared and not shared options is displayed in figure 10-32. Initially when the number of medical rooms is small 3 or less the segregated option dominates but when 4 or more rooms are available the shared option dominates. This can be attributed to the turn away decision rule.

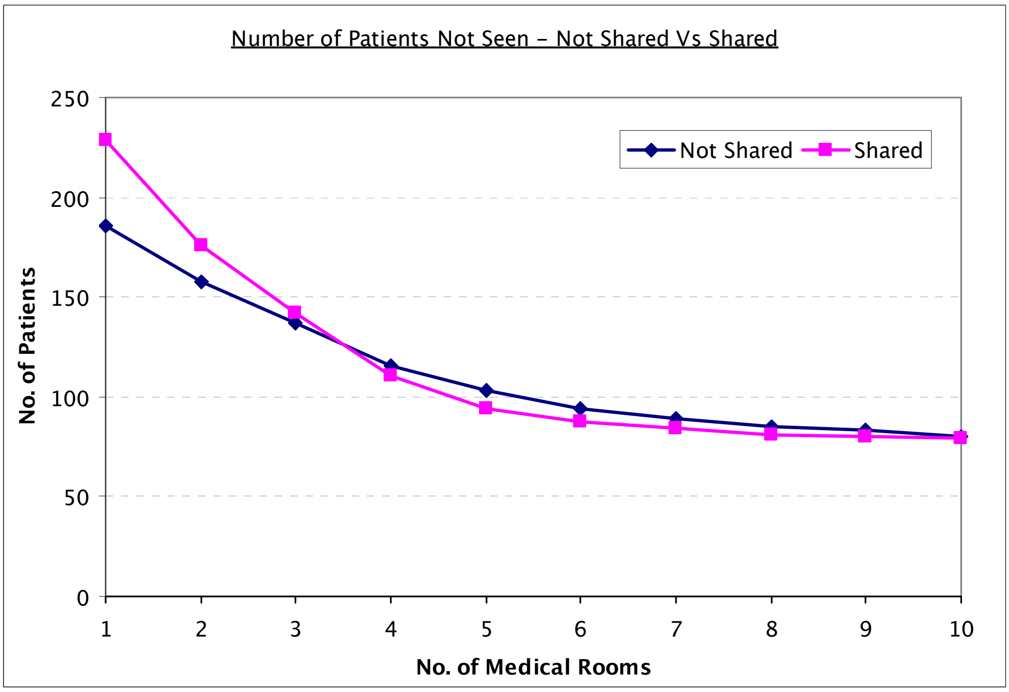

Figure 10-32: Not shared vs. shared resources – no. of patients not seen

The total number of conditions missed is illustrated in figure 10-33 and follows unsurprisingly the same pattern as figure 10-32 and the same rationale applies here.

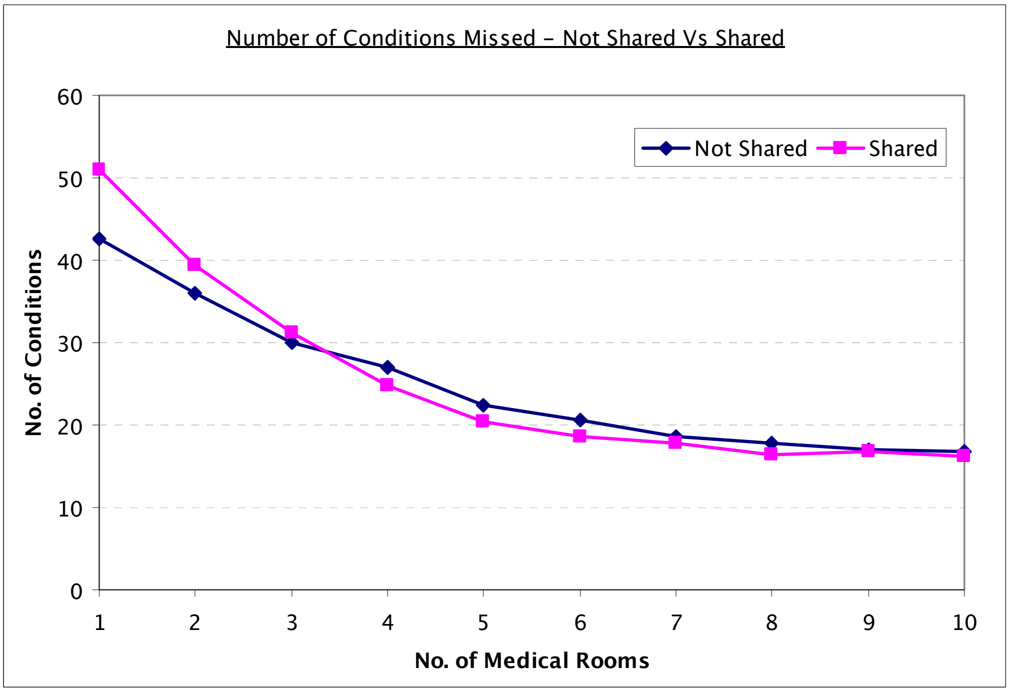

Figure 10-33: Not shared vs. shared resources – total conditions missed

Figure 10-34 is interesting and illustrates the patients waiting time in the reception waiting area by gender. The graph demonstrates that when the model is run in a shared state the male waiting time increases and the female waiting time decreases drawing them closer together compared to the segregated version where the waiting times are slightly higher for female patients throughout.

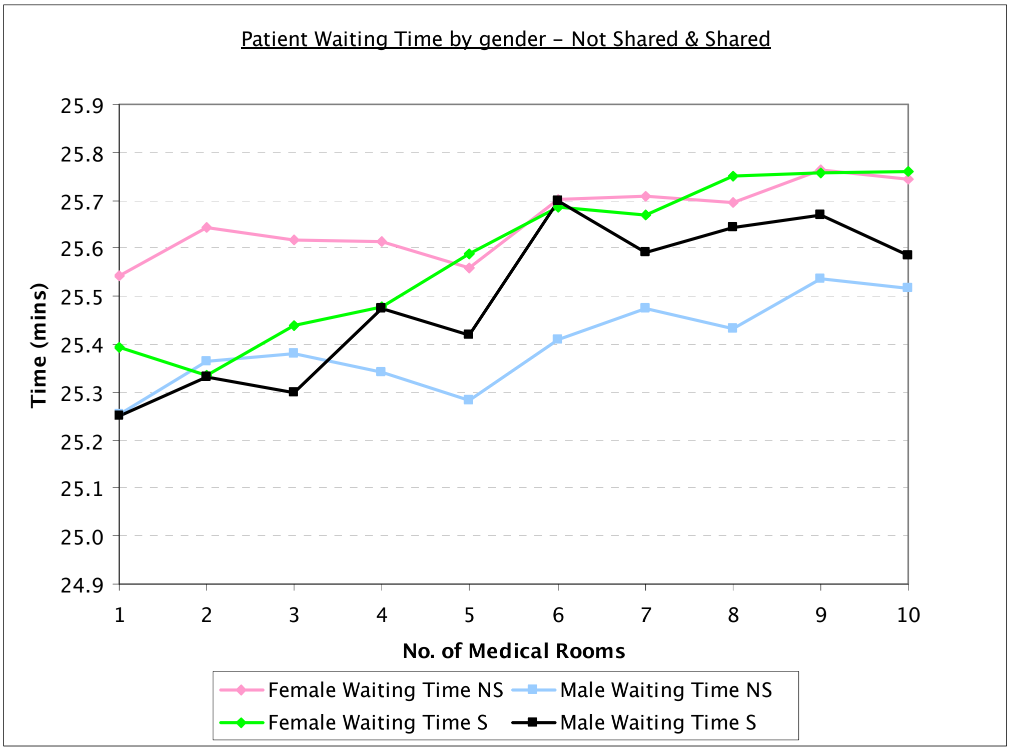

Figure 10-34: Not shared vs. shared resources – average reception waiting time

Figure 10-35 illustrates the time that a patient spends in the department that leaves with no appointment. The results are similar to those who leave with an appointment but to be concise only one set of results are provided. To a lesser extent the shared version of the model brings the total time in the system for the genders closer together initially and then the time in the system reverts to a similar pattern as the segregated results. This could be due, as previously stated, to the timing distributions associated with the male patients which are slightly longer in some instances.

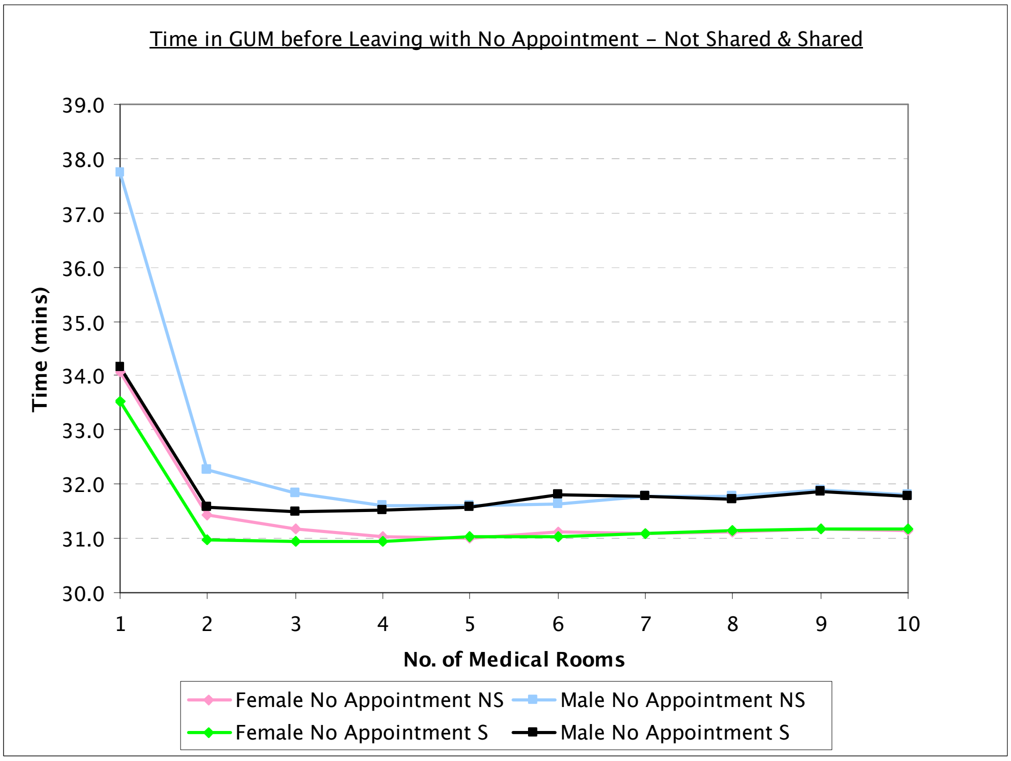

Figure 10-35: Not shared vs. shared resources - average time in GUM leaving with no appointment

Figure 10-36 looks solely at the utilisation of the medical rooms by gender and by segregated or shared. As expected by sharing the rooms the utilisation of the rooms increases which in turn results in fewer people being turned away at reception.

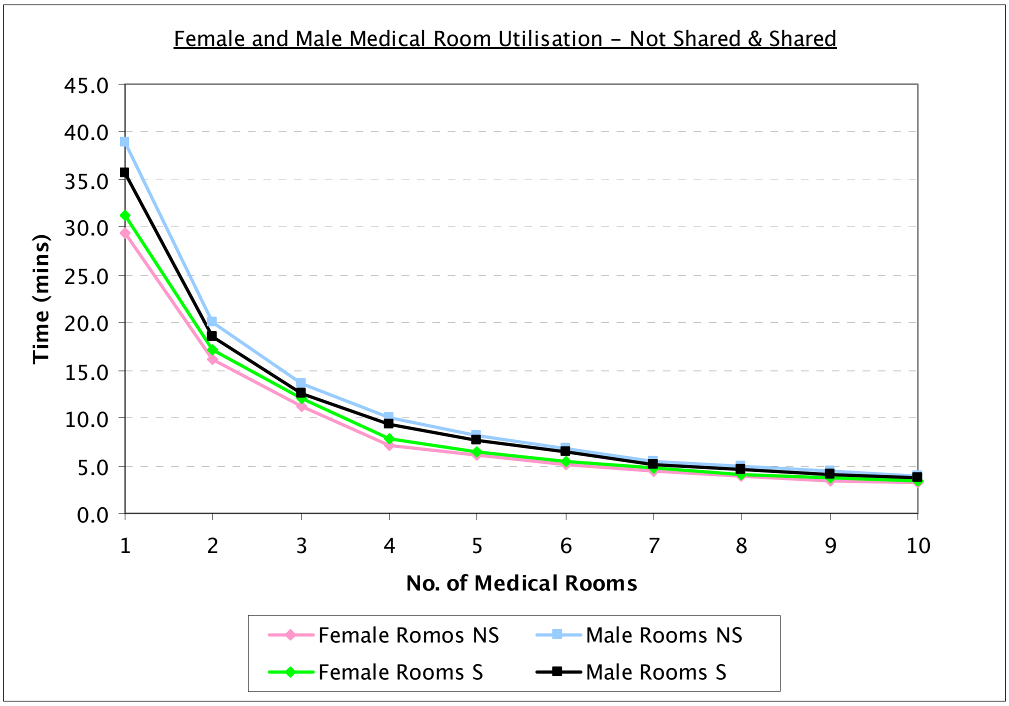

Figure 10-36: Not shared vs. shared resources – room utilisation

Figure 10-37 and figure 10-38are linked, rather than put all the information on one graph the shared and segregated results are displayed separately. It can be seen that initially when the number of rooms is small that the shared method results in a shorter time in the department, however after this the time in the department is comparable for the different options. It should be noted however that the time in the system is dependent on the number of people in the department at the time, and this is influenced by the number of people turned away. The shared option may result in a shorter total time in the system initially when compared with the segregated option; however it also results in more patients being seen. The increase in the number of patients seen in the shared option translates to similar times in the department as the segregated option.

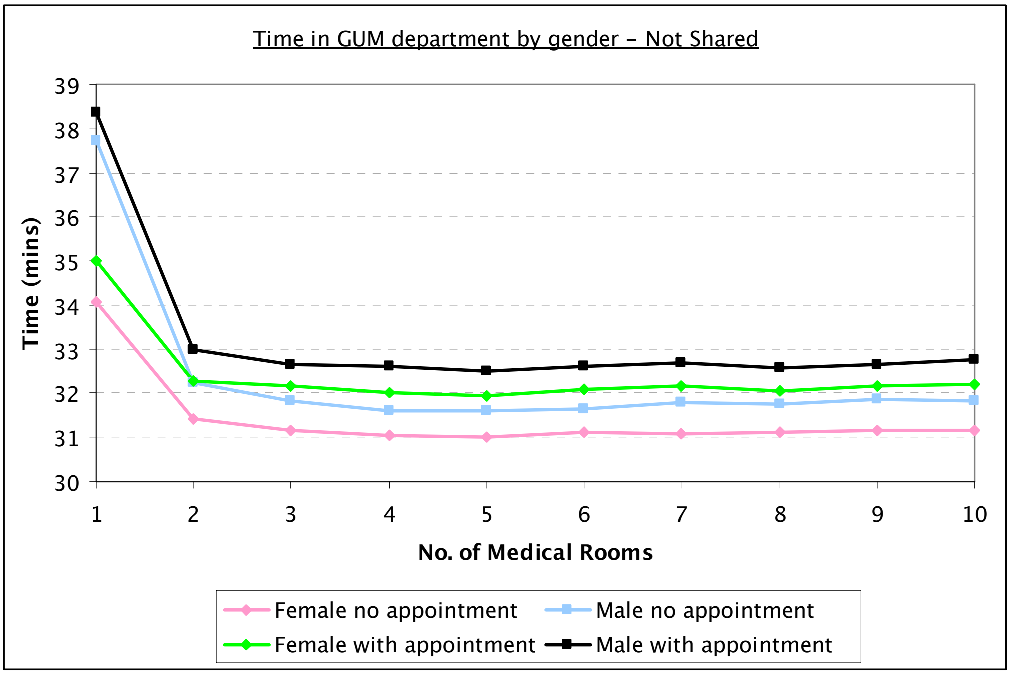

Figure 10-37: Not shared resources patient's average time in GUM

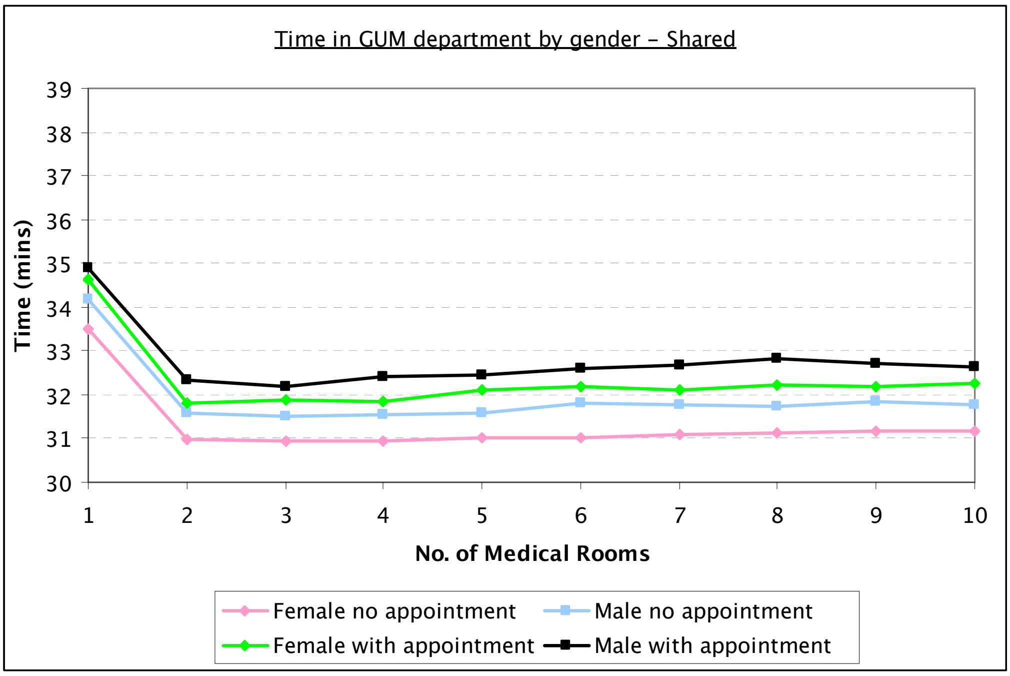

Figure 10-38: Shared resources patient's average time in GUM

10.7 Chapter Conclusions

The DES model created of the GUM model is fairly complex in order to capture the subtleties of the department without making too many simplifying assumptions. Many sources warn about making the model either too complicated or too simple, and thus modelling is very much both an art and a science.

The model captures the necessary detail of the model and was supported by the staff due to their continual input into its construction. This “buy in” by users of the model was crucial. Thus allowing the users confidence following training to operate the model and to begin exploring the “what if” space. Although the model allows parameters to be changed and many patient flows to be changed, the reception tasks are essentially hardwired in, apart from changing the duration of tasks and varying the number of resources. If this were to be amended or different pathways through the model investigated, then the model would have to be amended manually and the user interface updated. Although this could be potentially cumbersome and time-consuming, it would not be technically difficult.

The model suggests that:

1. The reception staff and the reception processes are key factors in controlling the patient flow into the department – if there are not enough then this adds unnecessary waiting time for the patient and underutilises the medical resources due to a delay in entering patient details onto the computer system.
2. Medical resources are being “starved” of patients due to delays in reception arising from the processes that need to be completed before the patient is available to be seen. The model suggests that the medical resources could see many more patients.
3. The “turn away” decision rule used by the department may be unnecessarily turning away patients who could have been treated within department working hours. The average time approach may need to be reviewed.
4. Shared medical resources are more efficient than segregated resources when the number of medical rooms for each gender is four or more.

10.8 Chapter Summary

This chapter:

- Provides a detailed summary of the GUM DES model.
- The fractional factorial experiment and stakeholder devised experiment structure and results.
- The sensitivity analysis was encapsulated in the stakeholder experiments.

11 System Dynamics Chlamydia Prevalence Model

11.1 Research Tasks Addressed

T5. Can behavioural dynamics be adequately captured in a System Dynamics model of Chlamydia? Does the inclusion of behavioural factors make a difference in the evaluation of Chlamydia screening strategies?

T6. Can the developed DES and SD models be successfully integrated? Is the combination of DES and SD models in this healthcare context beneficial?

11.2 Chapter Introduction

This chapter focuses on a System Dynamics model which was developed to aid in the understanding of the complex relationships involved in the spread of Chlamydia. The chapter will briefly describe the development of a system dynamics model, highlighting the key elements and functions. Validation and verification of the model was conducted in close collaboration with Dr Harindra, and was combined with the sensitivity analysis which will also be discussed. The experimental design and results are followed with a thorough sensitivity analysis. The aspects of the user interface associated with the model are touched upon. Key conclusions are then drawn from and discussed before a summary of the chapter is provided.

This chapter primarily addresses research task T5. The SD model developed and discussed in this chapter represents the second half of the composite model developed to address research task T6.

11.3 Method

As previously stated in the literature review (part 4.3.2) the system dynamics method is ideal for the modelling of infections and diseases and has been used extensively. This section will provide a concise account of the model development, including the software used to create the model, the initial causal loop diagram used to facilitate discussion with stakeholders of what to include in the model, the data collection, the main features of the model will be described and where appropriate discussed, the specific parts of the developed interface including the VBA will be summarised before the validation and verification processes are discussed.

11.3.1 VENSIM

There are many SD Simulation packages available including Stella/iThink (www.iseesystems.com), Powers (www.powersim.com), AnyLogic (www.xjtek.com) and OptiSim (www.optisim.pl) to name a few. The model was developed in Vensim (www.vensim.com) as Dr Harindra was familiar with simulation models produced in the package and the University had access to a professional version. The researcher had to learn the subtleties and nuances of the software but SD software all function around the same basic principles. Screen shots of the model are provided in part 11.3.4 where the key aspects of the model are summarised.

11.3.2 Causal Loop Diagram

Causal loop diagrams tend to be used as a tool in the initial development of SD models, as they provide an intuitive visual representation of the feedback present in the system under investigation. This visualisation is crucial in developing a shared understanding with the stakeholders before the construction of the computerised SD model takes place. The causal loop diagram in figure 11-1 is a representation of the processes exhibited in the spread of Chlamydia.

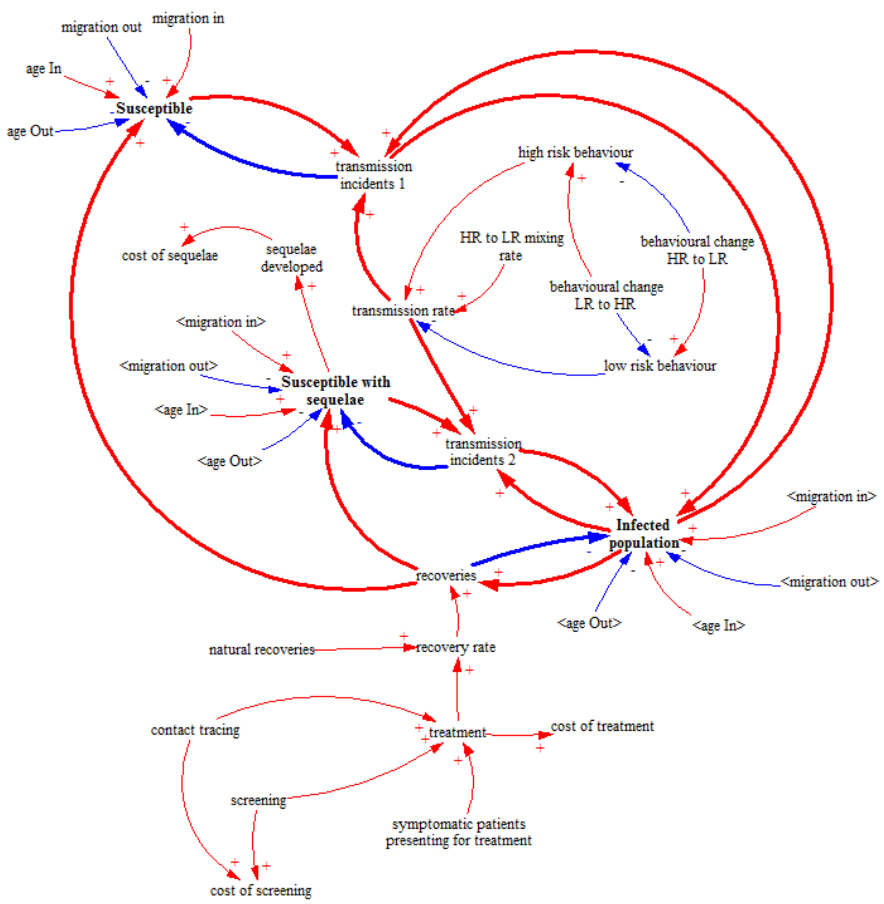

Figure 11-1: Causal loop diagram

The main aspects of the casual loop diagram are represented by the thicker red and blue lines with the red lines representing a positive effect on the target variable and the blue a negative effect. In the causal loop diagram there are two identical parts in the model relating to the change in state from susceptible to infected. This is to differentiate the two main types of susceptibility, those who have never had Chlamydia or have been treated/naturally recovered from Chlamydia without any negative consequences are in the “susceptible” state, and those who have had Chlamydia and may have developed sequelae are in the “susceptible with sequelae” state. The factors that influence the main infection recovery pathway are illustrated by the non-bold variables attached to the target variables with single weight red and blue lines.

From the casual loop model the full SD model was constructed. There were several factors that were included in the final model that were not included on the initial causal loop diagram. This was due to the continuing development with the clinical stakeholders as the project progressed. Where additional factors have been added these will be highlighted in part 11.3.4.

11.3.3 Data Collection

The data required for the construction of the SD model came from multiple sources. What the data was used for the data source and the amount of data used are displayed in table 11-1, in relation to a selection of variables from the model. Additional data used in the SD model were obtained through the analysis conducted in the previous chapters. Where data from preceding chapters have been used this has been highlighted in table 11-1.

Data Use	**Data Source**	**Related Variables in Model**
Population	Office for National Statistics (ONS)	Susceptible 1, Susceptible 2, Infected A, Infected S
Probability of Infection	Turner & Adams (2006), **Chapter 6**	LR probInfection, HR probInfection
Contact Rate	Mercer et al 2009, Townshend & Turner 2000 **Chapter 6** **Chapter 9**	LR contactRate, HR contactRate
Mean Time to Recovery	Evenden (2006)	time to recover

Data Use	**Data Source**	**Related Variables in Model**
Screening Rate	National Chlamydia Screening Programme (NCSP) **Chapter 6**	LR screen, HR screen
Behavioural Change	Expert Opinion **Chapter 8** **Chapter 9**	Chance of changing behaviour, LRS1 to HRS1, HRS1 to LRS1 (etc.)
Costs	National Chlamydia Screening Programme (NCSP)	screening cost per patient, treatment cost per patient, sequelae cost per patient
Age of population	Office for National Statistics (ONS)	average time in cohort

Table 11-1: Data requirements for SD model and sources

11.3.4 Key Features of the Model

The developed SD model was too complex to capture in a single view in the opinion of the author and Dr Harindra. The necessary detail of the model led to the use of multiple views. VENSIM enables models to be split into various views rather than having a one view which would be difficult for both technical and non-technical users to understand. Essentially views allow the model to be constructed on several screens which can be linked together rather than having one large model which can become complicated to follow. The key views are displayed and discussed in subsequent parts, with several of the views being replicated for the two risk groups: Low Risk (LR) and High Risk (HR) groups. Two risk groups were included in the model to capture what is referred to as the core group theory (Zenliman et al, 1999) in which a small proportion of a population maintain the infection as the prevalence in this group is larger. The complete SD model can be found in appendix N.

Figure 11-2 illustrates the infection recovery process. There are two similar views which represent the LR and HR groups. The infection process is influenced by the sexual contact rate and also the probability of infection given that one of the partners is infected. The model distinguishes between two infection states, symptomatic and asymptomatic. This is important as the method of treatment sought by the person differs in the presence of symptoms, with most symptomatic patients assumed to present for treatment voluntarily and asymptomatic patients identified through contact tracing or screening.

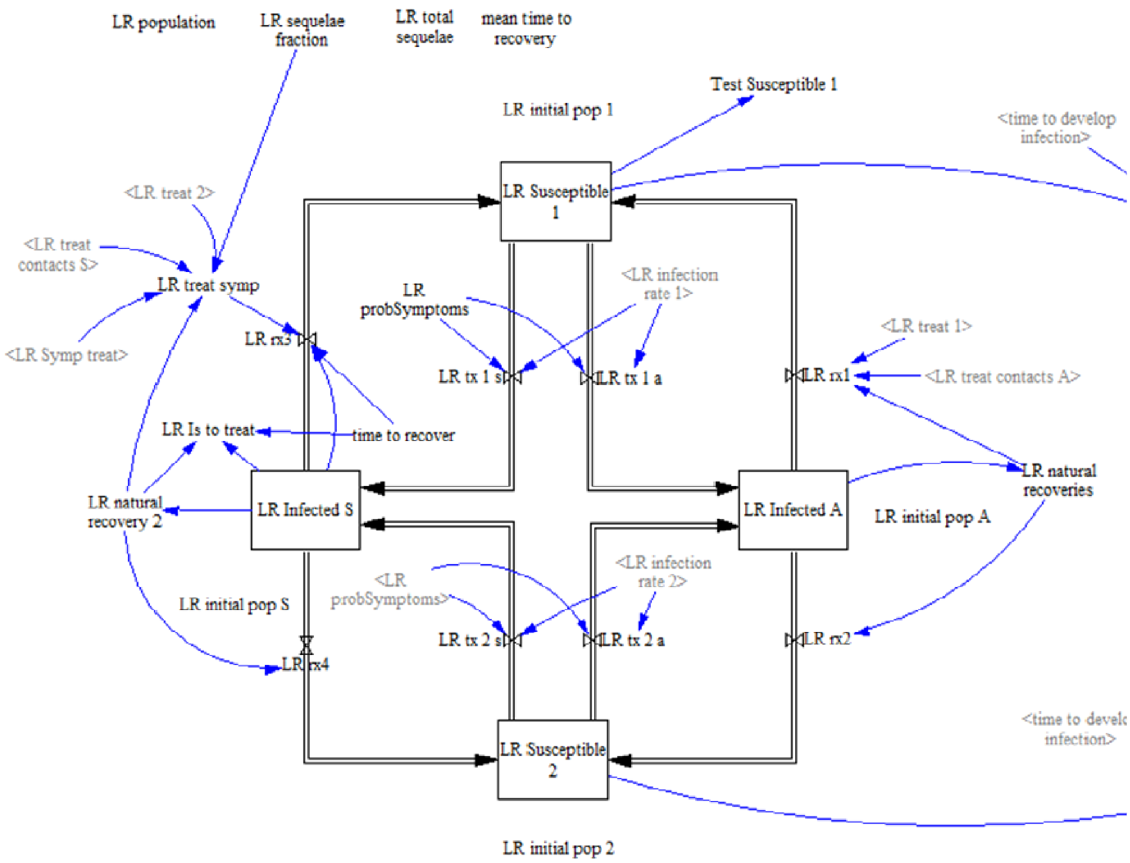

Figure 11-2: Infection processes

There are multiple points in which patients can receive treatment. Those include: symptomatic patients presenting for treatment, patients identified via screening, and patients identified from positive patient contact tracing. Figure 11-3 illustrates the processes involved in capturing the treatment processes.

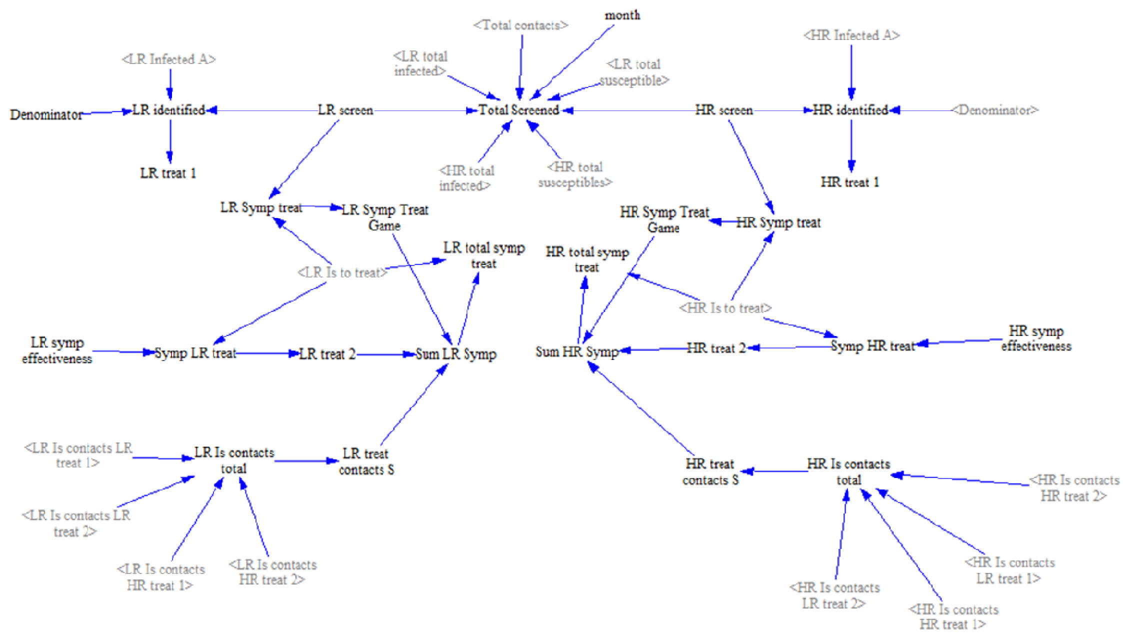

Figure 11-3: Treatment

The SD model makes use of VENSIM's subscripts, which allow single variables to represent more than one thing e.g. contain an array of values associated with defined groups. Subscripts in this model are primarily used to replicate the model structure and facilitate ageing, without making the model unmanageable. The SD model contains two subscripts that are used to subdivide the population into different classes one for gender and one for age. The gender subscript consists of two variables "male" and "female" and the age subscript covers 4 age groups, 16 to 19, 20 to 24, 25 to 34 and 35 to 44. Ageing is crucial in the infection process as partnerships as well as behaviour can change over time and this can be taken into account with these subscripts. Figure 11-4 represents the ageing process and is associated with all the stock variables which include the two states of infection and the two states of susceptibility for the low and high risk views. The "Low Risk" susceptible 1 ageing process is shown in figure 11-4. If the model did not make use of subscripts then the part of the model illustrated in figure 11-4 would need to be replicated 4 times for the age groups and then duplicated for the genders which would add an additional 16 versions of this particular part of the model. It is therefore more efficient and provides greater clarity to use subscripts otherwise the model would be at least 16 times larger.

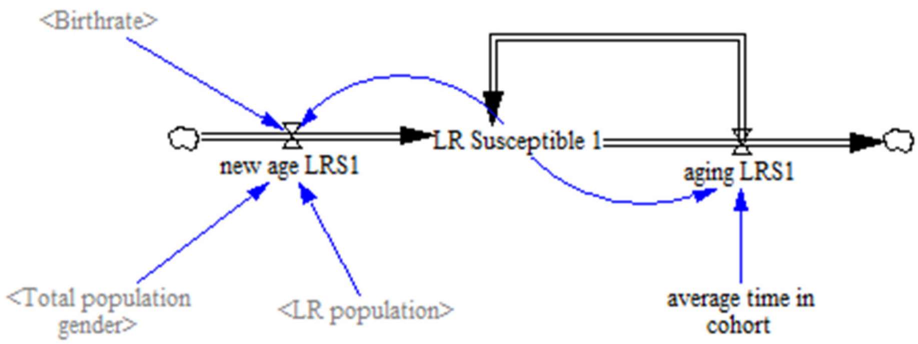

Figure 11-4: Ageing

As well as ageing discussed in figure 11-4 with new people entering the first age group and people leaving the final age group, migration is crucial when looking at the population of an area. The model allows for migration in and out of the area, by gender and age group. The migration process in and out of LR susceptible 1 group (those who are susceptible without associated sequelae), is shown in figure 11-5, and as with the ageing process is the same for the other stock variables.

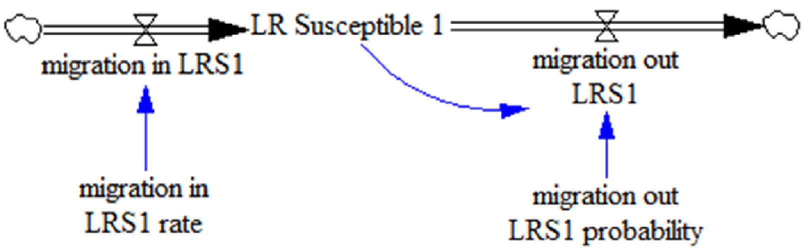

Figure 11-5: Migration

Previous SD models of Chlamydia infection (Evenden et al, 2006, Townshend et al, 2000) have not included behavioural change. Behavioural change is incorporated in this model in a variety of ways. There is the natural behavioural change associated with ageing where each age group has a specified contact rate which will affect the rate of infection in that population. Behavioural change has also been added to the model where there is a probability of change of behaviour from LR to HR groups and vice versa, which is again specified by age group and gender. In addition to these natural trends in the change of behaviour there is an additional point of behavioural change following treatment of Chlamydia by healthcare professionals. All of these behavioural change options are included in the model and are illustrated in figure 11-6. The natural behavioural change is shown for the “Susceptible 1” stage and the “Infected Asymptomatic” stage. It was assumed that the change following treatment would take place after the patient has been treated and that is why it is associated with the "Susceptible 1" behavioural change.

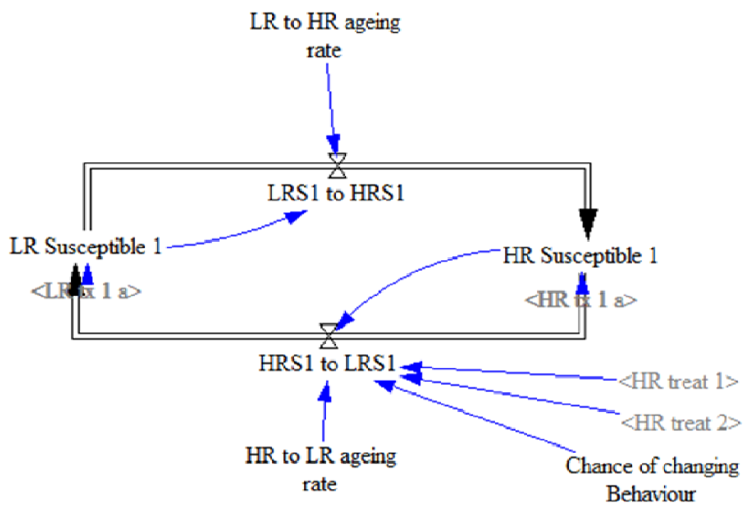

Figure 11-6: Behavioural change

In order to evaluate different screening strategies and combinations of other variables as well as being able to ascertain the number of people in each susceptible and infected stock, costs are always used to evaluate different strategies. Figure 11-7 illustrates how the costs are calculated in the model, where the different configurations can be compared. Essentially screening is cost effective when it reduces the number of cases of sequelae that can be developed.

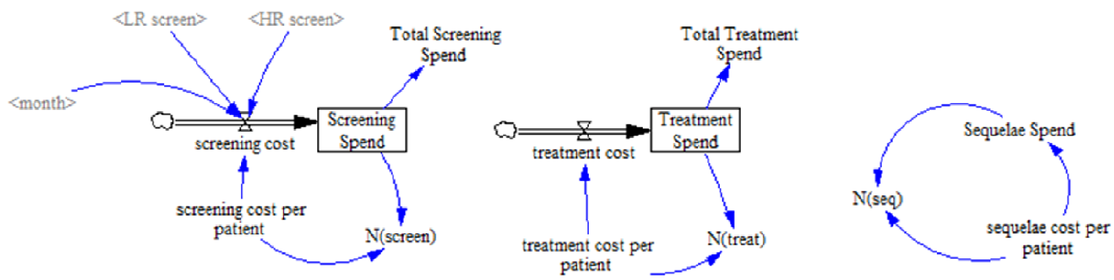

Figure 11-7: Costs

Contact tracing is an essential strategy in reducing the spread of every STI and other infections. As SD modelling does not operate at the individual level rather a higher aggregated level, contact tracing is calculated backwards, by using the contact rate and also the number of people in the stocks at that point in time to estimate the number of contacts. The process is illustrated in figure 11-8 for the contacts of the LR patients who are treated as a result of screening. This process is similar for the symptomatic patients and the corresponding asymptomatic and symptomatic patients in the HR group.

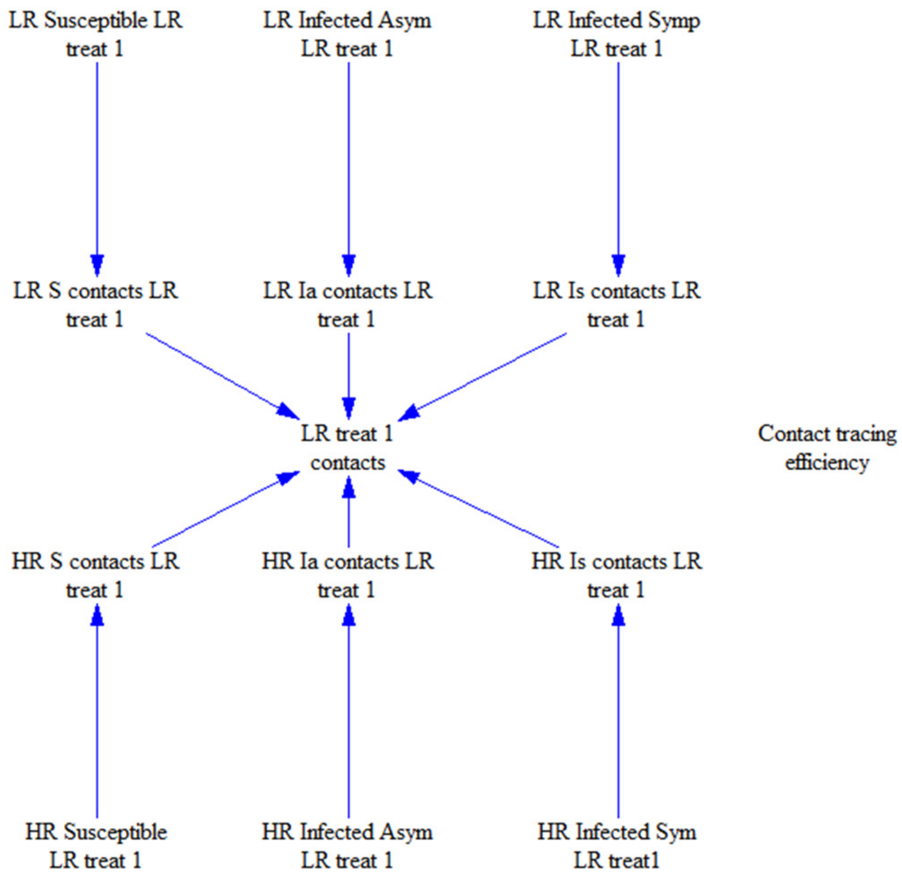

Figure 11-8: Contacts

Only a very brief overview of the views in the SD model has been provided. For a more detailed account see appendix U which includes the formulas associated with all of the variables in the model.

11.3.5 Interface and VBA

The interface developed for the operation of the DES GUM model discussed in part 10.3.7, was extended to allow the operation of the SD model. Figure 11-9 shows the two main screens from the interface related to the SD model. The interface can be found in appendix O. Unlike the DES model VENSIM does not have an equivalent to visual logic in Simul8 hence VBA is heavily used to operate the SD model. This is evident as there are over 9,000 lines of VBA to control the simulation.

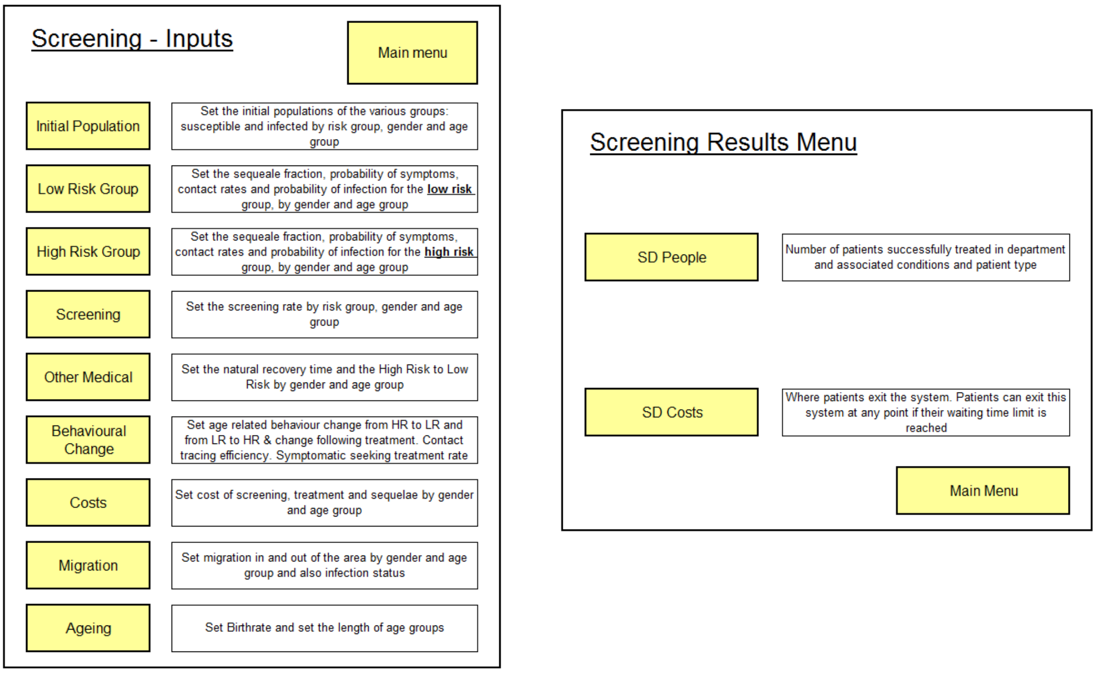

Figure 11-9: Selected elements from screening model from user interface

Seventeen sheets of the Excel interface are allocated for the SD model. More information about the interface and the associated VBA can be found in appendices I and P respectively.

11.3.6 Model Validation and Verification

The model was validated and verified in collaboration with Dr Harindra. Extreme value tests were performed. For example setting the contact rate very high and the probability of contracting Chlamydia very high and observing that the higher levels of Chlamydia in the population. The sensitivity analysis discussed in section 11.6 was part of the validation process and highlighted some interesting properties. Unlike the DES model there is no actual data to validate the model to, as the underlying prevalence of Chlamydia is unknown due to the fact that it is a largely asymptomatic condition, but the underlying model effects which can be predicted can be checked to see if this happens.

11.4 Base Model Parameters

The model consists of a total of 242 variables. 51 are solely parameters and 191 are equation related. What follows in table 11-2 is a selection of the key base parameters which were agreed with the healthcare stakeholders. The 51 variables which are parameters contain 629 values due to the age and gender subscripts. For a full description of the base level parameters and the equation variables see appendix V As the true underlying prevalence of Chlamydia is unknown parameters are based on estimated figures from the literature as well as building on expert opinion.

LR Susceptible 1

	Age1	Age2	Age3	Age4
Female	5,084.87	8,122.31	14,681.50	13,979.50
Male	4,686.89	7,443.33	14,475.40	13,460.60

LR Susceptible 2

	Age1	Age2	Age3	Age4
Female	0.00	0.00	0.00	0.00
Male	0.00	0.00	0.00	0.00

LR Infected A

	Age1	Age2	Age3	Age4
Female	442.10	706.29	299.62	141.21
Male	407.56	647.25	295.42	135.97

LR Infected S

	Age1	Age2	Age3	Age4
Female	0.00	0.00	0.00	0.00
Male	0.00	0.00	0.00	0.00

LR sequelae fraction

	Age1	Age2	Age3	Age4
Female	0.25	0.25	0.25	0.25
Male	0.50	0.50	0.50	0.50

LR prob of Symptoms

	Age1	Age2	Age3	Age4
Female	0.25	0.25	0.25	0.25
Male	0.50	0.50	0.50	0.50

Average time in cohort

	Age1	Age2	Age3	Age4
Female	48	60	120	120
Male	48	60	120	120

Birthrate

Female	347.26
Male	375.76

LR Probability of Infection

		Contact female			
	Age Group	Age1	Age2	Age3	Age4
Index male	Age1	1.0000	1.0000	1.0000	1.0000
	Age2	1.0000	1.0000	1.0000	1.0000
	Age3	1.0000	1.0000	1.0000	1.0000
	Age4	1.0000	1.0000	1.0000	1.0000

Mean time to recovery

	Age1	Age2	Age3	Age4
Female	30	30	30	30
Male	30	30	30	30

LR Screen

	Age1	Age2	Age3	Age4
Female	0.20	0.20	0.00	0.00
Male	0.00	0.00	0.00	0.00

Screening cost per patient

	Age1	Age2	Age3	Age4
Female	20	20	20	20
Male	20	20	20	20

Treatment cost per patient

	Age1	Age2	Age3	Age4
Female	20	20	20	20
Male	20	20	20	20

Sequelae cost per patient

	Age1	Age2	Age3	Age4
Female	2000	2000	2000	2000
Male	80	80	80	80

Table 11-2: Selection of SD base model parameters

Many of the parameter values illustrated in table 11-2 follow a matrix structure with the gender subscript represented by the rows and the age subscript as the columns. Where the variable begins with LR there is also a corresponding HR variable. Other variables include single values which apply to both genders and all age groups: Contact Tracing Efficiency, Probability of presenting for treatment if exhibit symptoms; and also other matrices for contact rates between genders and age group which differ from those previously described include the contact gender and age represented on the rows and the partner gender and age represented as the columns. There are 16 matrices of this type for the 4 gender potential contacts (Female-Male, Male-Female, Female-Female and Male-Male), these are then replicated for the HR group and then 4 more which represent the contact rate between the HR and LR groups. The values that the parameters can take are either absolute numbers, e.g. months, numbers of births, initial population sizes, costs or probabilities, e.g. contact rates, screening rates etc. All the parameter values and the equations are provided with a detailed explanation in appendix U.

11.5 Experimental Design and Results

The experimental design for the SD model differed substantially from the DES design. Part 11.5.1 discusses the experimental design. The remaining parts discuss the results of the key experiments devised. In total including the runs of the model for sensitivity analysis discussed in section 11.6, the parameters in the model were adjusted for the various experiments 1,573 times. The model itself would take under a minute to run however the exporting of results from the VENSIM software to Excel would take a couple of minutes.

11.5.1 Experimental Design in Collaboration with Experts

Unlike the DES GUM model in chapter 10 see part 10.6.1 the design of even a fractional factorial experiment was extremely difficult given the number of variables and the number of interactions possible. As such the experimental design was dictated by expert opinion with experiments conducted that the healthcare stakeholders viewed as being important to investigate in the real world. The remaining parts of section 11.5 relate to the experiments identified by the experts including:

11.5.2 Screening Younger Age Groups with Contact Tracing

Currently government policy in the UK implemented by the NCSP and in many other countries is to focus screening on young women and men aged under 25 as this group carries the majority of the risk as the consequences are more detrimental particularly for women. A popular method for screening men is through contact tracing, and although screening of men through other methods has improved some argue (Ginocchio et al, 2003) that as young men are a difficult group to engage with in terms of health care that more effective contact tracing is the way forward.

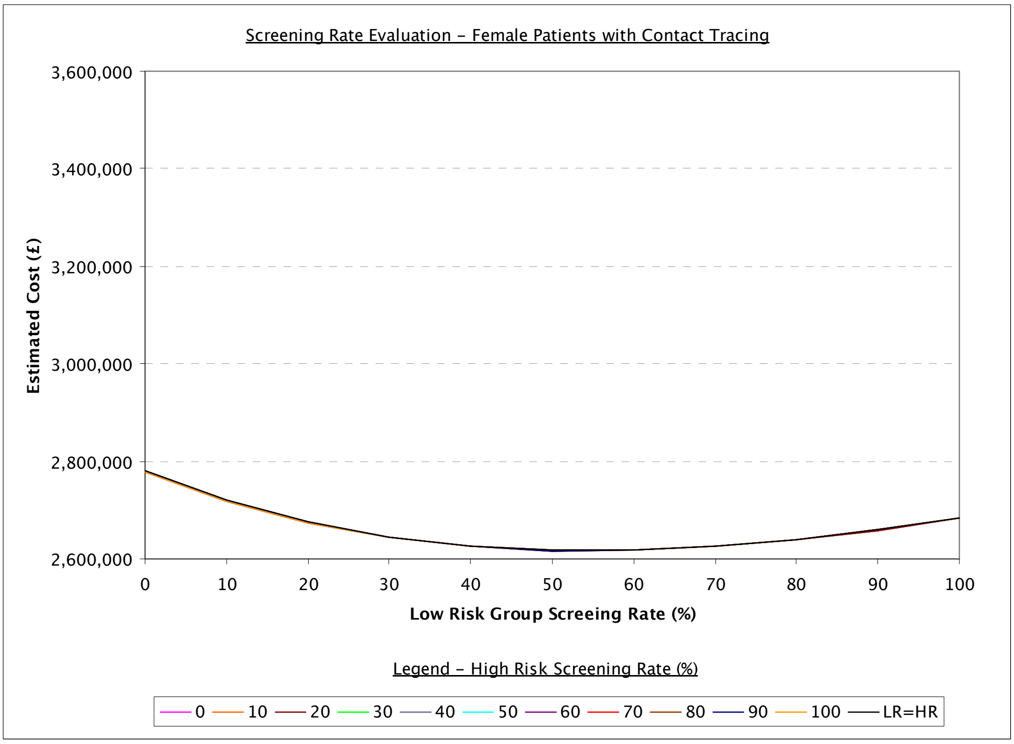

Figure 11-10: Screening female patients under 25 with 60% contact tracing efficiency

Figure 11-10 shows the "Estimated cost" of Chlamydia for different screening rates of the two female risk groups with 60% contact tracing. The 60% contact tracing refers to 60% of index female (male) partners being traced. The "Estimated cost" of Chlamydia in this research relates to the total costs of Chlamydia: the screening costs, the treatment costs and the sequelae costs. The x-axis represents the low risk group screening rate and the legend underneath the x-axis represents the high risk screening rate. The graph illustrates that as screening increases the savings made increase up to a point (around 60%) this is far higher than the government's target of 20% but is very much dependent on the underlying prevalence in the population derived from discussion with the stakeholders, and this is explored further in the sensitivity analysis provided in section 11.6. What is not clear from the graph is that by increasing the screening rate of the high risk group shifts the lines representing the increase in the screening rate of the high risk groups closer to the x-axis indicating a greater saving. The scales of the remaining graphs in section 11.5 are the same to allow comparison of the different screening strategies, which makes distinguishing the different levels of screening the HR group indicated by the different coloured lines in figure 11-10 difficult as it appears that there is only one line on the graph. Table 11-3 contains the data used to plot the graph plotted in figure 11-10. It has been provided to provide clarification of the figure 11-10 and can be found below.

Screening	HR – 0	HR – 10	HR – 20	HR – 30	HR – 40	HR – 50	HR – 60	HR – 70	HR – 80	HR – 90	HR – 100	LR=HR
LR – 0	2,780,866	2,780,502	2,780,181	2,779,897	2,779,646	2,779,425	2,779,228	2,779,054	2,778,901	2,778,767	2,778,649	2,780,866
LR –10	2,720,296	2,719,983	2,719,711	2,719,471	2,719,261	2,719,078	2,718,916	2,718,776	2,718,655	2,718,549	2,718,459	2,719,983
LR – 20	2,675,805	2,675,543	2,675,316	2,675,118	2,674,948	2,674,801	2,674,675	2,674,566	2,674,475	2,674,400	2,674,337	2,675,316
LR – 30	2,645,091	2,644,876	2,644,693	2,644,538	2,644,405	2,644,294	2,644,201	2,644,125	2,644,064	2,644,016	2,643,980	2,644,538
LR – 40	2,626,198	2,626,030	2,625,889	2,625,771	2,625,676	2,625,599	2,625,539	2,625,493	2,625,461	2,625,442	2,625,432	2,625,676
LR – 50	2,617,464	2,617,339	2,617,238	2,617,159	2,617,099	2,617,055	2,617,026	2,617,010	2,617,005	2,617,012	2,617,029	2,617,055
LR – 60	2,617,476	2,617,391	2,617,329	2,617,286	2,617,260	2,617,247	2,617,248	2,617,261	2,617,284	2,617,317	2,617,358	2,617,248
LR – 70	2,625,029	2,624,984	2,624,958	2,624,950	2,624,955	2,624,973	2,625,003	2,625,043	2,625,092	2,625,149	2,625,214	2,625,043
LR – 80	2,639,099	2,639,092	2,639,101	2,639,125	2,639,162	2,639,209	2,639,266	2,639,332	2,639,406	2,639,488	2,639,575	2,639,406
LR – 90	2,658,814	2,658,843	2,658,885	2,658,940	2,659,006	2,659,080	2,659,164	2,659,255	2,659,353	2,659,457	2,659,567	2,659,457
LR – 100	2,683,428	2,683,490	2,683,564	2,683,649	2,683,742	2,683,844	2,683,952	2,684,068	2,684,187	2,684,314	2,684,444	2,684,444

Table 11-3: Screening female patients under 25 with 60% contact tracing efficiency

11.5.3 Screening All Women with Contact Tracing

An alternative strategy is to screen all women as the consequences of untreated Chlamydia infection are much more severe. The results of this screening strategy are displayed in figure 11-11.

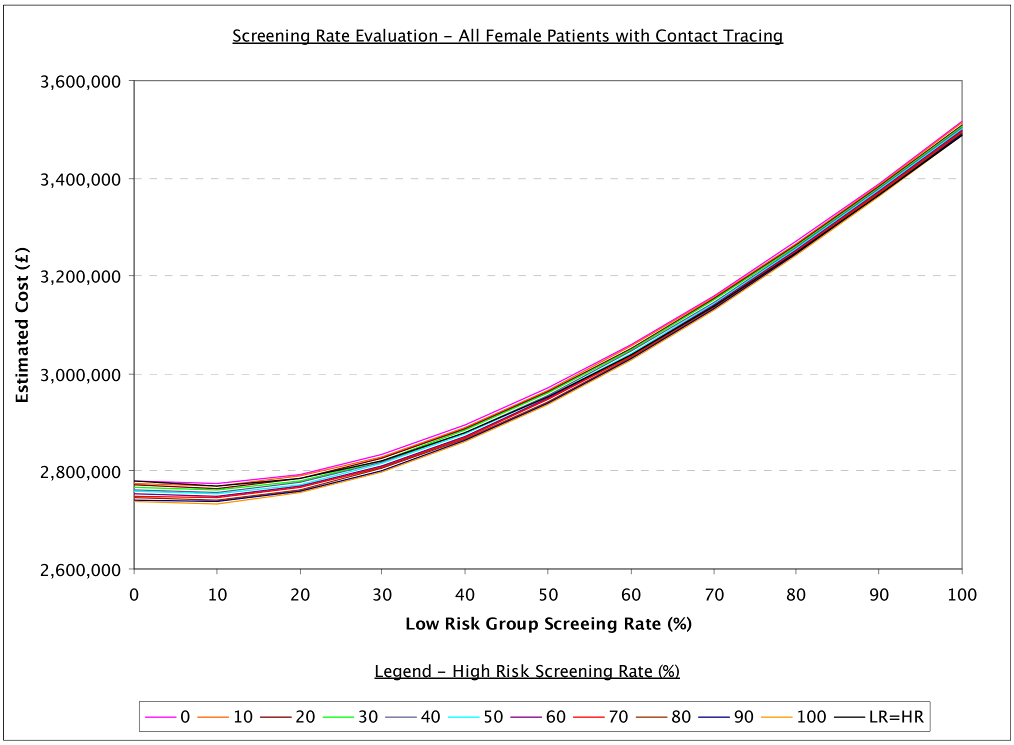

Figure 11-11: Screening all female patients with 60% contact tracing efficiency

Table 11-4 contains the data used to plot the graph plotted in figure 11-11. It has been provided to provide clarification of the figure 11-11 and can be found below.

Screening	HR – 0	HR – 10	HR – 20	HR – 30	HR – 40	HR – 50	HR – 60	HR – 70	HR – 80	HR – 90	HR – 100	LR=HR
LR – 0	2,780,866	2,775,956	2,771,239	2,766,691	2,762,294	2,758,033	2,753,897	2,749,876	2,745,962	2,742,148	2,738,429	2,780,866
LR –10	2,774,740	2,770,082	2,765,604	2,761,284	2,757,103	2,753,050	2,749,114	2,745,284	2,741,554	2,737,917	2,734,368	2,770,082
LR – 20	2,794,130	2,789,707	2,785,452	2,781,344	2,777,366	2,773,509	2,769,758	2,766,108	2,762,550	2,759,080	2,755,691	2,785,452
LR – 30	2,835,242	2,831,040	2,826,993	2,823,084	2,819,297	2,815,620	2,812,045	2,808,562	2,805,165	2,801,850	2,798,612	2,823,084
LR – 40	2,894,876	2,890,879	2,887,027	2,883,304	2,879,694	2,876,188	2,872,775	2,869,450	2,866,204	2,863,035	2,859,937	2,879,694
LR – 50	2,970,320	2,966,515	2,962,846	2,959,297	2,955,854	2,952,506	2,949,247	2,946,068	2,942,964	2,939,931	2,936,965	2,952,506
LR – 60	3,059,286	3,055,660	3,052,162	3,048,775	3,045,488	3,042,290	3,039,174	3,036,132	3,033,161	3,030,256	3,027,413	3,039,174
LR – 70	3,159,834	3,156,377	3,153,038	3,149,804	3,146,662	3,143,605	3,140,621	3,137,710	3,134,863	3,132,077	3,129,350	3,137,710
LR – 80	3,270,323	3,267,022	3,263,834	3,260,742	3,257,738	3,254,811	3,251,954	3,249,162	3,246,432	3,243,760	3,241,139	3,246,432
LR – 90	3,389,360	3,386,207	3,383,159	3,380,203	3,377,326	3,374,521	3,371,782	3,369,104	3,366,483	3,363,915	3,361,397	3,363,915
LR – 100	3,515,765	3,512,752	3,509,836	3,507,004	3,504,248	3,501,558	3,498,931	3,496,359	3,493,840	3,491,371	3,488,949	3,488,949

Table 11-4: Screening all female patients with 60% contact tracing efficiency

There is a clear difference between screening those women under 25 and all women in our population. As Chlamydia prevalence is assumed to be less in the older age groups and the contact rate is also less the chance of those women in the older age groups developing sequelae are reduced and hence the increase in cost which is a result of the higher number of women screened. What can be seen from the graph however is the same process that was unclear in the previous figure 11-10, that increasing the screening rate in the high risk groups dominates the “same rate for all” approach – further supporting the notion that targeted screening is less costly and that the enormous costs of such a screening programme totally outweigh any benefits from preventing sequelae.

11.5.4 Screening Both Genders with Contact Tracing

To build upon the experiments conducted on screening those women under 25 whilst contacting men primarily through contact tracing (part 11.5.2) the impact of screening both men and women aged under 25 was also investigated. Figure 11-12 illustrates the results of these experiments. What can be seen is that there are initial savings up to screening to the 30% level but the savings achieved are not superior to those achieved by focussing screening on women only.

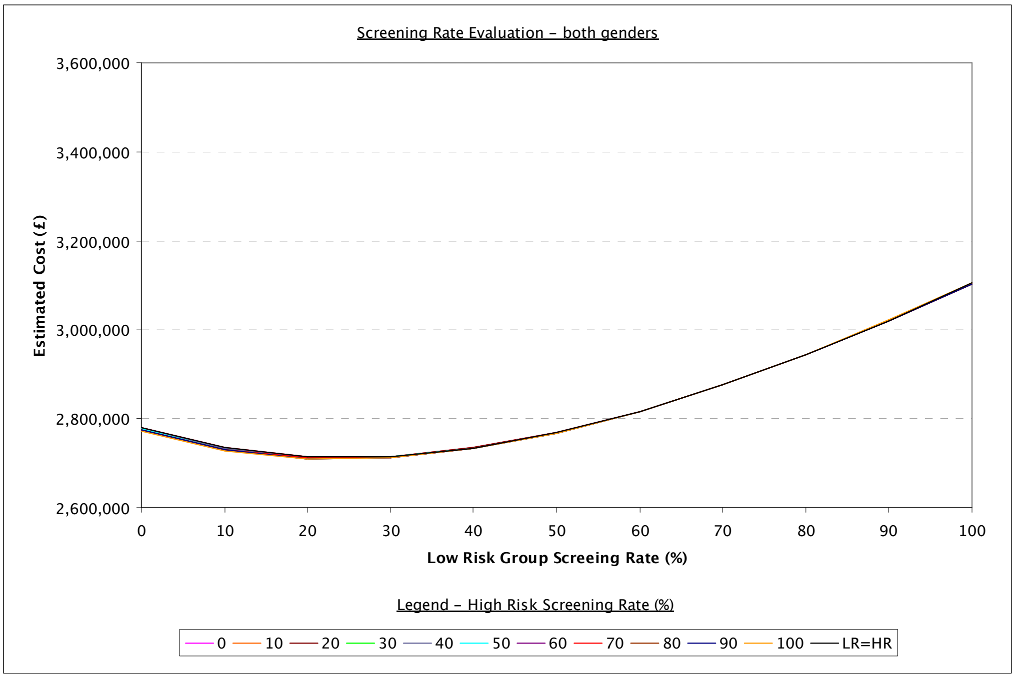

Figure 11-12: Screening all people under 25 with 60% contact tracing efficiency

Table 11-5 contains the data used to plot the graph plotted in figure 11-12. It has been provided to provide clarification of the figure 11-12 and can be found below.

Screening	HR – 0	HR – 10	HR – 20	HR – 30	HR – 40	HR – 50	HR – 60	HR – 70	HR – 80	HR – 90	HR – 100	HR-LR
LR – 0	2,780,904	2,779,747	2,778,696	2,777,727	2,776,831	2,775,999	2,775,227	2,774,515	2,773,858	2,773,256	2,772,708	2,780,904
LR – 10	2,735,157	2,734,244	2,733,407	2,732,628	2,731,902	2,731,224	2,730,594	2,730,009	2,729,471	2,728,979	2,728,531	2,734,244
LR – 20	2,714,776	2,714,082	2,713,438	2,712,830	2,712,257	2,711,720	2,711,216	2,710,748	2,710,318	2,709,923	2,709,568	2,713,438
LR – 30	2,715,807	2,715,309	2,714,837	2,714,385	2,713,952	2,713,542	2,713,153	2,712,791	2,712,458	2,712,154	2,711,883	2,714,385
LR – 40	2,734,934	2,734,615	2,734,301	2,733,989	2,733,683	2,733,387	2,733,103	2,732,838	2,732,594	2,732,374	2,732,179	2,733,683
LR – 50	2,769,382	2,769,225	2,769,053	2,768,870	2,768,678	2,768,486	2,768,300	2,768,123	2,767,961	2,767,815	2,767,691	2,768,486
LR – 60	2,816,816	2,816,806	2,816,765	2,816,697	2,816,612	2,816,516	2,816,417	2,816,321	2,816,233	2,816,158	2,816,098	2,816,417
LR – 70	2,875,272	2,875,397	2,875,475	2,875,514	2,875,525	2,875,517	2,875,499	2,875,477	2,875,458	2,875,446	2,875,445	2,875,477
LR – 80	2,943,100	2,943,347	2,943,535	2,943,672	2,943,771	2,943,844	2,943,899	2,943,946	2,943,989	2,944,036	2,944,090	2,943,989
LR – 90	3,018,905	3,019,266	3,019,553	3,019,780	3,019,961	3,020,107	3,020,231	3,020,341	3,020,442	3,020,543	3,020,648	3,020,543
LR – 100	3,101,513	3,101,979	3,102,359	3,102,669	3,102,924	3,103,140	3,103,325	3,103,493	3,103,649	3,103,799	3,103,951	3,103,951

Table 11-5: Screening all people under 25 with 60% contact tracing efficiency

The same process as observed in the previous experiments by targeting the screening in the high risk group greater savings can be made was apparent in these experiments also.

The experiments suggest that given the underlying assumptions made in the base model that screening those women under 25 and contacting men via contact tracing is the least expensive strategy. However as many of the parameters in the base run have been determined by using estimates from the literature and incorporating expert opinion, a thorough sensitivity analysis will be conducted of the key parameters in the base model.

11.6 Sensitivity Analysis

This sensitivity analysis was essential to determine the effect of what the investigator and the healthcare stakeholders viewed as the key parameters in the model. The variables considered crucial were: the underlying Chlamydia prevalence, the size of the high and low risk groups, the probability of infection, the probability of developing sequelae and the costs associated with sequelae, screening and treatment. Univariate sensitivity analyses were conducted with the variables mentioned. The choice was made to analyse the variables in isolation given the extremely large combinations of variables that could potentially be analysed simultaneously. The results of the sensitivity analyses are discussed briefly in the following parts.

11.6.1 Chlamydia Prevalence

Chlamydia prevalence is the key variable in the model, it is also the most difficult to estimate as no one is entirely sure of the true value given that many cases are asymptomatic and can resolve naturally. Figure 11-13 illustrates the effect of different Chlamydia prevalence levels, indicated by the legend under the x-axis, on the estimated cost for different screening levels. To make the sensitivity analysis feasible screening here refers to screening both the LR and HR groups equally. To clarify, the Chlamydia prevalence levels under which are used in the sensitivity analysis relate to the two age groups under 25 for both genders with the Chlamydia prevalence for the 2 older groups remaining the same as in the base case. The screening in this case relates to the screening of the two under 25 female age groups with contact tracing with an effectiveness of 60%.

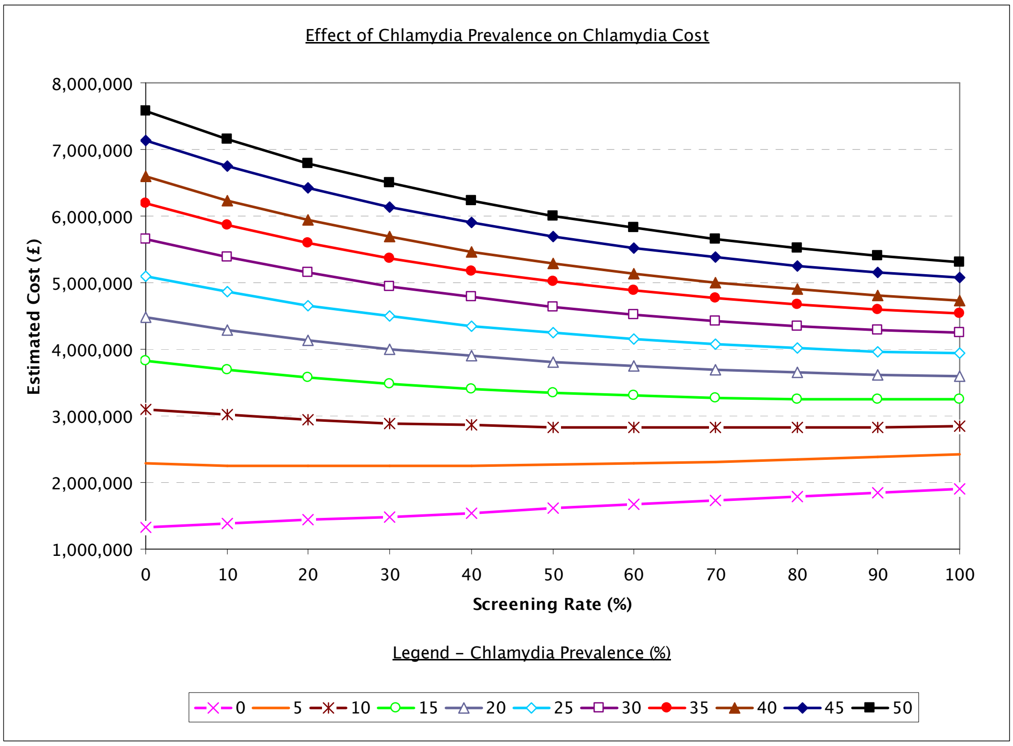

Figure 11-13: The effect of Chlamydia prevalence

Figure 11-13 demonstrates that as the Chlamydia prevalence increases screening becomes more cost effective, as indicated by the 20-50% prevalence lines in these cases universal screening would be the best option. Between 15-20% prevalence levels screening is cost effective up to a point becoming less effective as the screening levels increase. If screening levels are between 0-5% then the model suggests that Chlamydia screening is not beneficial.

11.6.2 High Risk Group Size

The experiments conducted in section 11.5 all suggest that targeted screening of the HR group (core group) leads to more cost effective outcomes. The second variable chosen therefore is the split of the population between HR and LR. In the base model the proportion of the population in the HR and LR groups was 3% and 2.2% for males and females respectively in the 4 age groups. The results from the sensitivity analysis of the high risk group size can be found in figure 11-14. The “High Risk” group size proportion of the population is indicated by the legend underneath the x-axis. The size of the group relate solely to the under 25 age group with the older two ages groups retaining the same high risk group proportion as in the base case. As with previous sensitivity analyses the screening rate refers to the screening rate of the low and high risk groups. What figure 11-14 illustrates is that the larger the proportion of the population who are HR result in a much greater cost as they have higher contact rates and as the model progresses the Chlamydia prevalence in this group maintains a very high level in comparison to the LR group, the interaction with the LR population also results in more sequelae developing in the LR population.

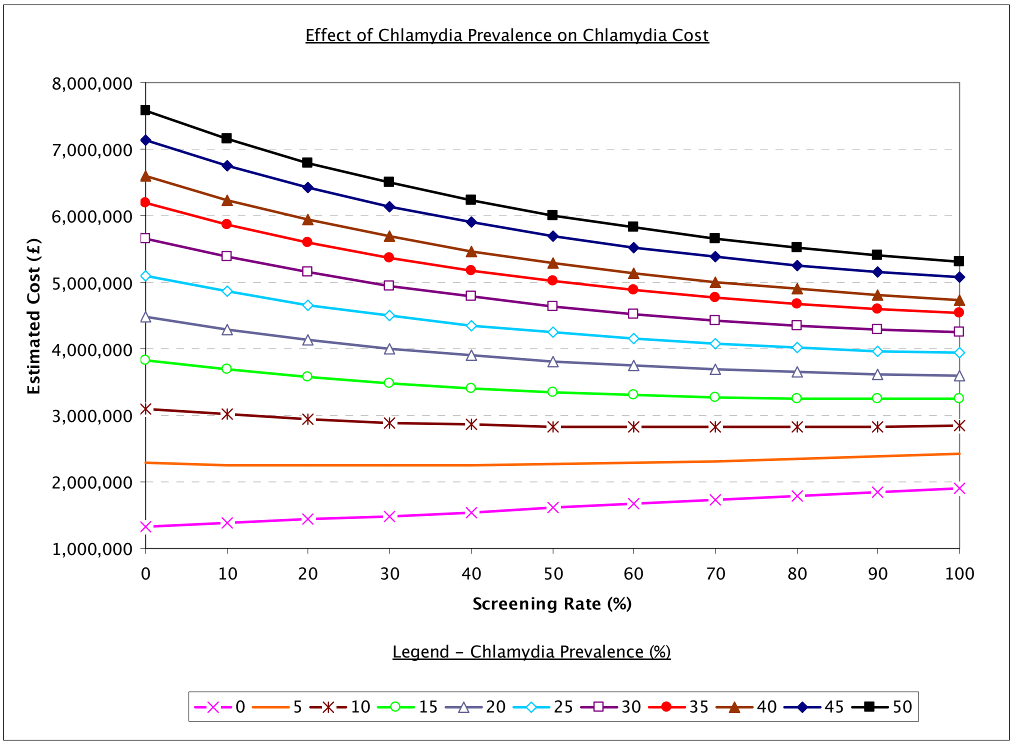

Figure 11-14: The effect of high risk group size

11.6.3 Probability of Infection

It is assumed in the base model and in the experiments in section 11.5 that the probability of infection following contact with a positive partner is 100%. However many papers dispute this fact (Adams et al, 2004; Low et al, 2006; Roberts et al, 2007; Roberts et al, 2004, Roberts et al, 2006; Turner et al, 2006) and in fact the probability of infection is much less. The probability of 100% infection was utilised as it was assumed that partnerships would consist of enough sexual interaction and last long enough to enable Chlamydia transmission. Figure 11-15 illustrates the effect varying the probability of infection to various levels shown in the legend beneath the x-axis with values between 0-100%. The analysis suggests that the probability of infection needs to be above 20% if any benefit from screening is to be maintained.

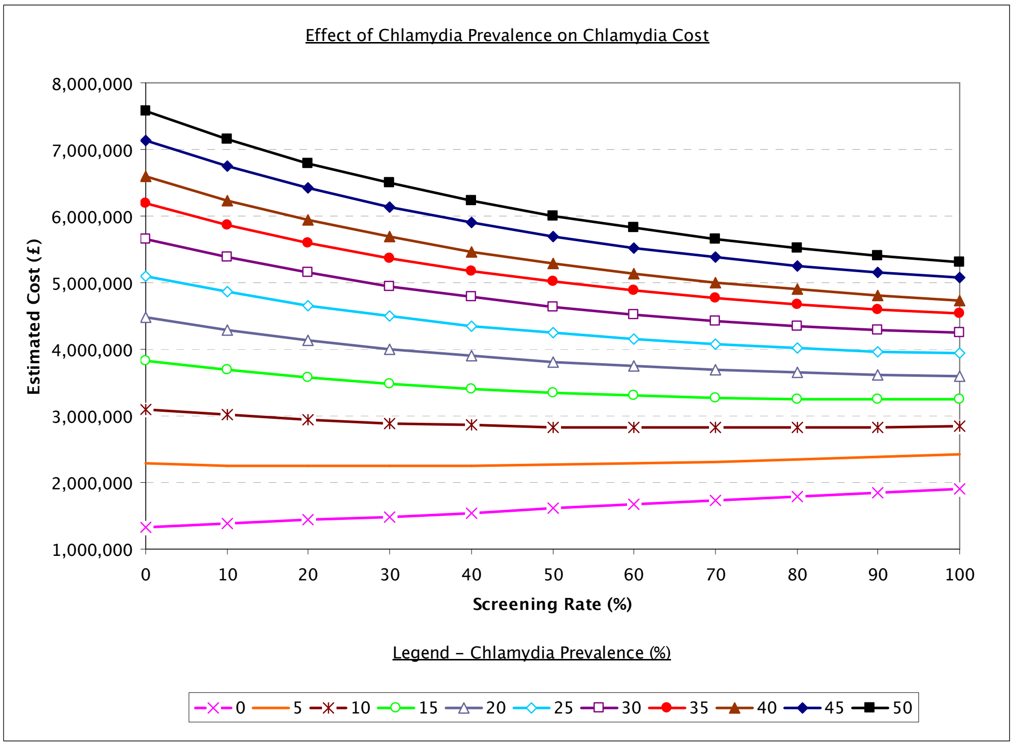

Figure 11-15: The effect of probability of infection

Once the probability of infection is over 20% then screening becomes beneficial and increased savings can be made once the probability approaches 100%. It should be noted that as the screening rate increases there comes a point, irrespective of the probability of infection, where no additional savings can be made and the screening programme becomes more expensive.

11.6.4 Sequelae Probability

Sequelae can potentially be extremely detrimental to women as previous discussed (see part 2.5.2). It is due to the fact that the consequences of Chlamydia can be so severe that many screening programs have been established. It is the cost saved from averting cases of sequelae that are offset against the screening and treatment cost and this is used to evaluate screening strategies. In the base model it was assumed that the probability of developing sequelae were 25% and 50% for females and males respectively. Female sequelae are more detrimental and expensive sensitivity analysis has been conducted examining the varying the effect of this probability. Figure 11-16 clearly indicates that as the probability of female sequelae increases (indicated by the legend under the x-axis) that screening becomes more viable.

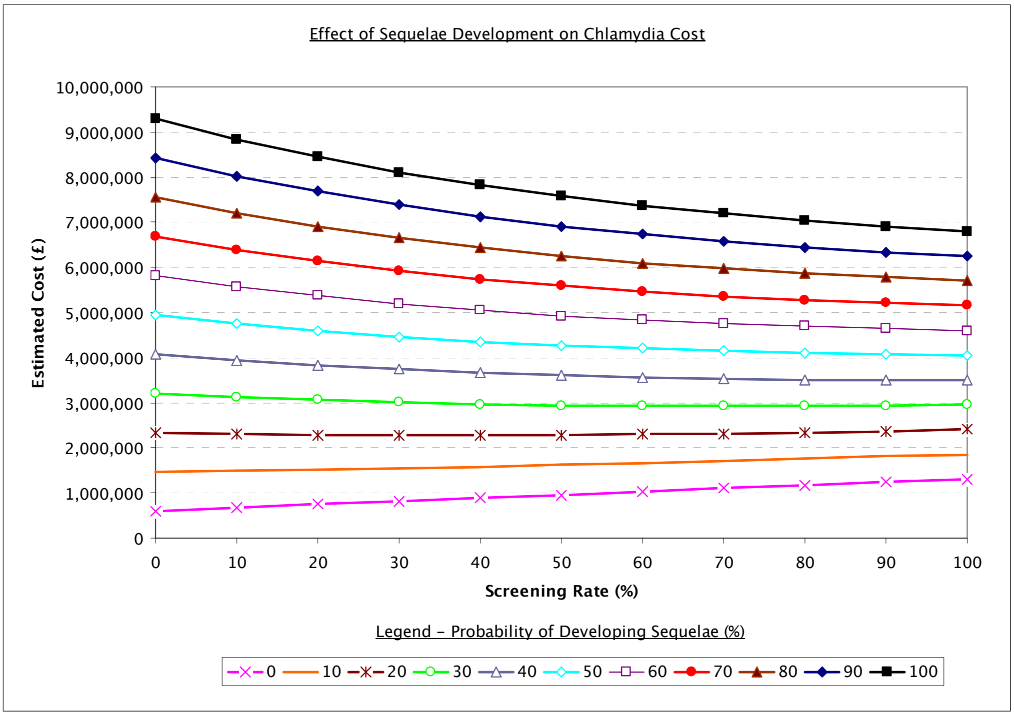

Figure 11-16: The effect of probability of developing sequelae

The analysis suggests that the probability of sequelae development needs to be greater than 20% if screening is to be considered beneficial.

11.6.5 Sequelae Cost

As discussed in the previous part sequelae are a key determinant of whether a screening programme is appropriate or not. As mentioned one of the key aspects of a Chlamydia screening programme is to reduce the cost of the sequelae which can develop as a consequence of untreated Chlamydia. It is assumed that the cost of Chlamydia given the potential serious nature of the outcomes for women can be very expensive and in many studies (Evenden et al, 2006; Evenden et al, 2005; Honey et al, 2002; Hart et al, 2002; Roberts et al, 2006) the cost of female sequelae is seen as a single point estimate. In the base study the cost of sequelae is estimated to be £2,000 with the male equivalent being £80. As a result sensitivity analysis was conducted on the cost of female sequelae and the results are displayed in figure 11-17.

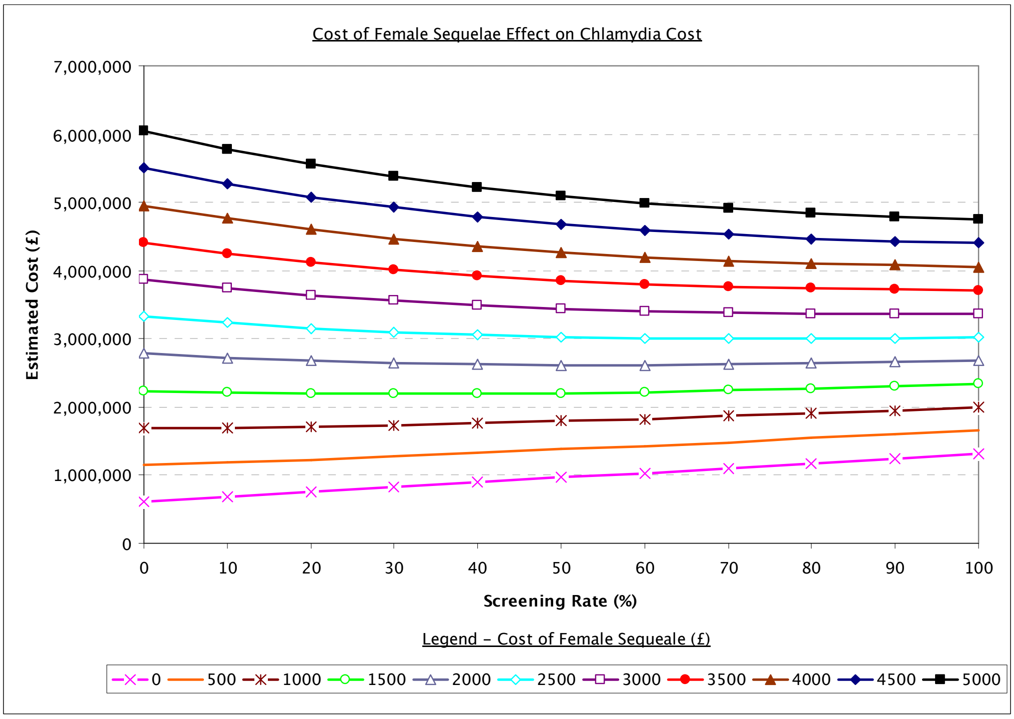

Figure 11-17: The effect of the cost of female sequelae

What is clear from the graph is that the potential costs of females developing sequelae have to be reasonably high before any benefit can be obtained from screening. The sensitivity analysis suggests that if the cost were less than £2,000 then the screening program would not be beneficial given the price of screening and treatment.

11.6.6 Screening Cost

The success of any screening programme is related to the costs required to implement it. It was assumed in the model that the cost of screening both females and males was £20 (Evenden et al 2006, Townshend et al 2000, NCSP, 2011). Figure 11-8 highlights the effect of varying the screening cost between £0 and £50, with all over parameters remaining at base case levels. It can be seen that screening ceased to be viable once the screening cost reached £30.

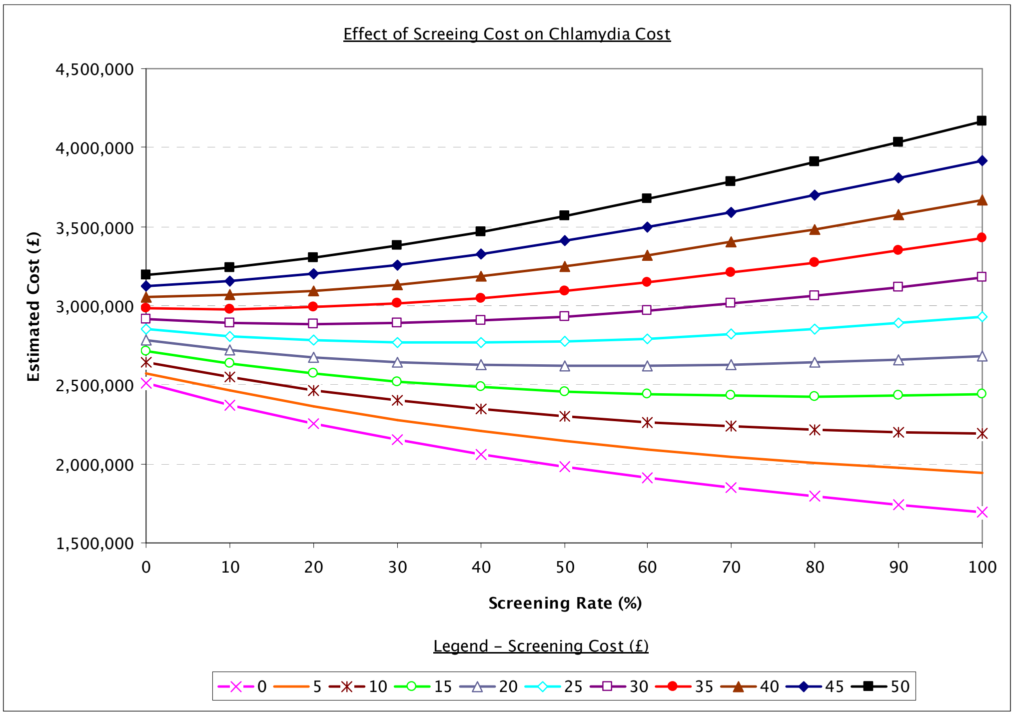

Figure 11-18: The effect of screening cost

11.6.7 Treatment Cost

Closely associated with treatment cost is the treatment cost and like part 11.6.6 the price of treatment was varied between £0 and £50. Figure 11-19 demonstrates that if the other variables are kept at base rate levels that all of the experiments prove to follow the same cost pattern to a degree by producing the same shaped graphs, but the starting costs increase as the treatment costs increase.

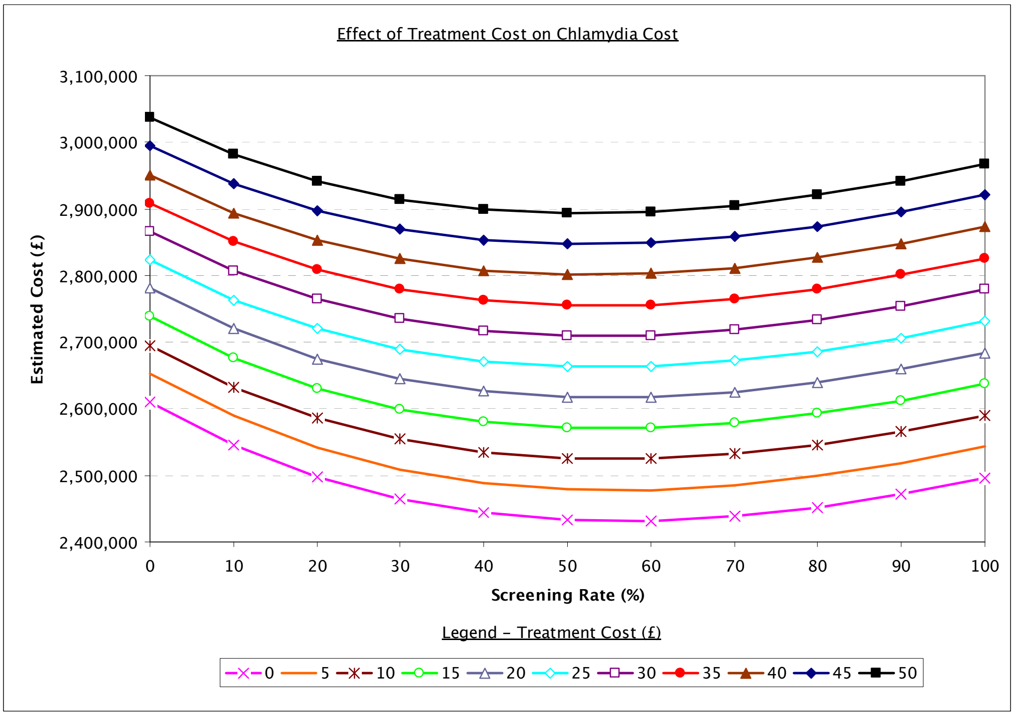

Figure 11-19: The effect of treatment cost

11.6.8 Contact Tracing

Contact tracing has been shown to be an effective method of screening by identifying a smaller group in this case male partners of positive female patients. However these people may be difficult to reach as it has been proven difficult to attract men to health care environments (Ginocchio et al, 2003), as such the efficiency of contact tracing in the base case was set to 60% which is ambitious. This part explores the effect on costs associated by altering this probability, with the results shown in figure 11-20. The results indicated that as contact tracing efficiency increased further savings were made. This is intuitive as rather than screening every male in the population under 25 those partners of positive females are identified and screened so a smaller population resulting in smaller screening and treatment costs. What could be interesting is screening males under the age of 25 with contact tracing, as 50% of men could develop symptoms and when seeking treatment female partners could be obtained through contact tracing. However as already stated the male population is less inclined to seek medical attention this may not be feasible.

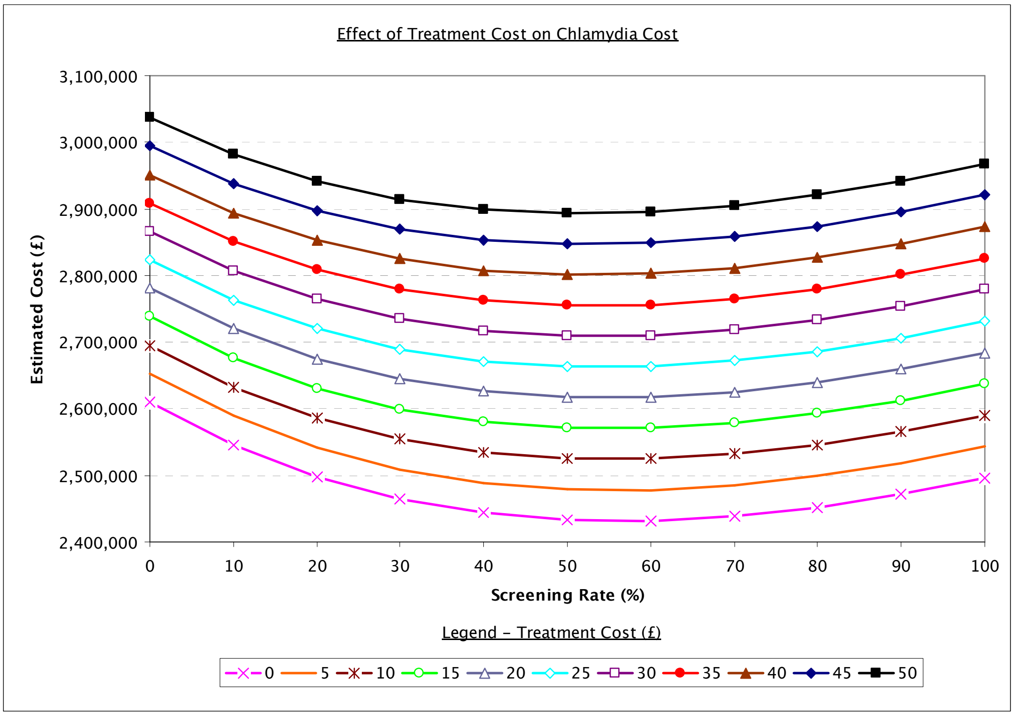

Figure 11-20: The effect of contact tracing efficiency

11.6.9 Behavioural Change Following Treatment

Behavioural change is one of the unique features of this Chlamydia screening model. Not only does it incorporate behavioural change over time but also behavioural change from HR to LR at discrete events i.e. following treatment. Figure 11-21 indicates the effect of different probabilities of changing behaviour following treatment. In the base case and the experiments the behavioural change probability following treatment was assumed to be 0. Figure 11-21 varies this parameter between 0 and 100%.

The graph clearly indicates that as the behavioural change probability increases the cost effectiveness of the screening improves. The behavioural aspect is an area that tends to be ignored when constructing screening models of this nature. This is partly due to the fact that defining a value for this variable is difficult and it is also influenced by politics and the view that we shouldn't tell people how to behave, however they should be given the information to make up their own mind whether to change their current sexual practices.

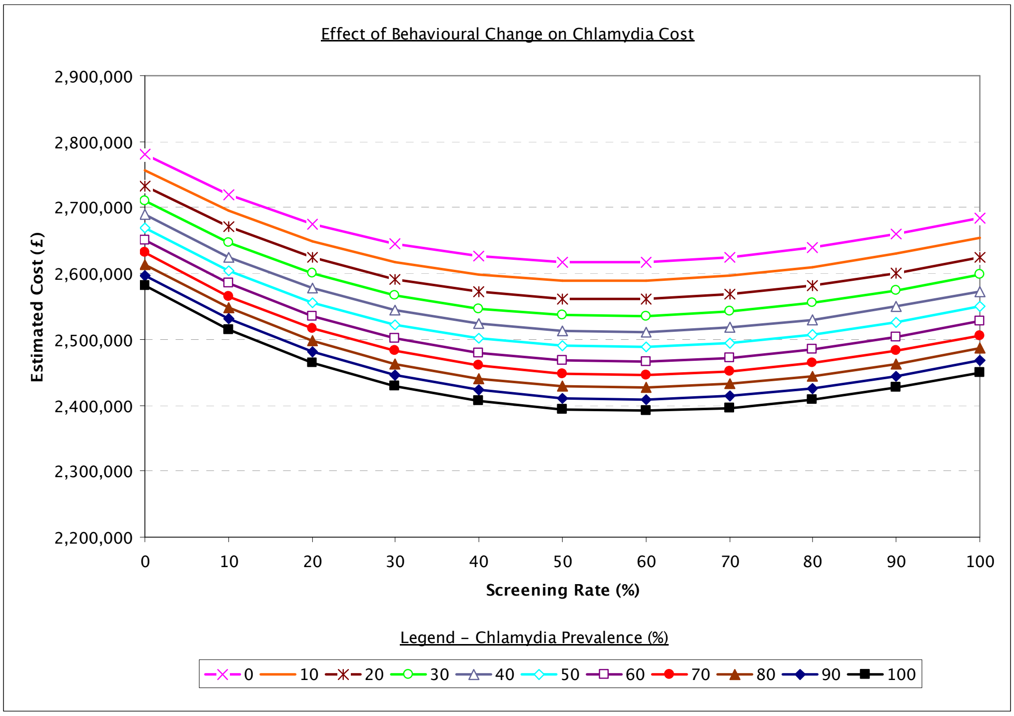

Figure 11-21: The effect of behavioural change following treatment

11.6.10 Symptomatic Patients Treatment Seeking Rate

This model has two infectious state possibilities: those who are infected and asymptomatic and those who are symptomatic. The model has built in a probability of 50% that those who are symptomatic seek treatment. Figure 11-22 examines the effects of varying this probability. What is evident from figure 11-22 is that if the probability of seeking treatment increased from 0% to 10% the model suggests that an immediate saving of £500k could be achieved without screening. As the probability increases further each increase dominates the previous level.

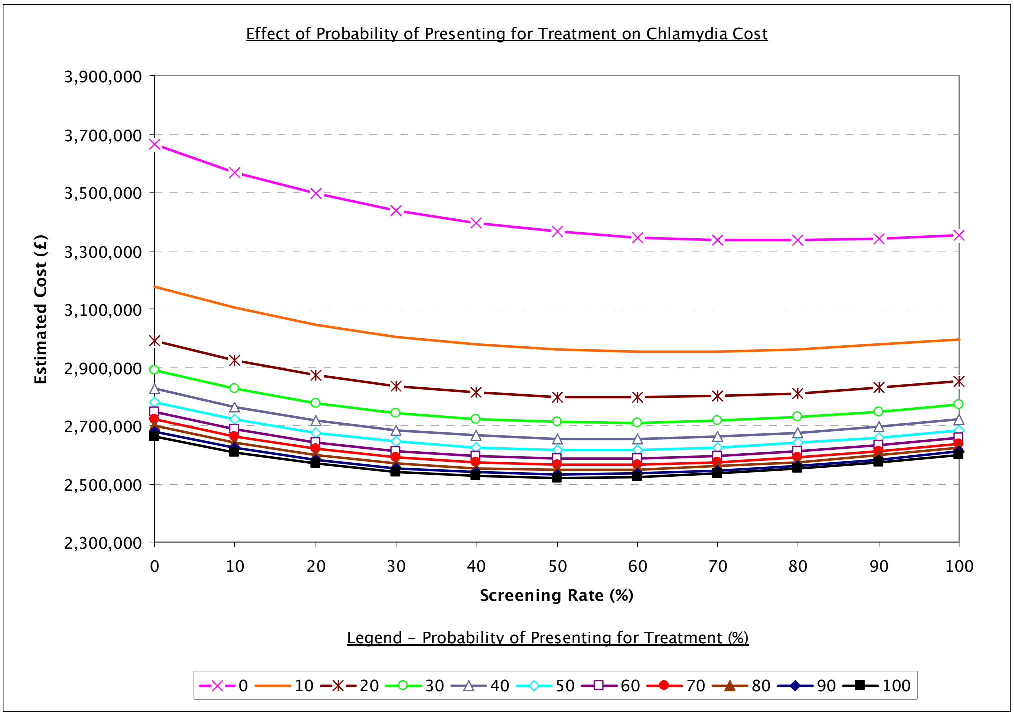

Figure 11-22: The effect of varying the probability of symptomatic people seeking treatment

11.7 Chapter Conclusions

The SD model constructed was very detailed and took a considerable time to conceive and to produce, however it does raise some interesting points:

1. The model suggests that screening those females under 25 and recruiting male partners through contact tracing is more effective than screening both genders.
2. Targeted screening of the high risk or "core group" is more effective than blanket screening.
3. The underlying prevalence of Chlamydia has to be sufficiently high to warrant screening.
4. The probability of developing and the cost of female sequelae have to be sufficiently high to warrant screening.
5. Behavioural evaluation or change though advice/counselling at treatment is an important strategy which may have been overlooked.

11.8 Chapter Summary

- This chapter summarised the SD model construction.
- The experimental structure as well as results was discussed.
- Sensitivity analysis was conducted as an essential exercise which highlighted some key points as well as aided in model validation and verification.

12 Composite Model

12.1 Research Tasks Addressed

T6. Can the developed DES and SD models be successfully integrated? Is the combination of DES and SD models in this healthcare context beneficial?

12.2 Chapter Introduction

This chapter provides the motivation for combining the DES GUM department model (chapter 10) and the SD Chlamydia Screening model (chapter 11), which addresses research question T6. How the models are combined is summarised and discussed. The aspects of the user interface developed to operate the combined approach are briefly discussed. The experimental design and the experimental results for the combined model are provided and evaluated. The chapter concludes with the key findings and evaluation of the new composite model.

12.3 Development of Composite Model

There were several reasons why a composite model was constructed:

1. Healthcare models tend to focus on a specific area and do not take into account the wider system, in terms of both upstream and downstream effects (see sections 4.2 to 4.8). The wider system can be incorporated in the composite model.

2. Detailed DES and SD models were constructed as part of this research so their design was amended slightly to allow them to communicate with one another.

3. Models of different levels can interact and have been constructed in other industries specifically to do this (see section 4.9). Why can't the principle be applied to healthcare?

Several other researchers known to the author were conducting work investigating the combining simulation approaches in healthcare, including: Mitul Desai (University of Southampton), Kirandeep Chahal (Brunel University), Jennifer Morgan (University of Strathclyde) and Sonia Vanderby (University of Toronto). This suggests that interest in combining models in healthcare is growing. Each of these researchers approaches the topic from different angles and where available papers have already been cited in the literature review see part 4.9.5.

An overview of how the models communicate with one another is provided in figure 12-1. The SD Chlamydia screening model (see chapter 11) generates the monthly demand for the DES GUM department model (see chapter 10). The DES model processes this demand based on the configuration of the GUM department and feeds back into the SD model the number of patients who were successfully treated. The DES model when the models are run in composite mode replaces the function/equation in the SD model which calculated the number of patients treated each time step (DT).

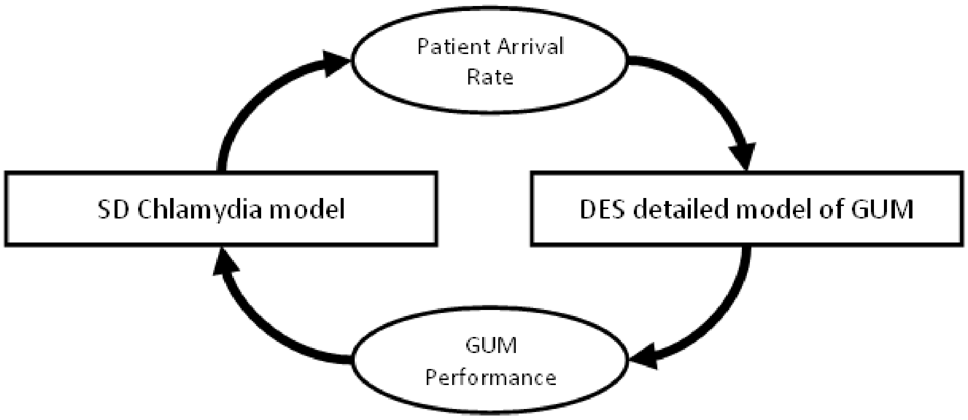

Figure 12-1: Overview of composite approach

Details of how this was achieved technically will be discussed here and is graphically displayed in figure 12-2. Each DT the SD model generates the number of patients available for treatment. The number of patients is then manipulated in the Excel user interface into a monthly arrival pattern. This arrival pattern is then used in the DES model, based on historical arrival patterns. The DES model imports the arrival profile as well as the variables representing the configuration of the department for that month. A trial of the DES model is conducted consisting of 20 runs. The results from the DES model are automatically exported from the DES model to the user interface. The results are then manipulated and fed back into the SD model before proceeding to the next DT incorporating the results from the DES model as the number of patients treated. The process was fully automated. The final composite model utilised a semi-automated approach to allow additional results and checks to be performed on the models manually, as they were running. The user controls when the models interact.

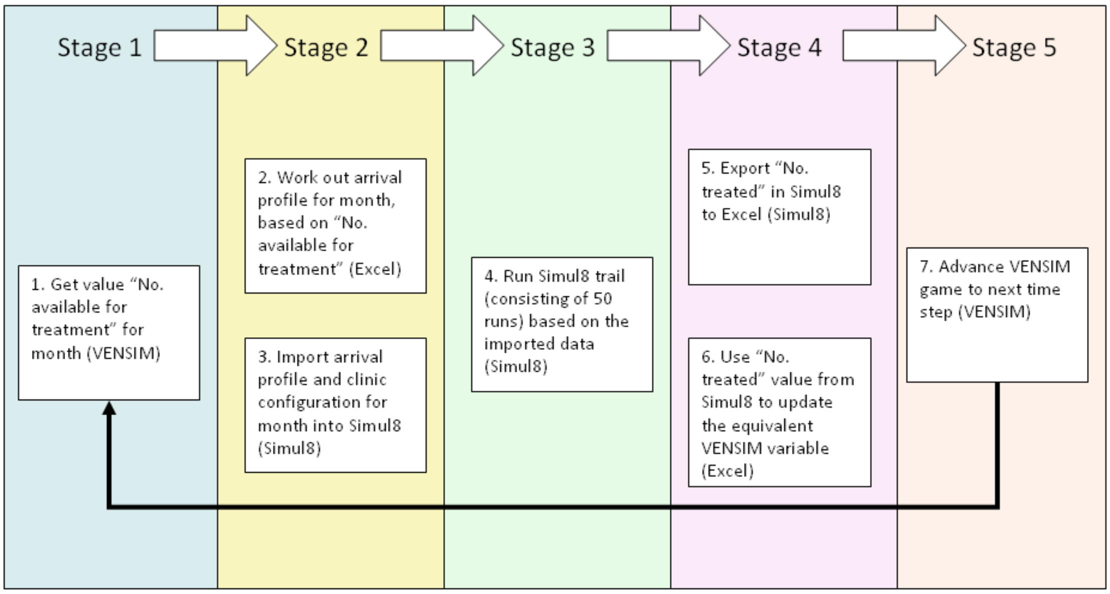

Figure 12-2: Stages involved in linking the SD and DES models

By combining the models potentially greater stakeholder "buy in" with both of the models was achieved. The "SD only" model calculated the number of patients treated using a variety of functions. The composite model replaced these functions with the DES model which had been approved and accepted by the stakeholders. The DES model benefited from the feedback aspect that the SD model provided.

12.4 Interface and Additions to the SD Model

The composite model used the same user interface developed for the SD and DES models (see appendix O). Three command buttons were added to the interface to allow control of the composite model, see the right section of figure 12-3. The VBA used to link the composite model operation consisted of 114 lines of VBA. The composite code was used in addition to the 11,000+ lines of VBA to control the SD model and the 10,000+ lines of visual logic (VL) to control the DES model to allow the user full control of the models. The VBA and the VL are provided in appendices P and S respectively.

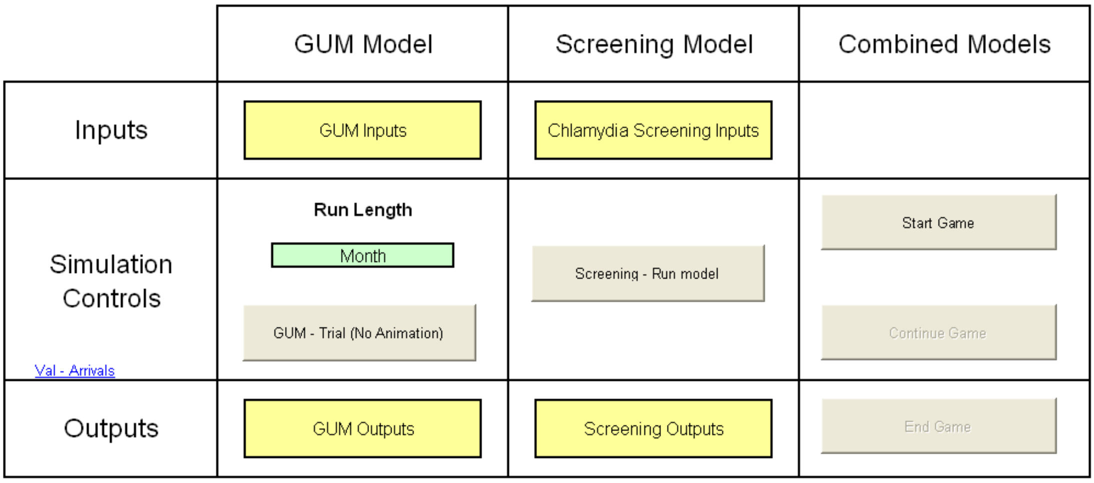

Figure 12-3: Screenshot of the specific composite related interface

The composite model required a small revision to the SD model with the DES model remaining the same as originally designed (chapter 10). The SD model had to be constructed as a "Game" model which is used to engage an individual with standard SD models. The game model enabled the person running the model to step through the model and make decisions regarding the value of the game variable(s) along the way to see what effect they have on the system. Examples of game models include: flight simulators and computer games.

Figure 12-4 illustrates the differences between the normal SD model and the game SD model. The values of the variables which are highlighted in green are combined to provide the arrival information for the DES model. The red highlighted variables which in the original non-game SD model were attached to the green variables are now detached and are the game variables. The game variables values are set as the outputs from the DES model.

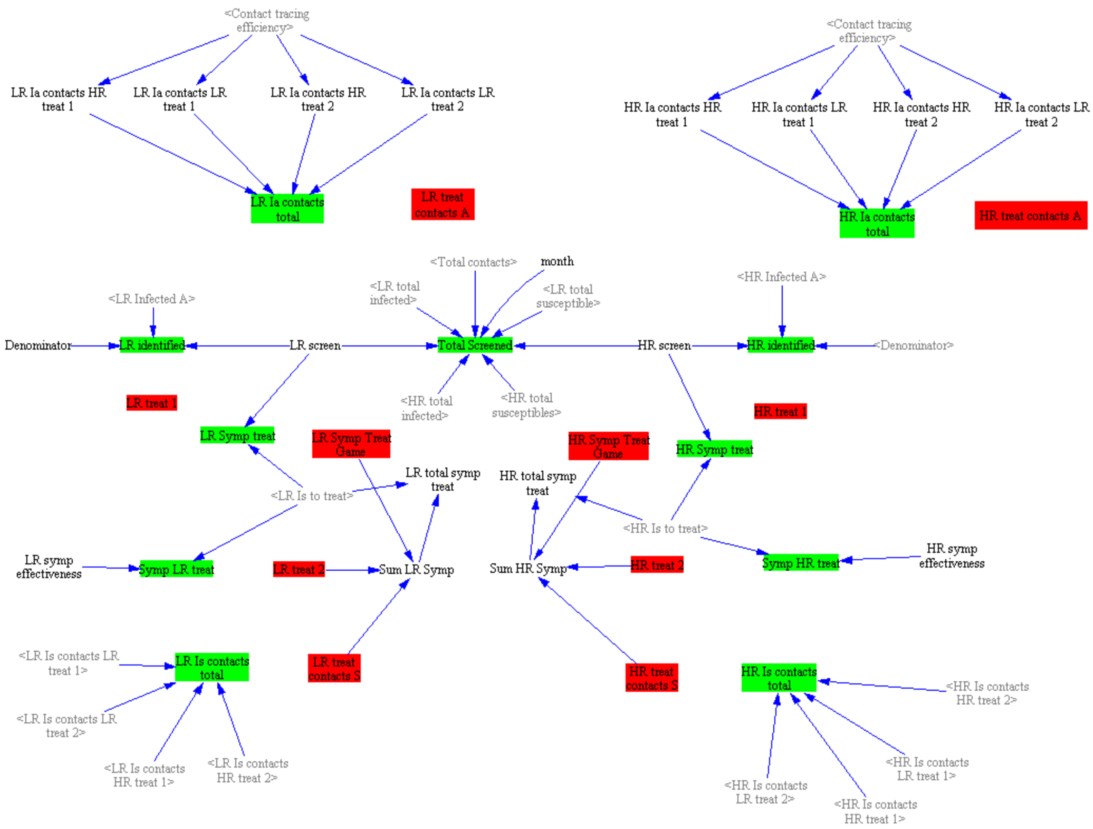

Figure 12-4: SD treatment view

12.5 Experiments

There were an extremely large number of potential experiments that could be conducted with the composite model. Therefore the experimental design was devised in close collaboration with the healthcare stakeholders. What follows in section 12.5 is: the rationale behind the experimental design chosen, discussed in part 12.5.1, the remaining parts discuss the results from the composite experiments in terms of both the models.

12.5.1 Experimental Design

The experimental design agreed with the stakeholders is discussed in relation to table 12-1 and table 12-2. Three experiments were proposed: “Base”, “Optimal” and “Max” in which the DES model parameters changed and the SD parameters and initial variable values remained constant. The “Base” experiment was based on a historical staff schedule and actual resources that the department had in June 2008. The “Optimal” experiment is based on the improved configuration discussed in chapter 10 (section 10.5), with “Base” and the “Optimal” model parameters can be found in appendix T. The “Max” experiment parameters are as expected the maximum for all the resources in the model resources. The waiting area was not changed in the experiments due to the space constraints in the department.

Table 12-1 provides a summary of the three experiments. In relation to the staff section of the table the values represent a variation of the full time equivalent (FTE) measure. In this case it is linked to the number of days E.g. the Example row in the table has a value of 5 for each of the staff and the department is open Monday to Friday so the table is saying that there is a person a day for each of these activities. The waiting area figures represent number of physical resources e.g. 40 chairs in the reception waiting area. As previously stated the experiments focus on the staff aspects of the department, with the number of staff in each area increasing apart from the Blood and Lab staff which had little effect on the number of patients who could be seen by the department – see chapter 10, with the waiting area resources remain constant.

	Staff					Waiting Areas				
	Reception	Female	Male	Blood	Lab	Reception	Standing	Female	Male	Shared
Example	***5.00***	***5.00***	***5.00***	***5.00***	***5.00***					
Base	14.91	10.50	7.73	4.75	4.75	40.00	10.00	10.00	10.00	No
Optimal	28.48	14.24	14.24	4.75	4.75	40.00	10.00	10.00	10.00	Yes
Max	47.46	47.46	47.46	4.75	4.75	40.00	10.00	10.00	10.00	Yes

Table 12-1: DES parameters for the three experiments

Selected SD model parameters and initial variable values are displayed in table 12-2. Many of the SD variables contain values which correspond to the gender and age of the population. For a complete description of the SD parameters and initial variable values see appendix W. The SD model's initial values were kept constant for each experiment and it was the variation of the DES model which influenced the SD results.

		Low Risk Group				High Risk Group			
		Age1	Age2	Age3	Age4	Age1	Age2	Age3	Age4
Susceptible 1	Female	5,084.87	8,122.31	14,681.50	13,979.50	114.38	182.71	330.25	314.46
	Male	4,686.89	7,443.33	14,475.40	13,460.60	144.96	230.20	447.68	416.31
Infected A	Female	442.10	706.29	299.62	141.21	9.95	15.89	6.74	3.18
	Male	407.56	647.25	295.42	135.97	12.61	20.02	9.14	4.21
Sequelae fraction	Female	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Male	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Prob Symptoms	Female	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Male	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mean time to Recovery	Female	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
	Male	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Screening Rate	Female	0.20	0.20	0.00	0.00	0.20	0.20	0.00	0.00
	Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Screening Cost	Female	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
	Male	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Treatment Cost	Female	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
	Male	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Sequeale Cost	Female	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00
	Male	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Average Time in Cohort	Female	48.00	60.00	120.00	120.00	48.00	60.00	120.00	120.00
	Male	48.00	60.00	120.00	120.00	48.00	60.00	120.00	120.00

Birthrate	Female	347.26
	Male	375.76

Contact Tracing Efficiency	0.6

Table 12-2: Selected SD parameters and initial variable values for composite experiments

12.5.2 Composite Results

The key results that the stakeholders were interested in were: the number of people who develop sequelae, the number of people infected and the number of people treated. These results are discussed briefly. The SD only model is compared with the three composite experiments in relation to each of the key results mentioned above. Figure 12-5 illustrates that the SD model is superior to the three composite experiments as fewer people developed sequelae. The results were as expected as the SD only model assumed that capacity was available to treat all the people who attended the department, the composite experiments with greater resources are closer to the idealised SD only model. The results of the composite experiments suggests that given the assumed underlying prevalence of Chlamydia and the other initial parameters, that if the local NHS trust managed to meet recommended screening rates, they could not be able to prevent the maximum number of sequelae possible if sufficient resources were not available. This is illustrated by the gap between the Vensim only and “Max” results with the “Base” results.

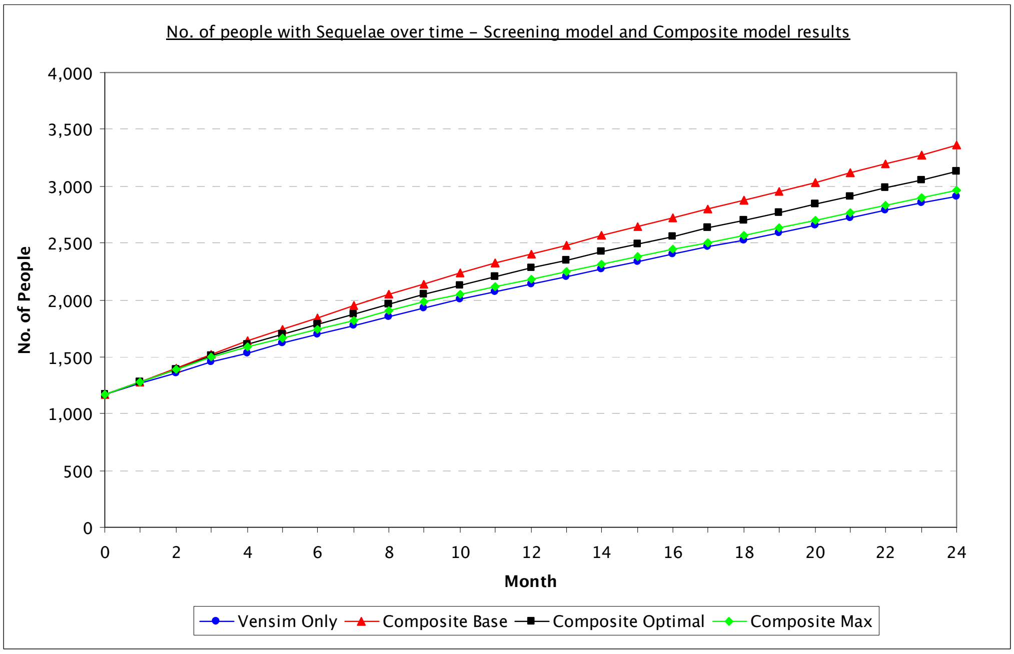

Figure 12-5: Sequelae Incidence by month comparing Composite and SD only models

Figure 12-6 represents the total number of people infected over time. Unsurprisingly it follows the same pattern as figure 12-5, with the SD only model resulting in the fewest number of people becoming infected. The same pattern is exhibited so that the more resources available the closer to the SD only model the results are. The greater the number of resources available the fewer people are infected.

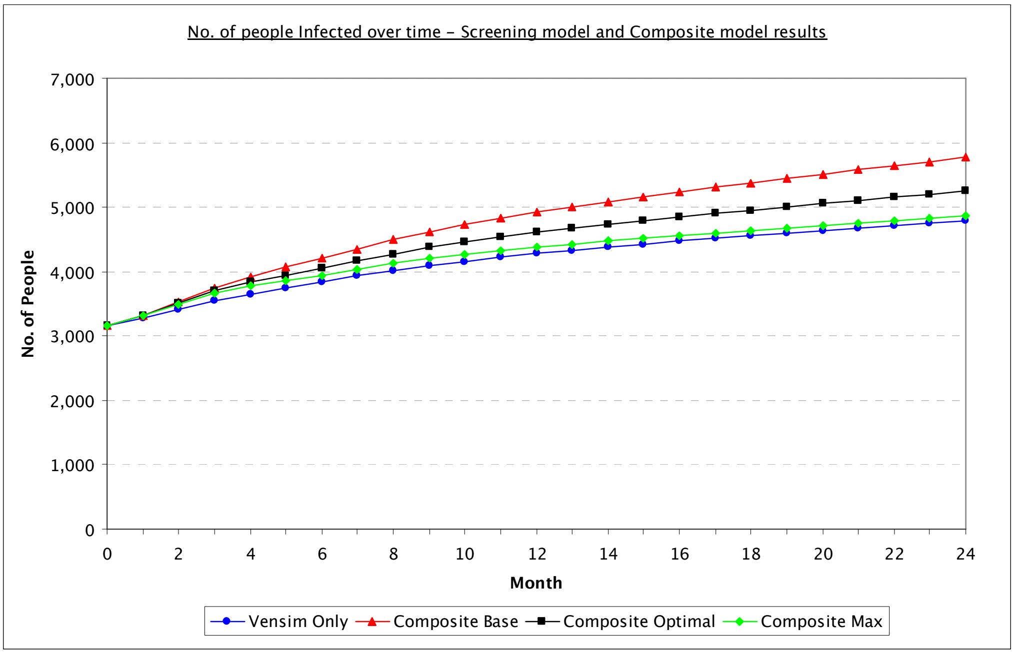

Figure 12-6: Cumulative no. of people infected by month comparing Composite and SD only models

Figure 12-7 displays the number of people treated per month under the four different conditions, the three experiments and the SD only model. This graph exhibits a different and more interesting pattern than the previous graphs. The model as anticipated predicts that as the number of resources increases the number of people who can be treated each month increases. What is interesting is that the “optimal” and the “max” experiments treat more people each month than the SD only model. The reason why the SD only model treats fewer patients than the optimal and max experiments was that in the initial couple of months more people are treated resulting in fewer people becoming infected which consequently led to fewer people requiring treatment. Whereas in the optimal and max experiments more people become infected resulting in a higher level of Chlamydia in the population and more people requiring treatment each month.

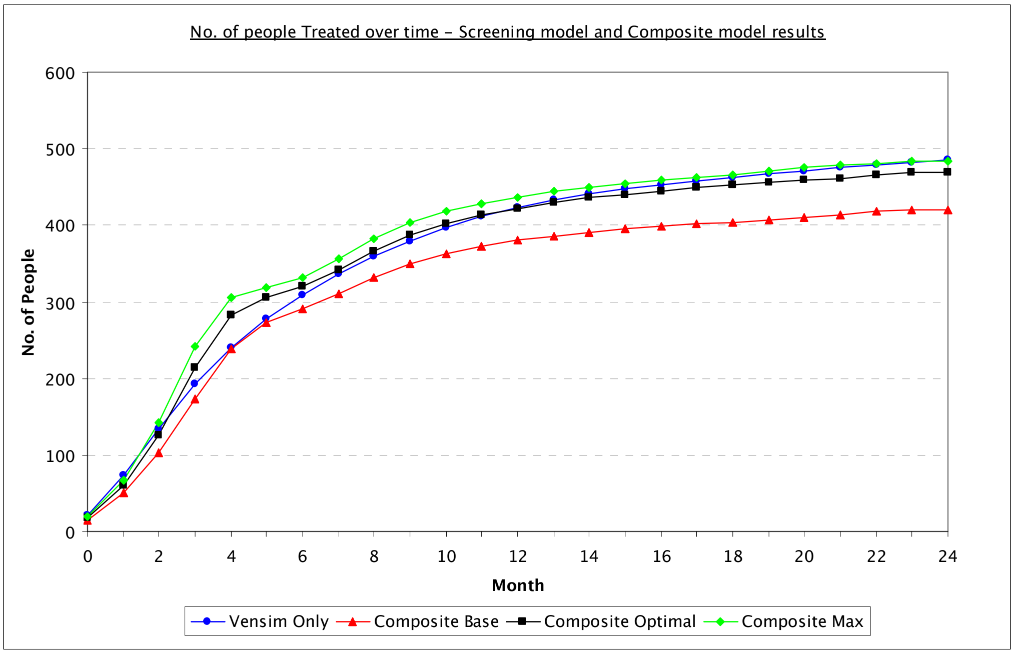

Figure 12-7: No. of people treated by month comparing Composite and SD only models

12.5.3 DES Results from Composite Experiments

Part 12.5.2 discussed some key results from the composite model from an SD perspective. What follows is a summary of the results generated from the DES model perspective. More detailed results for each of the three DES models: Base, Optimal and Max for each of the composite experiments can be found in appendix W.

Figure 12-8 provides aggregated data of the number of people who were unable to be seen by the GUM department given the demand and the resources available. What is striking about this graph is that given the underlying assumptions, regarding variable and parameter values in the SD model and the desired screening target of 20% of the 16-25 age group the department will be turning away over 1,200 patients a month. This figure is primarily associated with those people who turned away due to the available resources i.e. reception and medical staff, available in the department.

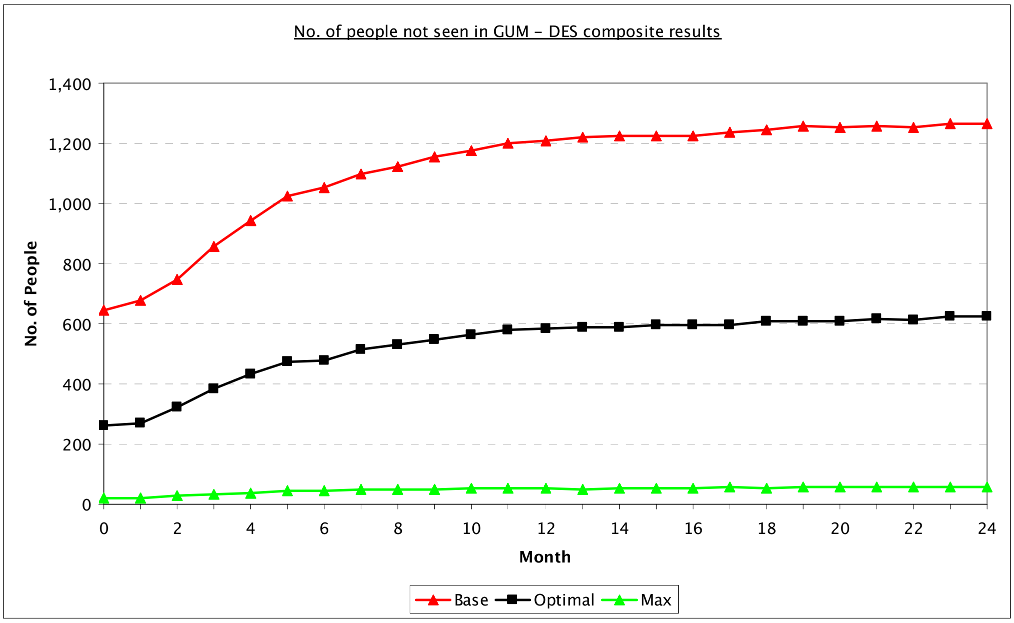

Figure 12-8: DES Composite results, number of patients not seen by GUM

Correspondingly figure 12-9 indicates the number of conditions that are missed each month for each of the experiment. As expected the lack of resources results in more people not being seen and as such more conditions are missed. The 7 conditions under examination are aggregated into a single figure for each month. What is important to note is that the optimal experiment proved to be more efficient for historical demand, see chapter 10. The demand generated by the composite model suggests that over time the suggested “Optimal” model would miss around 130 conditions per month.

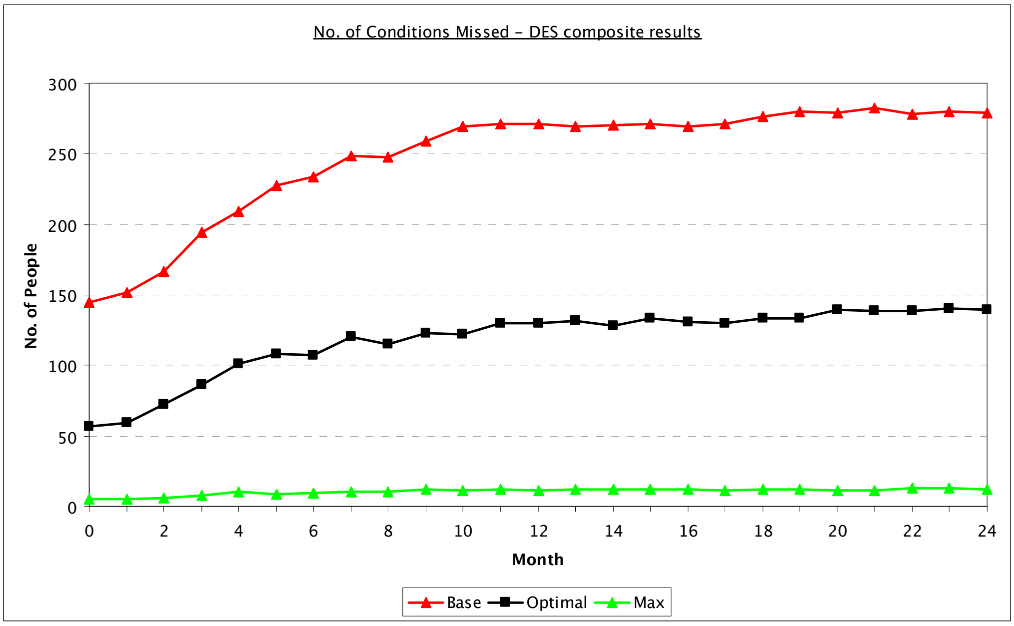

Figure 12-9: DES Composite results, number of conditions missed by GUM

Figure 12-10 displays the reception waiting time results and what is clear is that the base experiment exhibits a significantly higher waiting time. The optimal and max experiments waiting times are much reduced and likely to be more acceptable to patients, the reasons why this results is that the optimal and max have a greater number of FTE reception staff, relating to patients being able to be called in to the department due to the patients details being entered more quickly.

Figure 12-10: DES Composite results, average waiting time in GUM reception

Figure 12-11 demonstrates that patients have to spend longer in the system in the base scenario when compared with the optimal and max. The max is an idealised total time in the system, given the time it takes to complete the reception tasks, and the medical tasks

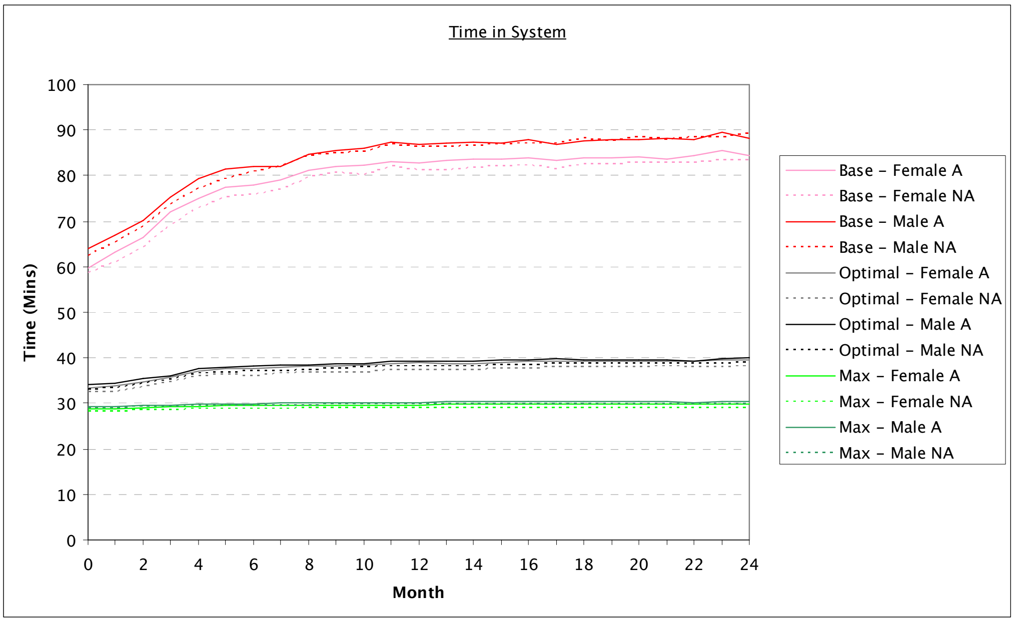

Figure 12-11: DES Composite results, average time in GUM

Figure 12-12 displays the waiting room utilisation for each experiment over the 24 months. The waiting room value for each of the experiments is kept constant at 40 chairs, and what can be seen is that as the reception and medical resources increase then the utilisation of the waiting room reduces due to patients spending less time in the waiting area.

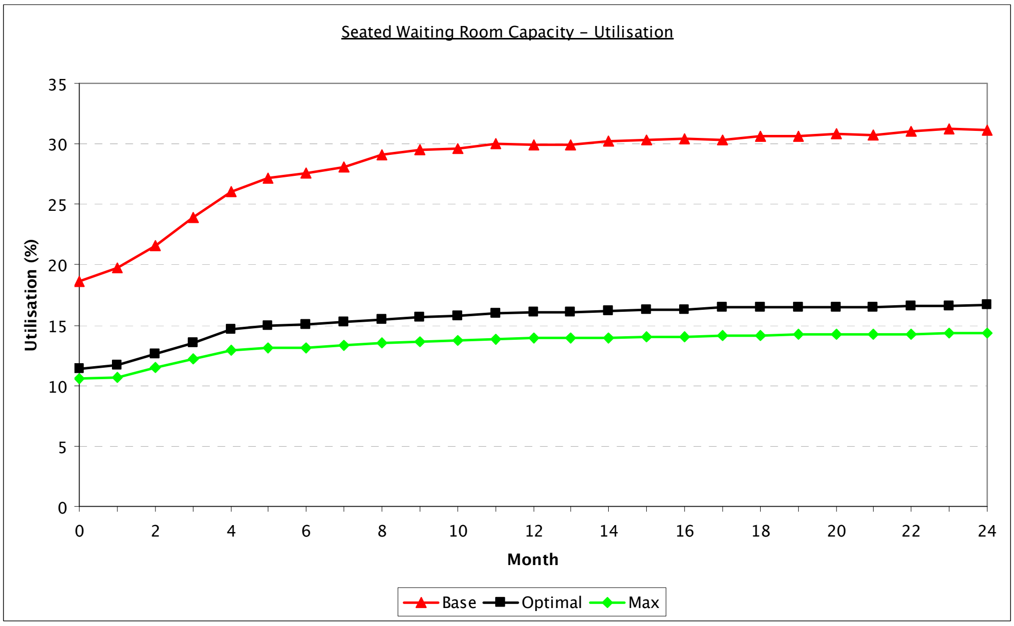

Figure 12-12: DES Composite results – seated waiting room capacity utilisation

Reception staff as previously discussed in chapter 10 are vital in the GUM system given that the patient details need to be entered onto the system before they are able to be called into the medical side of the department. As the number of reception staff increases from the base model to the max experiments, what can be seen is that the reception utilisation decreases although not to the same degree as the medical resources which will be discussed subsequently in this chapter. The max experiment consists of 10 reception staff working 5 days a week and yet the utilisation is still relatively high at 30%, this is due to fewer patients being turned away as more medical resources are available as well.

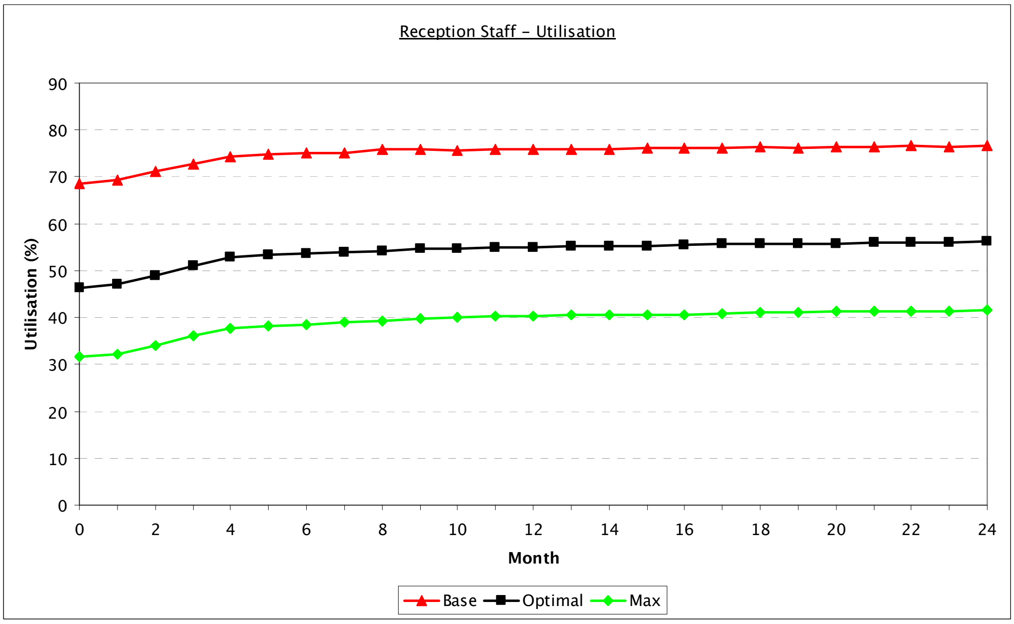

Figure 12-13: DES Composite results, reception staff utilisation

Figure 12-14 demonstrates that the female room/staff utilisation decreases as the number of medical rooms increases. What is interesting is that a suggested improved model "optimal" exhibits only slightly less utilisation than the current base configuration.

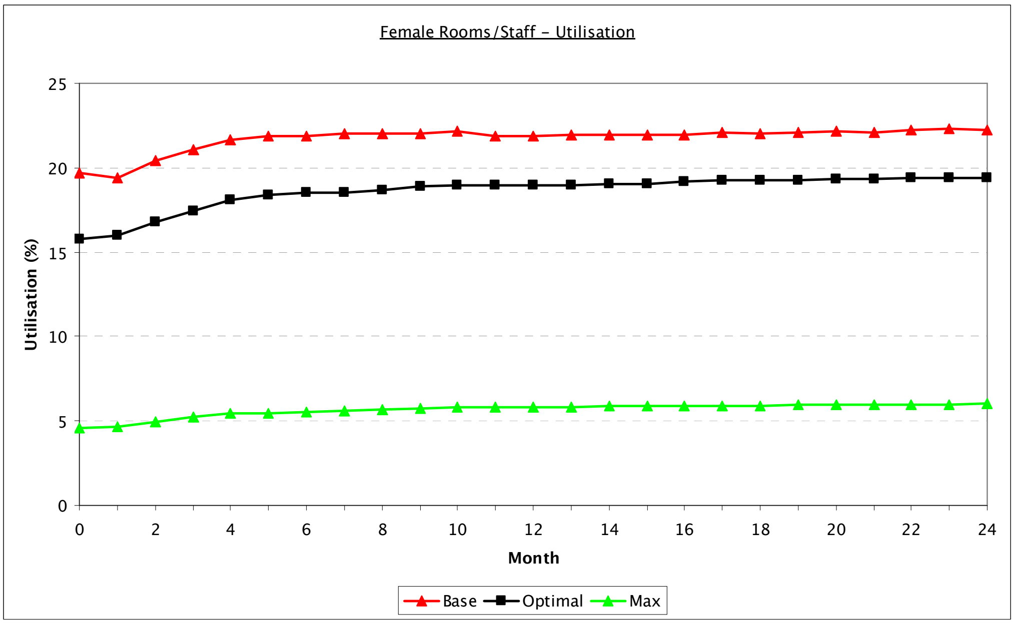

Figure 12-14: DES Composite results, female room utilisation

Like the female medical rooms discussed above. Figure 12-15 demonstrates that the male room/staff utilisation decreases as the number of medical rooms increases. What is interesting is that a suggested improved model "optimal" exhibits a larger improvement than the female improvement; this is due to the base number of male rooms being less than the base number of female rooms.

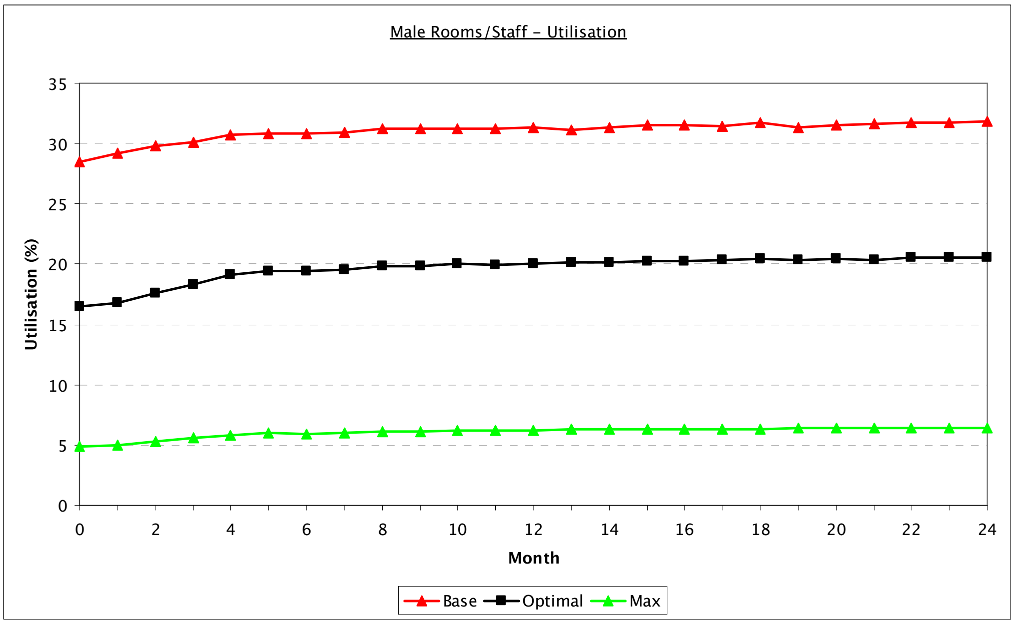

Figure 12-15: DES Composite results, male room utilisation

12.6 Reflections on Composite Modelling

Composite modelling in terms of this research relate to only one method in which SD models and DES models can potentially interact. As previously mentioned the SD model runs for one DT before pausing and passing information to the DES model. The DES model incorporates this information before conducting a trial consisting of multiple runs before information is fed back into the SD model. The SD model then advances a DT and the process continues. Hybrid or integrated simulation models have been proposed in many areas (see section 4.9) however few attempts have been implemented. This research provides a working composite model, combining DES and SD models. The composite model produced during this research did so through the use of commercial simulation packages (DES=Simul8 and SD=VENSIM). Though the necessary interaction was captured it initially required a substantial amount of effort. It may have been beneficial to develop the model from scratch through a programming language such as: C, Python or JAVA.

The entire process could potentially have been captured in a DES model. However due to the size of the population and the number of sexual relationships that would need to be captured in the study area; this would have made the DES model unnecessarily complicated and slower to run. The sexual relationships were thus captured in a model better suited to modelling larger populations.

There are many ways in which SD and DES combined this thesis explores one type. The amount of and how frequently the information is exchanged, is dependent upon the purpose of the combined models produced and what outcomes are required. The complexity of the individual models influences the potential to combine them. The more complex the models and the amount of interactions greater thought and additional effort may be required. It is important to note that the composite model produced in this thesis was not created as a replacement for existing techniques. The technique was devised to complement existing modelling approaches and to be used when a problem does not lend itself solely to one particular modelling approach.

12.7 Further Composite Modelling Research

Through the development of the composite model presented in this chapter, potential avenues for further work include:

- Exploration of the timings and mechanisms through which the DES and SD models communicate and exchange information.
- Evaluating the combination other forms of modelling including: Agent Based Simulation (ABS), SD, DES and other forms of modelling.
- Further evaluation of the composite modelling approach in relation to healthcare and other settings.
- Comparing the development of combined model from scratch compared with the integration of software packages.

12.8 Chapter Conclusions

A detailed DES model of a GUM department and a detailed SD model of Chlamydia screening were being produced. An opportunity presented itself for the models to be combined to show the effect that one had on the other. The joining process itself was relatively complicated and the details of how this was achieved have been briefly described in this chapter. Defining an effective experimental design proved difficult given the sheer quantity of possible experiments that could be conducted and although the experiments were agreed with the stakeholders a more thorough experimental design could have been adopted.

The main conclusions of this chapter are:

1. The composite model illustrates that decisions made at the GUM level have consequences in the population that the GUM department serves and these can be quantified based on the assumptions made.

2. By making savings at the GUM department configurations can still be devised to make effective use of the resources available but this has an effect on the prevalence of Chlamydia in the population, which can now be accounted for.

3. By combining the models in this way feedback normally associated with SD modelling is incorporated in the DES model.

4. The SD model benefits by incorporating the detail usually associated with the DES modelling.

12.9 Chapter Summary

This chapter:

- Provided a rationale and explanation of why and how the composite model was developed.

- The experimental design and results from the 3 composite experiments.

13 Key Findings, Conclusions and Future Work

13.1 Chapter Introduction

This chapter draws together the key results and conclusions from the previous 12 chapters, to draw conclusions of the research as a whole and suggest avenues for future work. The chapter is structured as follows: section 13.2 summarises the key findings and conclusions in relation to the six research tasks, from the analysis, models and combinations thereof previously discussed in the thesis; section 13.3 states the contributions of this research; section 13.4 provides the limitations of this research and how they impact on the research findings; and, section 13.5 discusses opportunities for future work.

13.2 Key findings and conclusions

The key findings and conclusions from each chapter will be discussed in relation to the six research tasks provided in chapter 5.

13.2.1 T1. What is the prevalence and incidence rate of Chlamydia in Portsmouth and surrounding area?

This research task was addressed with multiple methodologies, utilising both traditional summary statistics following data cleansing of GUM department data and also geographical referencing. Geographical referencing enhanced the analysis, enabling the display of analysed data and the identification of targeted screening strategies. The research task was primarily addressed by chapters 6 and 7.

The analysis conducted in chapter 6 identified incidence rates and also informed the geographical referencing conducted in chapter 7. 28,802 of the GUM department records (61.1%) were used in the postcode district analysis. The screening rate achieved over the period of the data was collected was between 15-25% of the 13-26 age. In the Portsmouth area the Chlamydia incidence based on positive only tests was 16% and 25.5% for female and male groups respectively. Combining positive and equivocal results the incidence was 18.1% and 26.1% for female and male groups. The Chlamydia incidence among the male group was significantly higher for females. A potential reason why males exhibited higher incidence was that they were likely to be contacts of positive partners, as this became the main method of screening and treating male patients in the area.

Geographical referencing was used to compliment the statistical analysis. The geographical referencing focussed on the post code district level, i.e. SO17 and the sector level, i.e. SO17 1. Postcode district level incidence was found to vary between 20.5% and 33.0% for males, and 14.1% and 18.8% for females. Postcode sector incidence varies between 0% and 37.5% for males and 3.7% and 23.5% for females. Care needed to be taken when analysing these values as some were associated with very small samples.

The setting in which Chlamydia screening was offered was also analysed. Test location analysis indicated the top 4 locations for each gender, with Genito-Urinary Medicine (GUM, 22.6%), Gynaecology departments (Gyn_all, 14.5%), Family Planning Clinic (FPC, 12.5%) and East Hampshire General Practitioners (GPE, 11.7%) for females. For males the Ella Gordon Unit (EGU, 33.3%), Family Planning Clinic (FPC, 28.3%), Genito-Urinary Medicine (GUM, 26.1%) and Gosport General Practitioners (GPG, 22.2%) were identified as the top four.

Statistics for ethnic origin showed clearly that the white ethnic group dominated the other groups' ethnic groups. 74.9% of the female and 66.5% of the male patients were of white ethnicity.

Incidence peaked at 19 years old for both women and men. Higher incidence was found to be associated: with the female age group 18-22 and for the male age prevalence 20-24. 29.3% of female patients reported having a new sexual partner in the last 3 months compared to 42.4% of male patients. 36.2% of female patents reported having 2 or more sexual partners in the last 12 months compared to 54.1% of the male patients.

The Chlamydia screening coverage during the data collection period was plotted onto maps of the screening area to clearly indicate the number of patents in the 13-26 year age group and the location. Test result data including: the number of tests, the number of positives and the number of other test results, was plotted by gender. Clusters were identified from these maps by gender. By presenting incidence on maps, and identifying potential clusters of infections, screening areas, or areas that may benefit from targeted interventions were identified. This research identified some alternate screening areas than previously identified (Evenden, 2003) suggesting that they should be considered for targeted interventions and that the screening locations should be reviewed at regular intervals. The maps clearly showed that there were some differences between the female and male patients and that if possible they may benefit from specific screening strategies or interventions rather than a blanket strategy for both genders.

13.2.2 T2. What are the factors (e.g. socioeconomic and behavioural) that are associated with Chlamydia prevalence/incidence in an area?

Chapter 8 primarily addressed this research task. Analysis was undertaken to ascertain which socioeconomic factors, primarily from the CENSUS relating to the research area, are associated with Chlamydia prevalence. Many socioeconomic factors analysed in isolation were identified as being significantly association with Chlamydia. Regression analysis was used to determine the combination of significant variables that associated with Chlamydia levels in the research area. These are provided in table 13-1 below by gender:

Female Variables	Co-efficient	Male Variables	Co-efficient
Constant	8.762	Constant	19.090
NSSEC 04 Ratio - Intermediate Occupations	-84.804	Accom - Ratio - Other type of establishment	101.063
NSSEC 03 Ratio - Lower Managerial and Professional Occupations	83.568	Qualification - Ratio - Other	681.812
Ben - Ratio - Disability Living Allowance	109.673	Birth - Ratio - EU	805.422
NSSEC 01 - Large employers and higher managerial occupations	-0.013	Car - Ratio - Three	-832.043
Accom - Other type of establishment	0.005	Accom - Ratio - Caravan, mobile or temporary structure	1247.068
Age - 100 plus	-0.427	Child - Ratio - One dependent child aged 5-11	-2096.143
Ethnic - Asian	-0.011	Age - 90-99	-0.196
		Armed Forces - Armed Forces	0.023
		Per - 1.5 persons per room	-1.097

Table 13-1: Socioeconomic regression results

The variables identified exhibited a clear gender difference. The major factor identified by regression analysis which was strongly correlated with Chlamydia for females was the ratio of women in the patient's postcode sector who were claiming disability living allowance. The major factors identified for men were: the ratio of people born outside the UK but in the EU, and the ratio of how many people lived in mobile or temporary structures in the patient's postcode.

Decision trees were developed as they were deemed clearer and more understandable for healthcare professionals. The decision trees had the potential to aid healthcare professionals in the process of selectively offering screening to individuals. Decision trees were created for each gender based on the socioeconomic variables that were highly correlated with Chlamydia levels.

13.2.3 T3. What is the difference in sexual behaviour, knowledge and attitudes between: attendees at the St Mary's GUM department and students from the University of Southampton?

Chapter 9 focussed on addressing this research task through the analysis of questionnaires. The responses from a paper based questionnaire carried out by patients who attended the GUM department at St Mary's Hospital Portsmouth and an electronic online version of the questionnaire carried out by students from the University of Southampton where analysed. The analysis of the questionnaire focused on gender and Chlamydia history differences overall and specifically between and within the two groups of respondents.

The primary purpose of the analysis was to identify risk factors which then could be combined with the socioeconomic factors of chapter 8 and the literature to identify high and low risk sexual behaviour groups to be incorporated into the SD model discussed in chapter 11. The factors identified as being associated Chlamydia infection are displayed in table 13-2, below and are defined as the high risk group.

High Risk Group Behaviours
Self-perception of being at risk
Have anal sex
2 or more sexual partners in the last three months
Have sex under the influence of drugs or alcohol
Earlier sexual debut
They or their partner has ever used emergency contraception
Currently smoke

Table 13-2: Risk factors associated with Chlamydia

It is worth noting that there was a vast amount of information obtained through the questionnaires and that additional analysis could be undertaken on this data.

13.2.4 T4. Can DES be used to model a GUM department to assess scenarios that the stakeholders are interested in?

To the authors knowledge there were no published accounts of DES modelling being used to aid in decisions made in GUM departments. There was a Department of Health model but this was not implemented to the author's knowledge and has not been published in the literature. There was an opportunity to use DES to help improve the operation of a GUM department, which is already overstretched and is likely to remain so given the current changes in the NHS. The DES model created of the GUM department discussed in chapter 10 is fairly complex in order to capture the nuances of the department without making too many simplifying assumptions. For instance it contains over 10,000 lines of visual logic.

The model captured the necessary detail of the GUM department and was supported by the staff due to their continual input during its construction. This "by in" by users of the model was crucial.

Although the model allowed parameters to be changed and many patient flows to be changed, the reception tasks were essentially hard wired in. The users had the ability to change the duration of tasks and varying the number of staff available. If this were to be amended or different pathways through the model investigated then the model would have to be amended manually and consequently the user interface would need to be updated. And although this could be potentially cumbersome it would not be difficult.

The results from the scenarios run in the GUM model suggested that:

1. The reception staff and the reception processes were identified as key factors in controlling the patient flow into the department – if there were not enough then this resulted in unnecessary waiting time for the patient and under utilisation of the medical resources.

2. Medical resources were being deprived of patients due to delays in reception. The models suggested that the medical resources could see many more patients.

3. The turn away decision rule currently operated by the department may be unnecessarily turning away patients, who could have been treated in the departments working hours. The average time approach may need to be reviewed.

4. Shared medical resources are more efficient than segregated resources when the number of medical rooms for each gender is 4 or more based on the observed arrival patterns.

13.2.5 T5. Can behavioural dynamics be adequately captured in a System Dynamics model of Chlamydia? Does the inclusion of behavioural factors make a difference in the evaluation of Chlamydia screening strategies?

Behaviour factors associated with Chlamydia were identified through the literature review conducted in chapter 3 and the behavioural questionnaire discussed in chapter 9. The identified factors were then used to estimate the size of the population and their parameters to be included in the developed SD model which was discussed in chapter 11. The SD model was very detailed and took a considerable time to conceive and to produce, however it does raise some interesting talking points:

1. The model suggested that screening those females under 25 and recruiting male partners through contact tracing is more effective than screening both genders – the current strategy followed by many Chlamydia screening interventions.

2. Targeted screening of the high risk or "core group" is more effective than blanket screening.

3. The underlying prevalence of Chlamydia has to be sufficiently high to warrant screening.

4. The probability of developing and the cost of female sequelae have to be sufficiently high to warrant screening – a key factor.

5. Behavioural evaluation or change though advice/counselling at treatment is an important strategy which may have been overlooked in previous models of Chlamydia screening.

What should be noted is the novel use of behavioural parameters in the model to capture changes in behaviour not only as people age, but also as a consequence of treatment. Of course care needs to be taken when assigning a value to these parameters and extensive sensitivity was undertaken to assess the impact of this factor. As the SD model was complex a Microsoft interface was developed enabling non-specialist users the ability to run the model. The interface required a considerable amount of VBA to communicate with the SD model.

13.2.6 T6. Can the developed DES and SD models be successfully integrated? Is the combination of DES and SD models in this healthcare context beneficial?

Chapter 12 examined the possibility of combining two detailed models from what is considered different ends of the modelling spectrum to produce a new composite model in healthcare. The two models in question were the DES model developed of the GUM department discussed in chapter 10 and the SD Chlamydia screening model, discussed in chapter 11. As two somewhat sophisticated models were being developed an opportunity presented itself for the models to be combined to show the effect that one had on the other. The joining process itself was relatively complicated and was achieved after several failed attempts. The details of how this was achieved have been briefly described in chapter 12. Defining an effective experimental design proved difficult given the sheer number of possible experiments that could be conducted and although the experiments were agreed following discussion with stakeholders a more thorough experimental design could have been adopted. The key outcomes derived from the composite model were:

1. The composite model illustrated that decisions made at the GUM level have consequences at the population level which in turn affect GUM department which were previously missed.

2. The composite model could demonstrate that if budgetary constraints were imposed which limited the service the GUM department could provide, configurations could still be devised to make effective use of the resources available. However this has an effect on the prevalence of Chlamydia in the population which can now be estimated with the composite approach developed.

3. By combining the models in this way feedback normally associated with SD modelling was incorporated to a degree in the DES model.

4. The SD model benefited by incorporating the detail associated with DES modelling.

The produced composite model was the most significant contribution of this research. The combination of the two approaches it is hoped will expand the number of not only healthcare problems that could be explored by this form of model but also problems in other fields. The research demonstrated that those who model solely in one of the two approaches do not have to find novel approaches to adapt their method to perform what the other process is better suited for. The models produced can be tailored so that the benefits from the traditional separate models can be combined to complement one another and thus enhance future models.

13.3 Contributions

The contributions of this research were: the combination of DES and SD to produce a unique form of modelling previously not used in a healthcare setting; the creation of a DES model of a UK GUM department; the incorporation of behavioural change into a SD model of Chlamydia transmission/screening; and, the identification of risk groups associated with probability of carrying Chlamydia.

Combination of DES and SD

Many have spoken about and suggested the use of hybrid simulation in various industries (see section 4.9). To my knowledge this is the first working model in healthcare which doesn't simply mention the possibility of combining the models, but actually works in practice. The communication between the two modelling approaches is fully-automated, but to enable easier interaction with the new model has been semi-automated to enable the DES model to be updated in between time steps of the SD model.

DES model of GUM

Many DES models have been built of outpatient and Accident and Emergency (A&E) departments (see section 4.4.2), to improve their operation. Apart from a DES model of a GUM department that the Department of Health was working on this is the only know operational DES model available. Like DES models of other healthcare departments its purpose is to improve GUM performance by providing healthcare professionals the ability to evaluate "what-if" scenarios of their choice, to make better use of available resources.

SD model which incorporates behavioural change

Previous SD models (see section 4.3.2) captured the behavioural change associated with age. However at the time no know models had the ability to capture spontaneous behavioural change following treatment. This is a unique addition of the SD model developed during this research.

Identification of risk groups

Risk groups for incorporation into the SD model were identified through the use of multiple sources and various methods. The risk groups that were produced focussed on the geographical area of the research, which enhanced the validity of the simulation model with local data rather than use of national data. The risk group identification was a small part of the non-modelling side of this research. Addition insights were gained through the qualitative comparison in relation to the knowledge, attitudes and beliefs with regards to sex of the two groups: the GUM patients and University students. A highlight of this research was the gathering of information relating to relationships formed through social networks such as Facebook, Twitter, and MySpace etc.

13.4 Limitations

The limitations of the research and how they impact on the findings are discussed in this section:

1. The DES GUM model focused only on the walk-in service operated by the department. This therefore limits the use of the DES model to the walk-in service. The other services offered by the department cannot be modelled with the current model.

2. The SD model made simplifying assumptions about partnership formation. Partner choice, partnership length, and amount of sexual activity were not captured in a sophisticated manner. There is a risk group aspect but this is all. Partnership length, concurrent partnerships is not captured in a sophisticated way which could lead to higher infection prevalence in the model. This could be addressed through use of Agent Based Modelling (ABM) which would allow greater choice to be built into the model.

3. The SD model had the capability to incorporate migration although due to lack of data migration was excluded. The SD model may underestimate or overestimate Chlamydia prevalence by not including those people moving in and out of the area who have Chlamydia. This needs to be address by investigating or commissioning research to obtain this data.

4. The problems associated with self-reported information in regards to the questionnaire. Particularly noticeable in relation to sexual health with males tending to report higher numbers of partners than in reality. Other reported answers may have equally been affected due to the participant's belief that they

may be judged despite the questionnaires being anonymous. As the questionnaire was used to create risk groups inaccurate answer may overestimate the size of the high risk group.

13.5 Future work

This section suggests ideas for potential further work which arose as a result of this thesis. What should be noted is that sexual health and in particular methods to help reduce the spread of STIs will continue to be of interest not to just those in the sexual health field but to others in similar health related contexts. The future work is discussed by methodology, in the remainder of this section.

The analysis conducted on the data obtained from the GUM department information systems highlighted an interesting variation in the ethnicity of the patients who attend the department. 74.9% of the female and 66.5% of the male patients are of white ethnic origin. This reflected the demography of the area. However, further analysis could be undertaken based on ethnic origin, to examine the extent of any potential ethnic affects.

The GUM department had a new data information system installed during the project which collected time based data for individual patients. This new data source would be very useful in the development of statistical and simulation models. If the developed DES model or SD model were to be further refined, this new system should be able to provide more accurate data, which would be highly beneficial.

The geographical referencing discussed in chapter 7 is reasonably basic taking the data obtained from the Chlamydia screening databases from the GUM department and then manipulating the data to display on maps for analysis. The actual location of facilities was only touched upon in chapter 7 with the location of existing facilities provided. What would be interesting is the assessment of whether the existing facilities are located in the best locations? And, are mobile units being deployed to the areas that need them the most? Geographical Information Systems (GIS) could be integrated with the composite model produced to provide information to decision makers about the possible effect of placing an outreach van or screening site(s) in a particular location.

The behaviour questionnaire collected a vast amount of information. This was primarily due to enable a comparison between the GUM and University groups which was identified as an interesting issue for the GUM department. The main purpose in relation to this research was to identify key risk factors that could be incorporated into the SD model. There is scope for additional statistical analysis to be carried out on the questionnaire data that would be of interest to those who study sexual behaviour, knowledge, beliefs and norms.

The DES model as mentioned is fairly complex and is based solely on the GUM department at St Mary's hospital Portsmouth. It would be interesting to collaborate with them further to explore more scenarios, and to further refine the model. An important aspect of the model to explore would be in making the reception tasks more flexible, and the ability to test more radical changes in the model structure, as opposed to the current evaluation of scenarios which are based on certain constraints of the model. It would also be interesting to evaluate this model with other GUM departments and if possible obtain input and/or suggestions from the DH.

The SD model developed was novel in the manner in which it incorporated behavioural change, and migration. The migration functions of the model were not called upon in the scenarios evaluated due to the paucity of data. Migration data itself is difficult to obtain The possibility of obtaining accurate migration data which also included whether a person was Chlamydia positive or was susceptible 2 (recovered with sequelae) rather than susceptible 1 (sequelae free) was extremely difficult. It would be interesting to explore how migration influences the model even if several simplifying assumptions were made, in regards to the data.

The composite model represents the greatest opportunity for future work and further research in general. Problems that arise in healthcare are becoming more complex and require more novel solutions. The composite model has been shown in the context of this thesis to be beneficial. It would be interesting to explore the use of combining SD and DES not only in this way but in others. It would also be interesting to explore the combination of other approaches, such as Agent Based simulation.

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A. NHS Ethics Application Research Protocol

Portsmouth Hospitals NHS
NHS Trust

UNIVERSITY OF Southampton

RESEARCH PROTOCOL

STIGMA

Sexually Transmitted Infection GUM MAnagement toolkit

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Version 2.0 – 02/06/2008

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2.0 – Background

Chlamydia Trachomatis is the most prevalent Sexually Transmitted Infection (STI) in the UK. Genital Chlamydial infection is an important reproductive health problem; with 10-30% of infected women develop pelvic inflammatory disease (PID). A significant proportion of cases, particularly amongst women, are asymptomatic and so, are liable to remain undetected, putting women at risk of developing PID. Screening for genital Chlamydia infection may reduce PID and risk of ectopic pregnancy. The treatment for Chlamydia in most uncomplicated cases is antibiotics. However as most cases are asymptomatic the infection can spread rapidly.

As the prevalence level of Chlamydia and other STI has increased since the 1980s the Department of Health (DH) proposed a 10 year strategy to combat this rise, “Better prevention, Better services, Better sexual health: The national strategy for sexual health and HIV” (2001). The National Chlamydia Screening Program (NCSP) arose from this strategy and is the first such nationally organised programme in Europe. Currently estimates suggest that the Chlamydia prevalence rate is around 10% in people aged between 16 and 24 from the “New Frontiers: Annual Report of the National Chlamydia Screening Programme in England” (2006). Sexually health is also a core element in the government papers “Choosing Health: Making healthy choices easier” (DH, 2004) and “Our health, our care, our say: a new direction for community services” (DH, 2006).

The aim of this protocol is to provide an operational research toolkit for health care professionals at the Genito-urinary Medicine (GUM) clinic, St Mary’s Hospital Portsmouth to inform their decision making utilising evidence based techniques developed in fields of Operational Research and Management Science. Previously Operational Research techniques have been applied to Chlamydia screening, Evenden, Harper, Brailsford and Harindra (2005) and Townsend and Turner (2000).

This protocol was developed by Joe Viana with contributions from Dr Veerkathy Harindra, Professor Sally Brailsford, Professor Paul Harper, Dr Denise De Silva, Ms Martine Cross, Ms Kate Greenwood, Dr Lindy Dallen, Dr Martina Prude and Dr Nicole Stone.

3.0 – Research Justification

There are several reasons while this research is required. The tools developed will enable health care professionals to:

- Identify the key geographical areas that require specified screening, educational and intervention programmes.
- Identify changes in infection prevalence of STIs by location over time to determine whether existing strategies have been effective.
- Determine prevalence of STIs based on expert opinion and available data within a population. To estimate the underlying true prevalence of that STI in a geographical region.
- Develop an understanding of the risk taking behaviour of people tested for STIs compared to those who have not been tested for STIs.
- Evaluate different clinic designs and clinic strategies to determine best practice. This is a flexible tool that enables health care professionals to experiment with clinic design before implementing any changes in reality.
- Cost effective use of resources – if working with a limited budget(s) what measures can be taken to ensure the best use of resources. Likewise if resources are available what additional measures could be implemented?
- Project future infection prevalence based on current trends and expert opinion for planning purposes.
- Reduce the STI level in the Portsmouth area, the UK and with the potential to be globally applicable.

4.0 – Specific Aims

- Analyse data available from the GUM Clinic at St Mary's Hospital to determine the Chlamydia prevalence in the Portsmouth Region (those people with postcodes that start PO). Link in aggregated census data through use of postcodes.

- Produce a Geographical Referencing model to highlight the most high risk areas to aid in educational programme development and targeted screening campaigns.

- Develop a computer simulation model of Chlamydia infection to allow the spread of the infection to be modelled on a virtual population. The model will allow changes in key variables, enabling the knock on effect this has on Chlamydia prevalence rates within a virtual population to be observed.

- Conduct a behavioural study to ascertain the key behavioural indicators associated with positive STI results. Questionnaires will be completed by patients attending the GUM clinic at St Mary's and students at the University of Southampton.

- Develop a computer simulation model of the GUM clinic at St Mary's. Use model to examine generic patient pathways and the associated resources, treatments and processes that accompany these pathways to determine if they can be better utilised or improved.

- From the above elements construct a predictive regression model and a forecasting model.

- Produce an interface that will enable healthcare professionals to utilise the tools developed above without requiring in depth training of the above techniques.

- Depending on time constraints other STIs may also be examined in the same way, but the primarily focus is on Chlamydia.

5.0 – Research Overview

Figure 5.1 illustrates the overall aim of the research and how each component fits together.

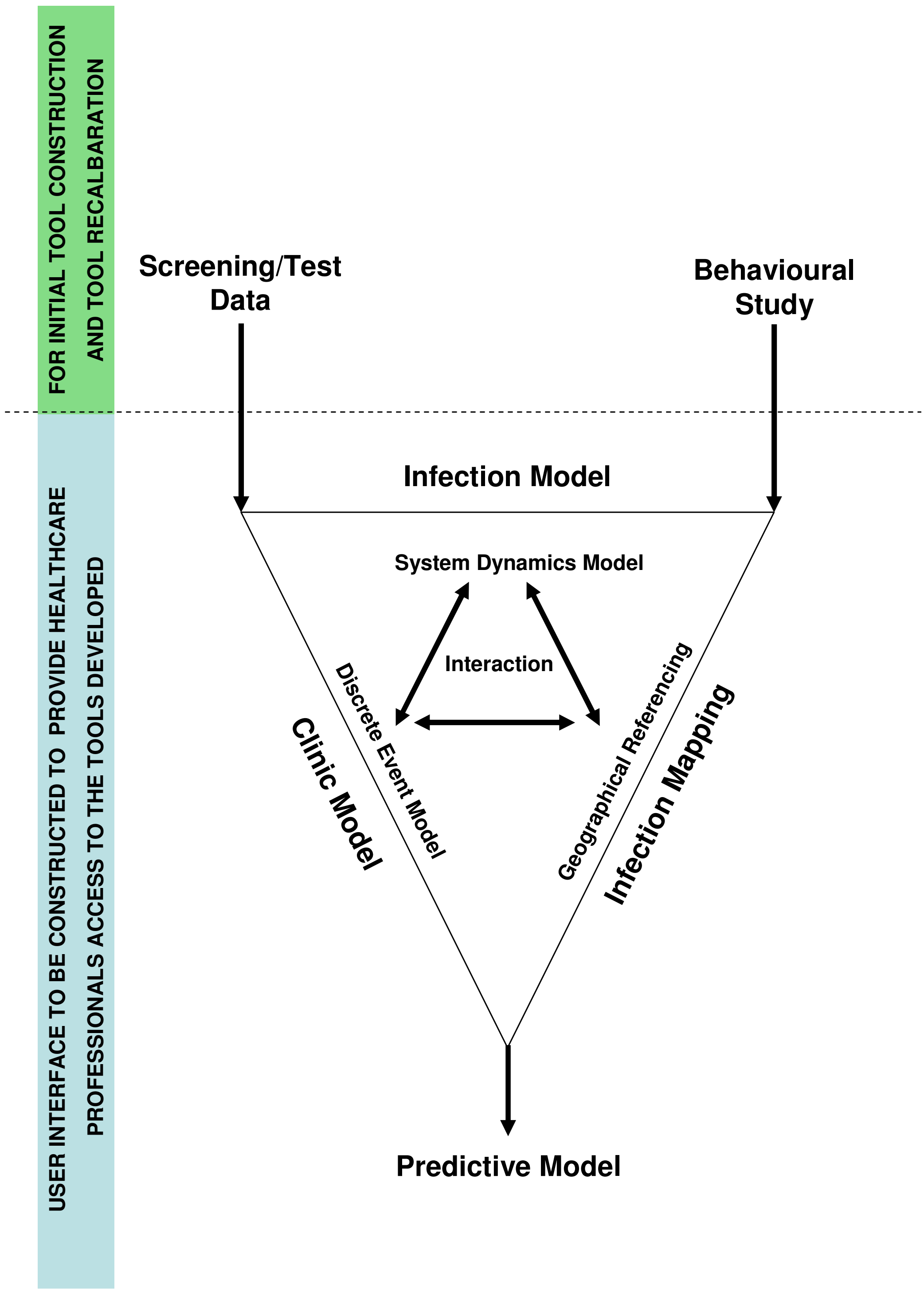


Figure 5.1 – Research Overview Graphical Representation

6.0 – Research Schedule

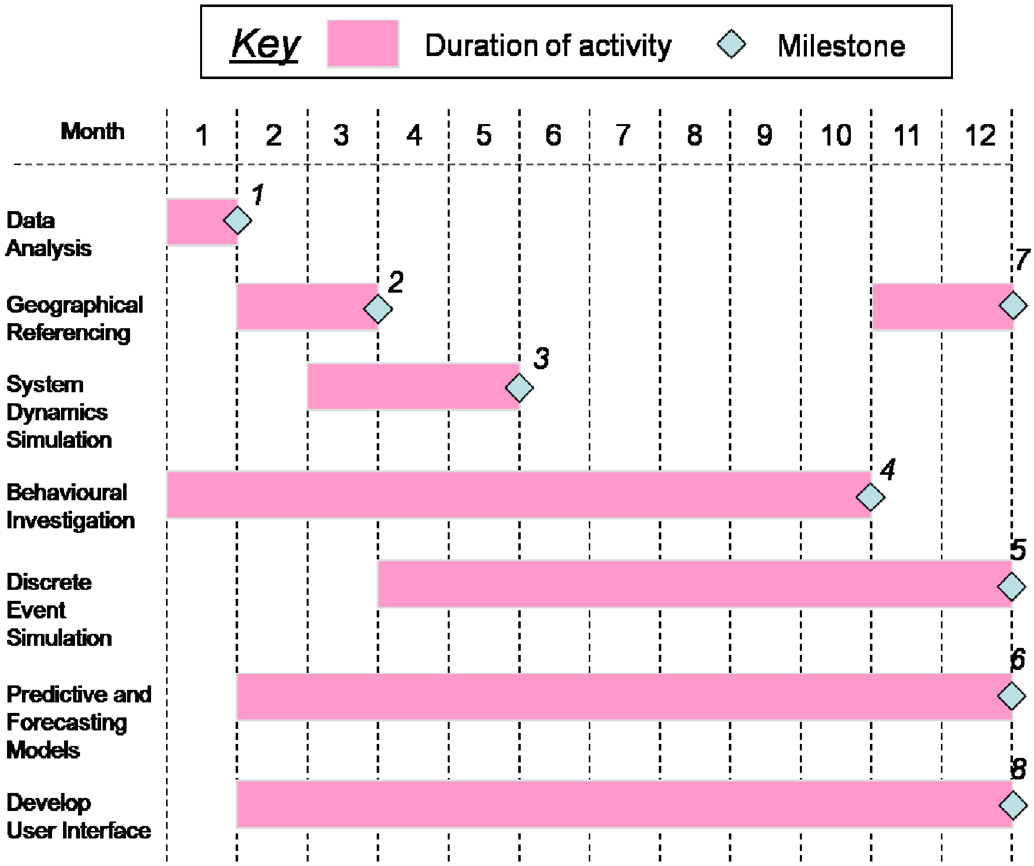


Figure 6.1 – Research Gantt Chart

6.1 – Key Milestones

1 – Completion of Primary Data Analysis

Data required for construction of simulation models and Geographical referencing. Data includes: Infection rates, social economic data and basic demographic data

2 – Initial Geographical Referencing, following on from data analysis

To provide graphical information to health care professionals to aid decision making by identifying infection "hot spots" where prevalence of infection are over a certain level.

3 – Chlamydia Infection System Dynamics Simulation model

Model created using VENSIM computer software based on data collected from the clinic (milestone 1) and expert opinion. This model will examine how changes in the key parameters affect infection levels in a virtual population. This work builds on the initial model developed by Evenden (2005) in collaboration with the GUM clinic at St Mary's Hospital.

4 – Completion of Behavioural Investigation

To specifically investigate the behavioural and attitudinal characteristics associated with people infected with STIs primarily Chlamydia. Two groups will be compared the clinic population at the GUM clinic at St Mary's Hospital Portsmouth and students from the University of Southampton.

5 – Discrete Event Simulation model of GUM Clinic

From data collected from the clinic and interviews with members of staff a model of the GUM clinic will be constructed using Simul8 computer software. The model will allow the investigation of different clinic configurations. Clinic configurations can then be discussed with clinic staff and decision makers resulting in possible alternative clinic configuration designs being implemented.

6 – Develop Predictive and Forecasting models

Using the collected data on infection prevalence (milestone 1) and the behavioural information obtained from the behavioural investigation (milestone 4), develop a regression model to predict the chance of having a STI (initially Chlamydia) given certain characteristics. With the same data build a model to forecast the level of prevalence of an STI (initially Chlamydia) over a specified period of time.

7 – Final Geographical referencing incorporating, relevant behavioural investigation results

Repeat the Geographic referencing (milestone 2 above) using the collected behavioural data (milestone 4), as well as the social economic data from the 2001 CENSUS available from the internet to provide a richer picture of the area.

8 – Development of a User interface to use in conjunction with the tools developed

Develop a user interface that will enable health care professionals to utilise all the tools produced above, without requiring expert knowledge of the software packages, and techniques used to create them.

7.0 – Study Design

This section provides a detailed account of the methodologies to be employed in the proposed research. There are six methodologies that will be employed and each has its own section indicated in brackets below. The methodologies are:

- Data analysis (7.1)
- Geographical Referencing (7.2)
- System Dynamics Simulation (7.3)
- Questionnaire (7.4)
- Discrete Event Simulation (7.5)
- Regression & Forecasting (7.6)

7.1 – Data Analysis

The data analysis is the key element of proposed research. Anonymised patient record data provided by the GUM clinic in St Mary's relating to Chlamydia will be analysed to ascertain information relating to infection rate, re-infection rate and general demographic data. The data will be made available in a non identifiable format by Dr Harindra. Socio-economic data will be associated with the data collected from the GUM clinic via reference to the 2001 census data that is available from the internet by use of postcode regions. The data analysis element contributes towards the other methodologies employed: the Geographical referencing (section 7.2), the System Dynamic Simulation of Chlamydia infection (section 7.3), the Discrete Event Simulation of the Clinic (Section 7.5) and the regression & forecasting models (Section 7.6).

Figure 7.1 illustrates the data analysis processes. The data required is shown in the boxes headed data and the census data is indicated at the bottom of the figure. The key analyses to be undertaken in the initial phase are shown in the "Test Results", "Population Stats", "Coverage Count and Prevalence" and "Excel Graphs and Tables" Boxes. The data requirements are discussed in greater detail in section 7.1.1.

7.1.1 – Data Requirements

The data analysis will consist of examining anonymised patient records. The key data fields are illustrated in figure 7.1. The unique identifier for each patient is the patient's hospital number (new system their clinic number). The hospital number will be used to determine re-infection rates within the data. The data that will initially be examined relates to 3 financial years 2004/2005, 2005/2006 and 2006/2007. The data will be analysed by financial year and monthly trends will also be investigated.

Census data from the 2001 census will be related to the data collected by postcode. Postcode analysis is discussed in section 7.2.

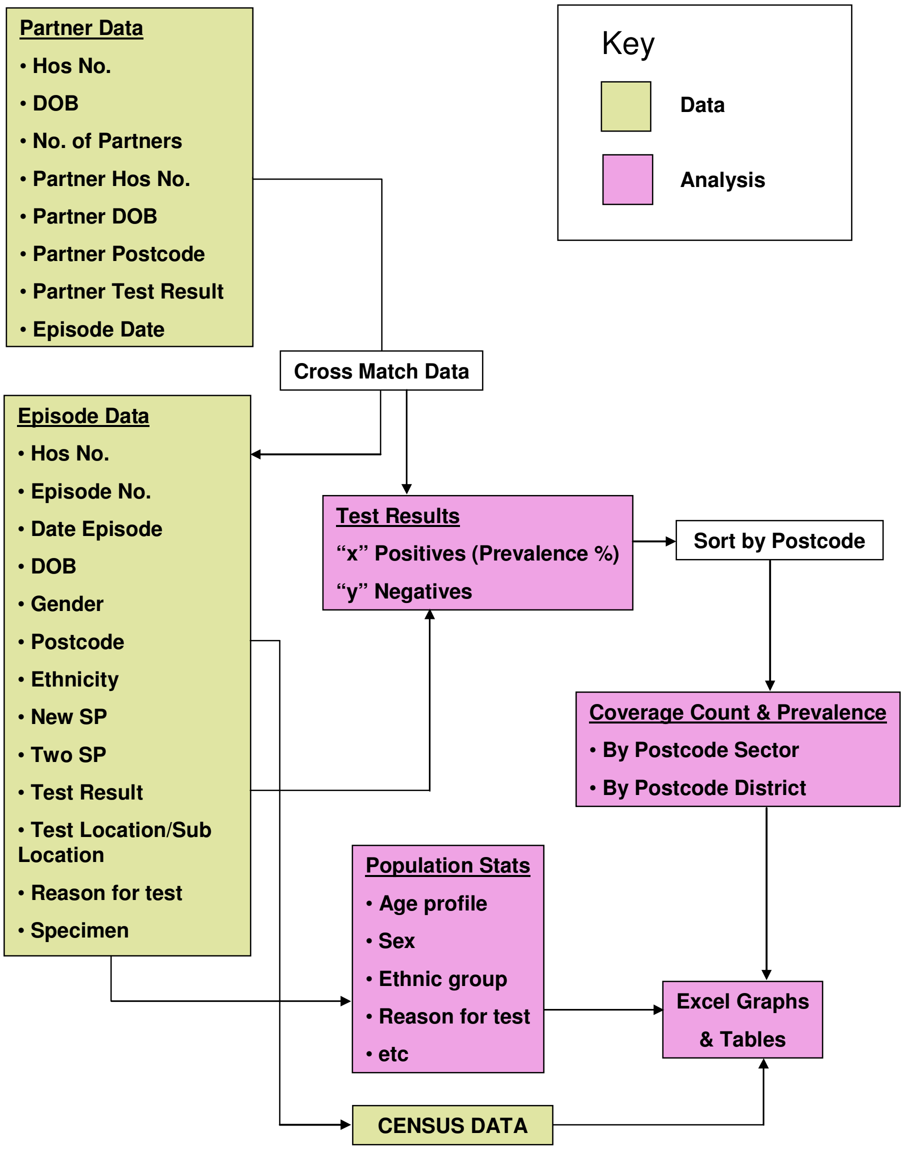


Figure 7.1 – Representation of Data Analysis

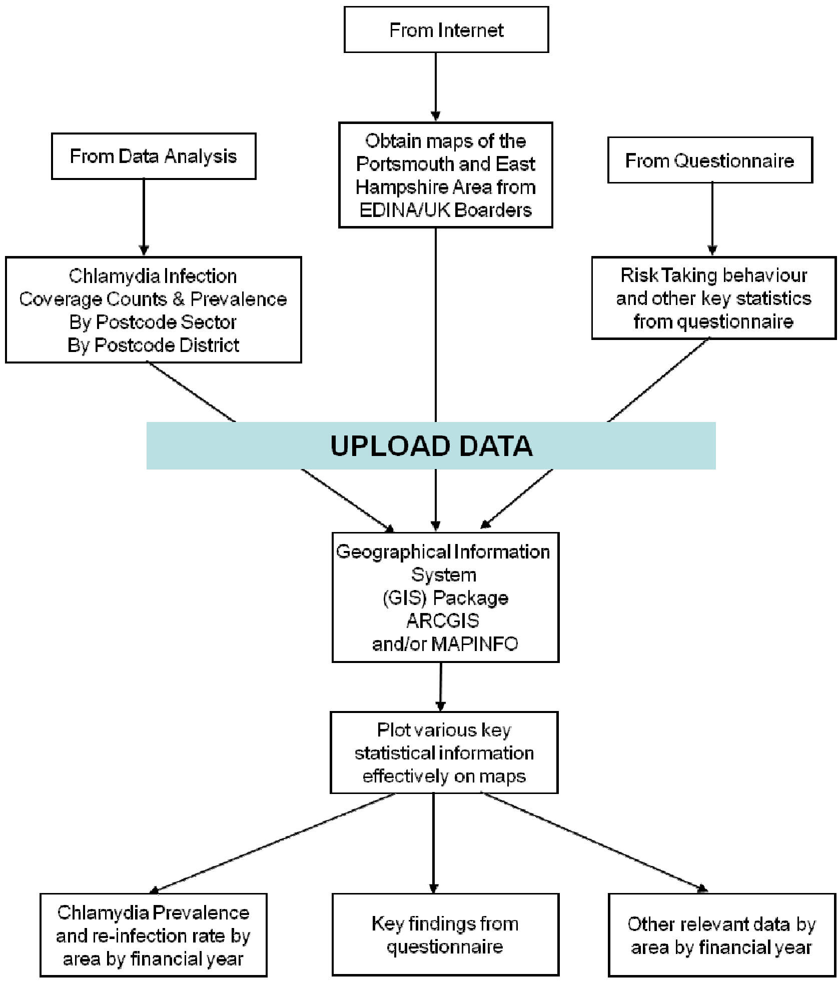
7.1.2 – Data Confidentiality

The research will be dealing with sensitive data, patient records. Data will be anonymised before being analysed and stored on a password protected computer. Data will only be accessed by the Principle Investigator (Joe Viana) and Dr Harindra Consultant in Genitourinary/HIV Medicine from the GUM clinic at St Mary's Hospital.

7.2 – Geographical Referencing

Geographical referencing enables data to be plotted on any map or picture utilising spatial co-ordinates. The geographical referencing for this research will enable health care professionals to examine the Chlamydia (and other STI) prevalence rates in certain areas. From this analysis healthcare professionals can develop targeted screening strategies and other interventions for these identified areas.

Chlamydia infection prevalence will be referenced on maps of East Hampshire by post code. Full postcodes will not be used to avoid identifiable places of residence. Postcode district the first element of the postcode (e.g. PO2) and post code sector the postcode district plus the digit from the second element of the postcode (e.g. PO12 6) will be analysed.



Data plotted will be by postcode district (i.e. PO1) and postcode sector (i.e. PO1 2) and therefore not identifiable with any individual

Figure 7.2 – Representation of Geo-referencing Method

7.2.1 – ARCGIS and MAPINFO

ARCGIS and MAPINFO are specialist Geographical Information System (GIS) software packages. The geographical referencing for this research will be undertaken in these packages. Each package is based on the same principles but has slightly different functionality, the package which will be used to produce the required maps will be determined based on the stakeholder's requirements and the available data.

7.3 – Chlamydia Infection Model

A System Dynamics (SD) model of Chlamydia infection allows for population data to be evaluated in response to varying levels of infection, re-infection and different rates of sexually partnering. The modelling process is illustrated in figure 7.3. The true prevalence of Chlamydia is unknown, with estimates around the 10-12% level in the population aged 18-25. The SD model will provide health care professionals with an estimate of the true Chlamydia prevalence level taking into account the people who are asymptomatic and therefore do not request testing or treatment. Thus identifying underlying prevalence will enable health care professionals to more effectively target: screening, treatment and their resources. The model will enable variations in attitudes, behaviours of the population, as well as strategies of prevention and treatment by the clinic to identify the impact on the infection prevalence of the population, providing cost effectiveness analysis of the many combinations.

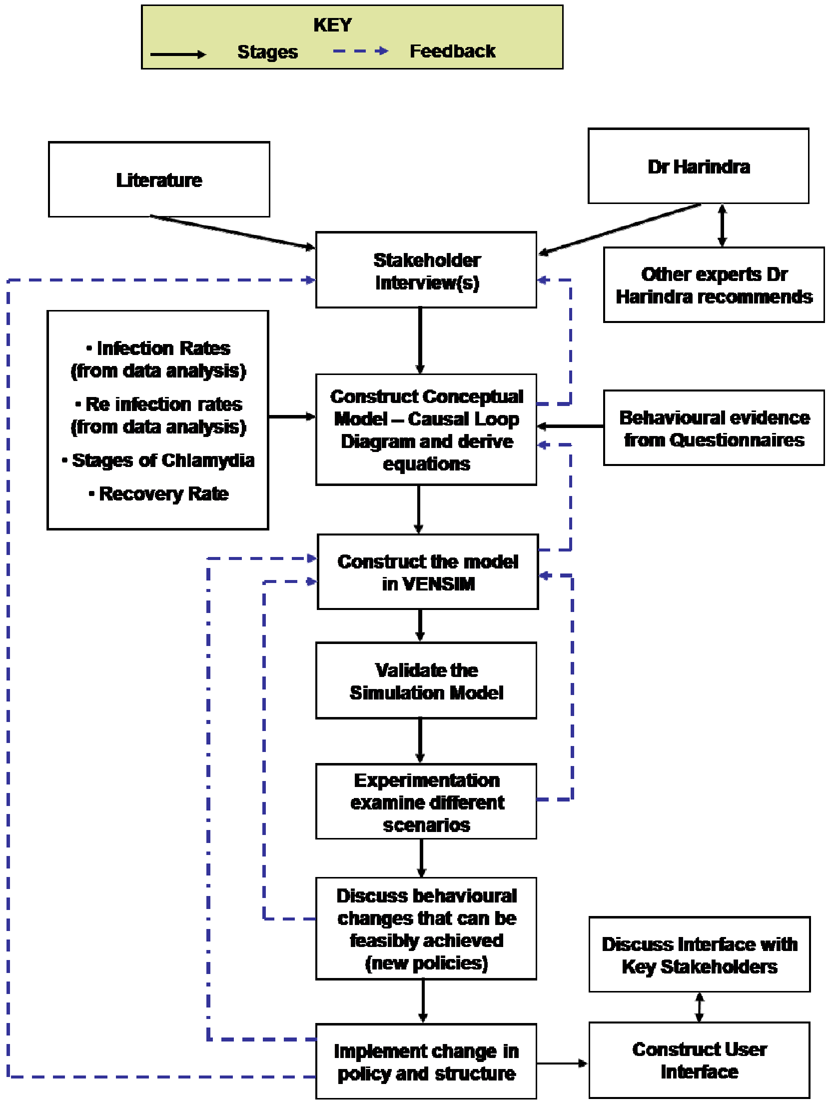


Figure 7.3 – Representation of Infection Modelling

7.3.1 – System Dynamics Simulation (VENSIM)

VENSIM is the System Dynamics Simulation software that will be used to create the Chlamydia infection model. SD operates in terms of stocks and flows which are affected by rates. SD allows the assimilation of quantitative and qualitative data and is commonly used to evaluate strategic choices (Townsend and Turner, 2000). SD allows for expert opinion to be incorporated into the model to better reflect the area under investigation and to promote the acceptability of the model by the stakeholder.

7.4 – Behavioural Investigation

A questionnaire has been designed to ascertain the knowledge about STIs and behavioural characteristics associated with the population under investigation. The questionnaire will be administered at two locations: GUM clinic, St Mary's Hospital Portsmouth and the University of Southampton. The questionnaire will enable comparison between 2 groups: those tested or treated for STI at the GUM clinic and University educated participants.

The implementation of the questionnaire at the two sites is illustrated in figure 7.4. The two groups are being investigated to determine if any difference in knowledge regarding STIs can be attributed to the educational level of the participants. Is it necessarily the case that those attending University have a greater knowledge about STIs?

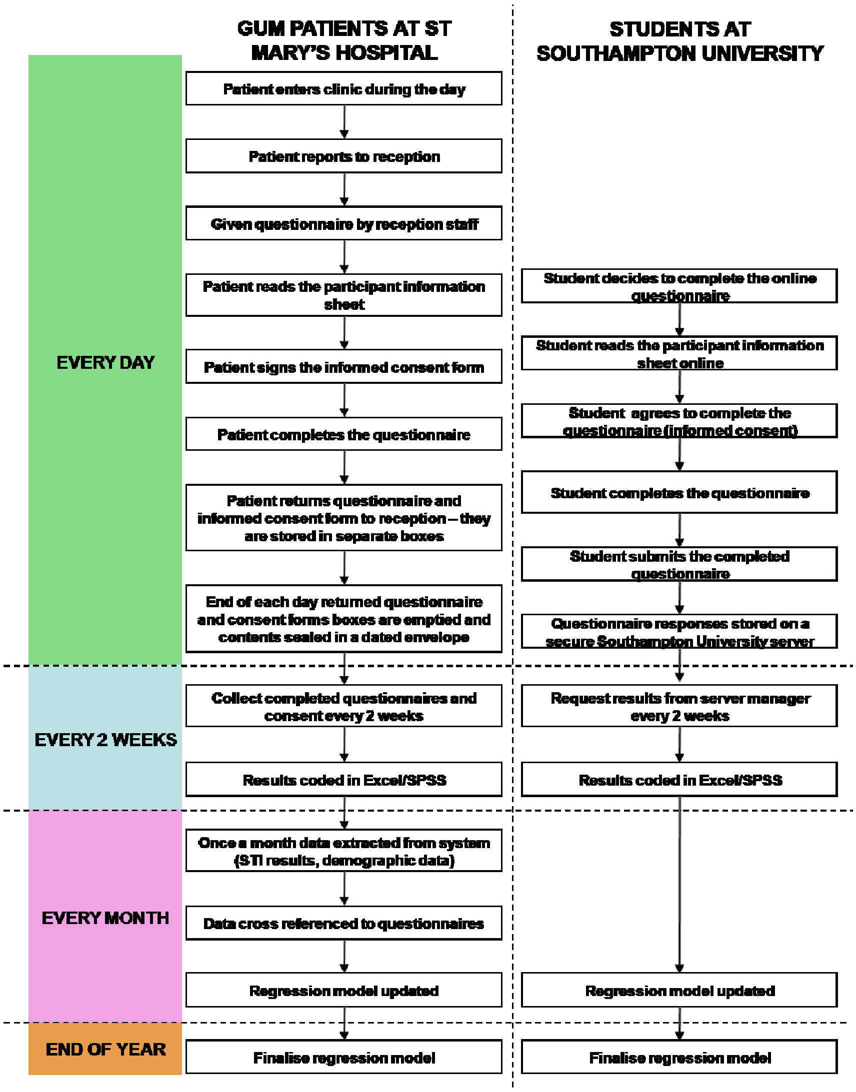


Figure 7.4 – Ideal Representation of Behavioural Investigation

7.4.1 – Population, Sample and Sample Size

The population consists of the patients who visit the GUM clinic who live in the PO Postcode Area, from the East side of Southampton through Portsmouth to beyond Chichester in the East also including the Isle of Wight and the student population at the University of Southampton.

The estimated annual population of patients over 18 year olds to pass through the GUM clinic is 16,000 a year. The estimated annual population of patients aged under 18 to pass through the clinic is 1,500 a year (the ethical implications of including under 18's in the study are discussed in section 10). It is estimated that the Chlamydia infection prevalence in this population is 30% (based on expert opinion). The annual student population at the University of Southampton is 20,000. It is assumed that the prevalence within the population is in line with the national average derived from the National Chlamydia Screening Programme (2006).

The sample size calculator developed by Creative Research Systems (2003) is used to determine the sample sizes. The formulae used by the online calculator to calculate the sample sizes for each group are shown below:

$$ss = \frac{z^2(p) \times (1-p)}{c^2}$$

$$new\ ss = \frac{ss}{1 + \frac{ss-1}{pop}}$$

ss = Sample size

z = Z value (e.g. 1.96 for 95% confidence level)

p = Percentage picking a choice, expressed as decimal

c = Confidence interval, expressed as a decimal

pop = population

Clinic sample size – Patients over 18 years old:

$$ss = \frac{1.96^2\,(0.50 \times 0.50)}{0.05^2} = 384$$

$$new\ ss = \frac{384}{1+\frac{384-1}{16000}} = 375$$

Clinic sample size – Patients under 18 deemed Gillick competent by GUM clinic staff:

$$ss = \frac{1.96^2(0.50 \times 0.50)}{0.05^2} = 384$$

$$new\ ss = \frac{384}{1+\frac{384-1}{1500}} = 306$$

University Student Sample Size:

$$ss = \frac{1.96^2(0.50 \times 0.50)}{0.05^2} = 384$$

$$new\ ss = \frac{384}{1+\frac{384-1}{20000}} = 377$$

7.4.2 – Justification of Sample Sizes

The study is comparing two groups of people, University of Southampton students and patients visiting the GUM clinic. In order to enable a comparison between the two groups we are comparing those who have ever had an STI in their lifetime. It is likely that a person attending the GUM clinic have a greater chance of having ever had an STI, however the majority of students at the University of Southampton fall in the age group that are at the greatest risk of STIs. For this reason it has been proposed that the probability a person has ever had an STI in their lifetime is 50% (p=0.5) this is a conservative estimate as it provides the largest sample size. The study also examines the behaviour of younger patients at the GUM clinic aged 16 and 17. The tables below indicate that when the probability varies from 30-70% for each of the three groups under investigation: GUM patients 18 and over, University of Southampton students and GUM patients aged 16-17, that the sample sizes do not radically change.

Percentage	10	20	30	40	50	60	70	80	90	100
Sample size	138	246	323	369	384	369	323	246	138	0
Adjusted population size	137	242	316	361	375	361	316	242	137	0

Table 7.4.2.1 – Sample size range for GUM patients aged over 18

Percentage	10	20	30	40	50	60	70	80	90	100
Sample size	138	246	323	369	384	369	323	246	138	0
Adjusted population size	137	243	318	362	377	362	318	243	137	0

Table 7.4.2.2 – Sample size range for University of Southampton Students

Percentage	10	20	30	40	50	60	70	80	90	100
Sample size	138	246	323	369	384	369	323	246	138	0
Adjusted population size	127	211	266	296	306	296	266	211	127	0

Table 7.4.2.3 – Sample size range for GUM patients aged 16 and 17

7.4.3 – Inclusion and Exclusion Criteria

People who visit the GUM clinic are included in the survey. The participants will include males and females. Patients attending the clinic who are aged 16-17 and deemed Gillick competent by clinicians will be included in the study those not deemed competent will be excluded from the research. The views of these younger patients are an important source of information regarding sexual health and how the GUM clinic operates. The lower age limit for participation in the research is 16. Students of the University of Southampton will be included in the research. Students will be invited from all schools of the University where approval has been given to do so by the School's Deputy Head for research.

7.4.4 – Informed Consent

Informed consent will need to accompany each completed clinic questionnaire. The Informed consent form used in conjunction with the clinic questionnaire can be found in Appendix II. Informed consent is not required for the student version of the questionnaire as the data collected from students is completely anonymous.

7.4.5 – Questionnaire Design and Implementation

The questionnaire was developed by Joe Viana, through consultation with experts in the field of GUM, by the examination of the literature and the existing sexual behaviour surveys in the UK and the USA. The questionnaire to be completed by the clinic population can be found in Appendix III and the participant information sheet (PIS) for the clinic and student population in Appendix I. The PIS and the questionnaire form the "Sexual Behaviour, Attitudes and Knowledge Survey". Following the PIS before the questionnaire a "definition of terms used" is provided to clarify meanings of terminology where needed (see Appendix III). The informed consent forms are distributed and collected with the questionnaire. Once collected the informed consent forms and the questionnaires are stored separately.

The clinic questionnaire will be given to patients when they enter the clinic if they are deemed competent to consent by the clinic staff. The patient will have the time to complete the questionnaire when they are in the waiting area, waiting for a healthcare professional to become available. If the patient requires time to think about whether they would like to complete the questionnaire they will be provided with a stamped addressed envelope to enable them to complete the questionnaire at home and post it into the clinic at their convenience. The questionnaire takes around 10 minutes to complete. If the patient completes the questionnaire at the clinic they can return it to reception where a member of staff will separate the consent form from the questionnaire and store them in two separate boxes. At the end of the day the boxes will be emptied and their contents stored in two dated envelopes one for consent forms and one for questionnaires. The envelopes will be stored at the GUM clinic at St Mary's. Every two weeks the completed questionnaire data will be coded into Excel at the GUM clinic by Joe Viana to enable data analysis to be undertaken and once coded the completed questionnaires will be stored at the GUM clinic. Questionnaires that are completed outside the GUM clinic that are sent in will be treated in the same way. When they are received by the clinic the consent form and the questionnaire will be separated and placed in the box for that day and treated in the same way mention above.

Once a month the clinic questionnaires will be cross referenced with the STI results using their unique clinic number. From this referencing the patient's date of birth, gender, test result(s) can be obtained and used in the data analysis.

The student version of the questionnaire has been developed online (can be accessed at url: http://apps.socsci.soton.ac.uk/phpq/behaviour-start.php) and contains the majority of the questions included in the clinic questionnaire with the following exceptions:

Student questionnaire includes:

1. Gender question
2. Age at time of completing questionnaire as opposed to DOB.
3. Drop down list to establish which School of the University that the student is from

Student questionnaire does not include:

1. Clinic number

The student questionnaire has been developed as an online version where the student can click on the responses, use drop down lists or type in their relevant answers. Once a student agrees to fill in the questionnaire they have to complete the questionnaire in one sitting. The online questionnaire should take around 10 minutes to complete. The students are informed on the PIS how long the questionnaire will take and that once started they need to complete it in one sitting, as they cannot save it and return at a later date. The data from the student questionnaire will be downloaded from the server every two weeks. The data does not have to be coded as the questionnaire has been completed online but the responses will need to be checked for obvious errors. E.g. someone aged 120 or aged 5.

7.5 – GUM Clinic Model

A simulation model of the clinic will be developed to provide health care professionals with the opportunity to examine alternative configurations of the clinic in a computer model. The model will be developed in the Discrete Event Simulation package Simul8. Figure 7.5 illustrates the stages of the models development.

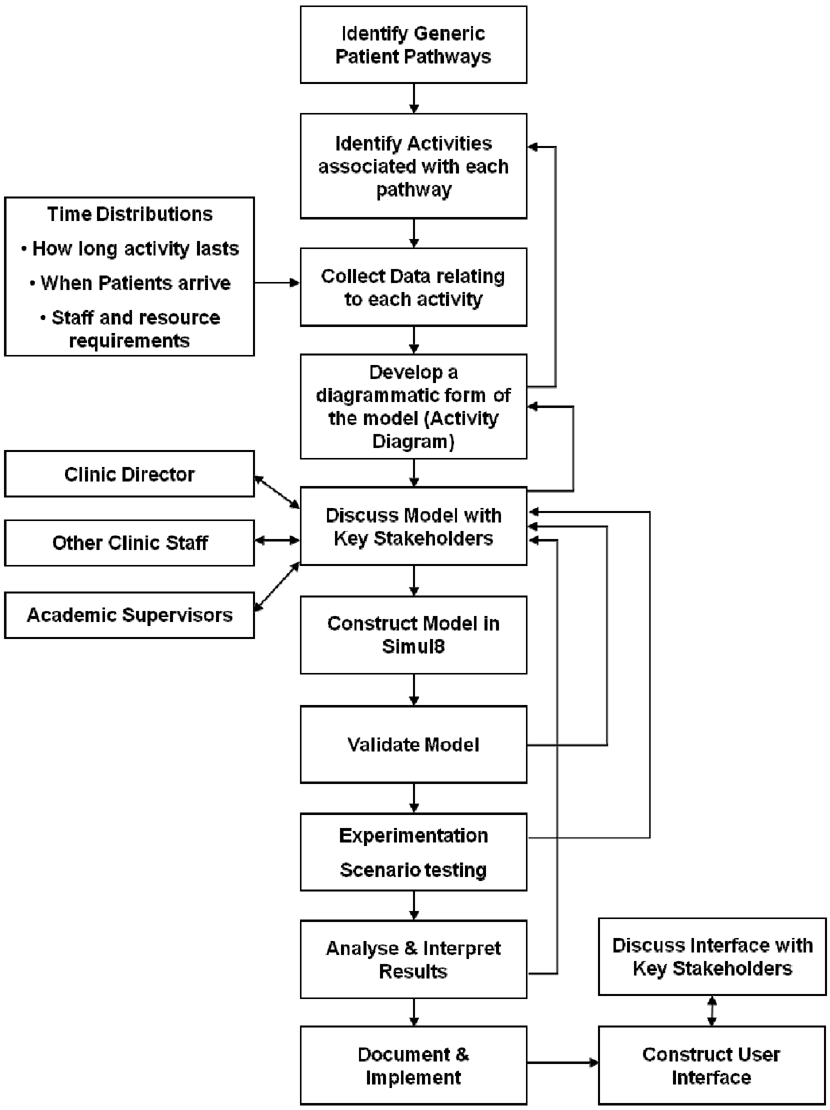


Figure 7.5 – Representation of Clinic Modelling

7.5.1 – Discrete Event Simulation (Simul8)

Discrete event simulation will be conducted in Simul8 computer software and enable situations to be modelled in a computer environment, to allow examination of potential alternatives before adjusting the real life situation.

7.6 – Predictive and Forecasting Models

The predictive model will be used to identify the characteristics associated with males and females and positive Chlamydia (other STIs) results. The Forecasting model will attempt to determine the level of Chlamydia (other STIs) infection in the area over time.

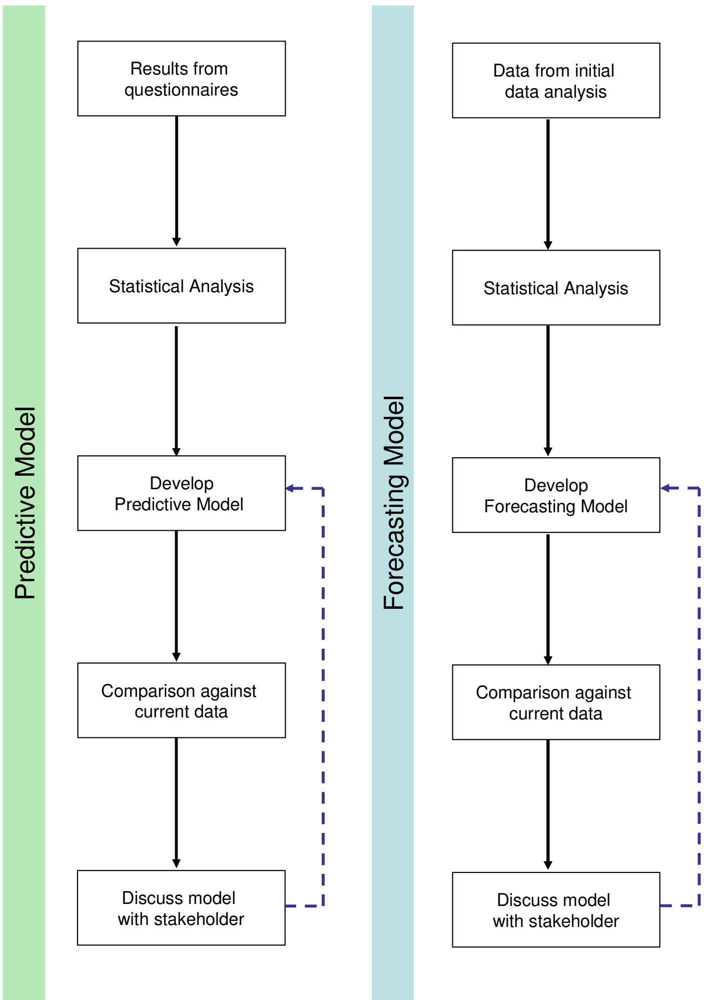


Figure 7.6 – Representation of Predictive and Forecasting Model

7.6.1 – Evolutionary Process

The development of the predictive model and the forecasting model is an evolutionary process as it is dependent on the quality of the data that is obtained. The quality of the data will effect what can be achieved. It cannot be determined exactly at this point how the model will be constructed and which form of forecasting model will best suit the data. It is likely that the predictive model will be a form of regression analysis.

8.0 – Data

Patient record data will need to be examined to determine infection prevalence, re-infection rate, and general demographic information and postcode details to facilitate the use of the geographical referencing software. This information is stored on the GUM clinics data base and this will need to be examined in an anonymised format.

Data will also be collected from the surveys conducted at the GUM clinic and at the University of Southampton.

8.1 – Data Handling and Record Keeping

As the data being collected is highly sensitive, data handling and record keeping is essential. The data will be analysed on a password protected computer and completed questionnaires and informed consent forms will be stored in locked filling cabinets in a secure location.

The completed paper based clinic questionnaires will be stored securely at the GUM clinic, St Mary's hospital Portsmouth. An electronic file containing the results from the clinic questionnaires will be stored on a password protected computer and will only be viewed by the Principal Investigator (Joe Viana) and Dr Harindra Consultant in Genitourinary/HIV Medicine at the GUM clinic, St Mary's Hospital.

Anonymised clinic data will be collected periodically to be analysed. The original complete data are stored at the GUM clinic. The data collected will be approved and anonymised by Dr Harindra before being analysed in an unidentifiable format by Joe Viana.

Student questionnaire results will be stored on a secure server at the University of Southampton. Results will be obtained periodically from this server for analysis.

8.2 – Data Anonymity

Due to the sensitivity of the data, all data used will be anonymised. The clinical records being analysed will be by unique clinic identifiers such as the patient's clinic number and hospital number.

The student responses to the questionnaire will be non identifiable as students do not provide any identifiable details, such as name, email address, or full postcode or data of birth.

9.0 – Statistical Considerations and Results

Statistical analysis will be undertaken in relation to the following:

- Completion of primary data analysis on unidentifiable patient records.
- Initial geographical referencing, following on from primary data analysis.
- Chlamydia infection System Dynamics simulation model evaluation.
- Completion of behavioural investigation.
- Clinic Discrete Event Simulation model evaluation.
- Development of predictive and forecasting models.
- Final geographical referencing incorporating, relevant behavioural investigation results.

The results reported from the above analyses will be in a non identifiable form to ensure participant confidentiality.

9.1 – Statistical Analysis of Questionnaire

The dependent variable for the analysis will be if the person has ever had an STI in their lifetime and independent variables are the other questions. Summary statistics will be produced and logistic and multi linear regression models will be performed on the questionnaire data. The analysis of the questionnaire data will take place in SPSS and in S-PLUS statistical software packages.

9.2 – Missing Data from Questionnaire

Missing data from the questionnaire will be dealt with in a number of ways depending on the question it relates to. Some missing data will not be included in the analysis, other missing data could be substituted with average values where this is possible, and some behavioural questions where there is missing data the answers from a comparable participant could be used to replace this data. Trends could be discovered if certain questions produce lots of missing data, which could provide opportunities for future research.

9.3 – Dissemination of Results

Anonymised results will be disseminated by means of:

- PhD thesis publication.

- Presentations at conferences, workshops and seminars, both in academia and medical settings.
- Publication of papers in refereed journals.

10.0 – Ethical Considerations

The ethical considerations that were identified are the following:

- Co-operation of an Advocate and Participants Under 18
- Psychological Stress or Anxiety
- Sensitive Topics
- Complaints Procedure
- Anonymity Problems
- Recruitment of NHS participants
- Informed Consent
- Confidential Data

Co-operation of an Advocate and Participants Under 18

As the participants will be recruited from the NHS population in the Portsmouth area and the student population at the University of Southampton advocates are required to provide access to the participants. Dr Veerkathy Harindra as Clinical Director at the St Mary's GUM clinic will act as an advocate in the recruitment of NHS patients.

A key group of patients who attend the clinic are under 18 years old and their views are an important element of the behavioural investigation, the forecasting and the predictive models. GUM clinic staff will assess the ability of a patient to consent. If they are deemed Gillick competent (DH, Seeking consent: working with children, 2001) by the member of staff they will be able to take part in the research.

Dr Harindra holds the STI test results in an electronic form at the clinic. Ethical approval is sought from the relevant bodies to be able to use this data to undertake the relevant statistical analysis to construct the simulation models and carry out the geographical referencing. Once ethical authorisation has been obtained the data will be anonymised by Dr Harindra and analysed by Joe Viana under his supervision.

Advocates from the University of Southampton have been identified as the Deputy Heads of School for Research at each of the University's schools. The Deputy Heads of School will be approached by Professor Brailsford Head of the Law, Arts and Social Sciences (LASS) Graduate School. It is hoped that Professor Brailsford will be able to facilitate the opportunity and approval from the Deputy Heads of Schools to advertise the link to the online questionnaire to the students of their school.

Psychological Stress or Anxiety

The aim of the survey developed is to assess an individual's sexual behaviour; as such the questions need to be worded in such a way as not to cause offence but also to elicit all of the required detail from the participants. The survey has been developed to cause as little stress as possible however it is anticipated that some concerns and questions may arise. Participants at the GUM clinic may feel anxious about providing personal data and allowing the research to link this data to their STI test results.

Participants are provided on the PIS with the contact details of an independent body separate from the study if they have any concerns or questions about the research. The independent body is the Research Governance Office at the University of Southampton.

Sensitive Topics

The sensitive nature of the survey has been touched upon in Psychological Stress or Anxiety section. Care has been taken in the wording of the questions and the design of the survey. It is however anticipated that some participants may be concerned or have questions about part of the research. Concerns or questions can be directed to the Research Governance Office as discussed in the Psychological Stress or Anxiety section above.

The participant information sheet indicates the importance of the study and that the answers given will be treated in the strictest confidence and stored securely. In addition at the top of each page of the questionnaire there is a notice informing the participants that they do not need to answer any question they don't want to. This may lead to statistical calculation problems later but this will be addressed as and when the situation arrives.

Anonymity Problems

The clinic questionnaire responses are anonymised and the patients' clinic number is used as a unique identifier. The student questionnaire responses are anonymous as the student does not provide any identifiable data. The participants have been informed on the PIS that the answers they give will be stored securely both in paper form and electronic form by means of locked filing cabinet and password protected computer respectively.

Recruitment of NHS participants

The recruitment of NHS patients will be undertaken by the staff at the GUM clinic at St Mary's hospital. Approval needs to be obtained from the NHS Research Ethics Committee, the R&D office at Portsmouth and Research Governance Office at the University of Southampton before the research commences. This approval relates to the entire scope of the research including the computer simulation and data analysis aspects of the research and is not limited to the behavioural investigation (questionnaire).

Informed Consent

Informed consent needs to be obtained from the participants taking part in the behavioural study at the GUM clinic as the data provided are initially identifiable and permission needs to be obtained to access their medical records. Informed consent is not required from University of Southampton students as the data they provide will be totally unidentifiable.

Confidential Data

Anonymised patient case records and participant's answers in the questionnaire are highly sensitive data sources and as such need to be kept confidential. The data as already mentioned will be treated with the strictest confidence and stored securely during the research and the period following the research. Data will be stored for 15 years as a requirement of the PhD programme. On completion of his PhD Joe Viana will transfer any data used for analysis to the GUM clinic for storage.

11.0 – Finance and Insurance

11.1 – Breakdown of Costs

The research will be undertaken by Joe Viana a PhD student from the School of Management, University of Southampton and is anticipated to last 36 months. The breakdown of costs (Table 11.1) relates to the data collection element of the research and the associated materials. The breakdown incorporates student time, materials for questionnaire design and deployment of the survey, software required to construct the simulations. The "Funded by" column details which organisation will cover the costs and relates solely to the data collection, analysis and model development period.

Activity	**Cost (£)**	**Funded By**
12 months – Student Maintenance	14,300	University

(£14,300 per year)		
Printing of 800 – Questionnaires and Patient Information Sheets – for use in GUM clinic (6 pages x 800 = 4,800 x 5p per page)	240	GUM clinic
Printing of 800 – Informed consent form – for use in the GUM clinic (1 page x 800 = 800 x 5p per page)	40	GUM clinic
800 Stamped address envelopes – for patients to return questionnaire if they do not complete it at the clinic (800 x 22p per envelope)	176	GUM clinic
Collect completed questionnaires every 2 weeks & discuss progress with Dr Harindra (26 trips to Portsmouth = 26 x £40)	1,040	University
Development of Online questionnaire and secure server space (2% of System programmer for 12 months)	570	University
VENSIM Simulation Package	100	University
Simul8 Simulation Package	500	University
ARCGIS Software	500	University
Total	**17,466**	

Table 11.1 – Financial breakdown

11.2 – Insurance

The University of Southampton will provide insurance cover as it holds Professional Indemnity and Clinical Trials Insurance – a copy of the letter of University support is enclosed in this document see appendix IV.

12.0 – References

Creative Research Systems (2003) Sample Size Calculator, url: http://www.surveysystem.com/sscalc.htm

Department of Health (2001) Better prevention, better services, better sexual health – The national strategy for sexual health and HIV, The Stationery Office, HM Government

Department of Health (2001) Seeking consent: working with children, The Stationery Office, HM Government

Department of Health (2004) Choosing Health: Making healthy choices easier, The Stationery Office, HM Government

Department of Health (2006) Our health, our care, our say: a new direction for community services, The Stationery Office, HM Government, ISBN 0101673728

Evenden, D., Harper, P.R., Brailsford, S.C., Harindra, V. (2005) Improving the cost-effectiveness of Chlamydia screening with targeted screening strategies, Journal of the Operational Research Society, pp1-13

National Chlamydia Screening Programme Steering Group (2006) New Frontiers: Annual Report of the National Chlamydia Screening Programme in England 2005/06, London, HPA

Townsend, J.R.P. and Turner, H.S. (2000) Analysing the effectiveness of Chlamydia screening, Journal of the Operational Research Society, Vol. 51, pp 812-8

B. Chlamydia screening database

1.0 – Old GUM system

Following figures 1.1 through 1.9 are extracts from the previous computer system that the GUM clinic used to record Chlamydia screening information. This system along with the current system discussed in section 2 were utilised to obtain some of the data used in the produced computer models.

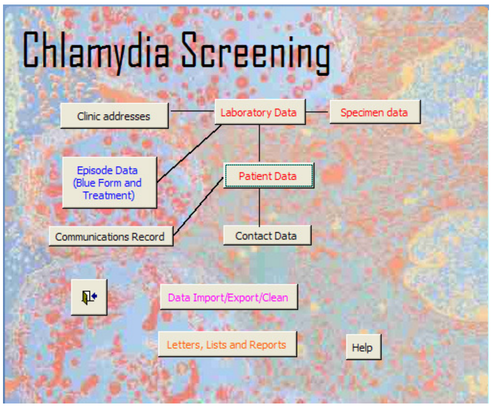


Figure 1.1: Previous Chlamydia screening database held at GUM at St Mary's Hospital

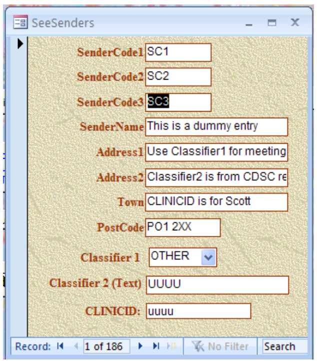


Figure 1.2: Clinic addresses

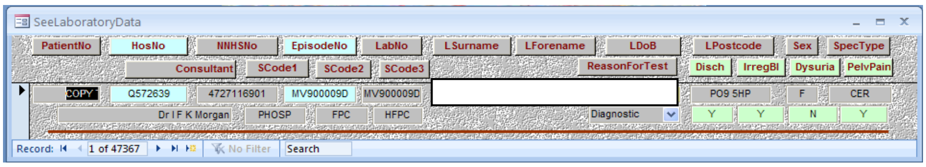


Figure 1.3: Laboratory Data

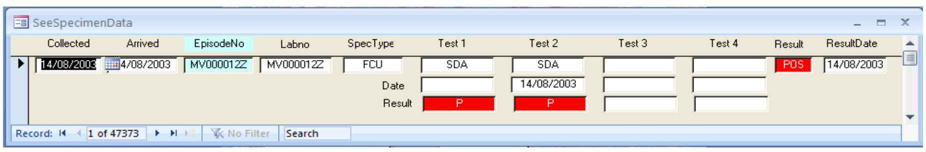


Figure 1.4: Specimen data

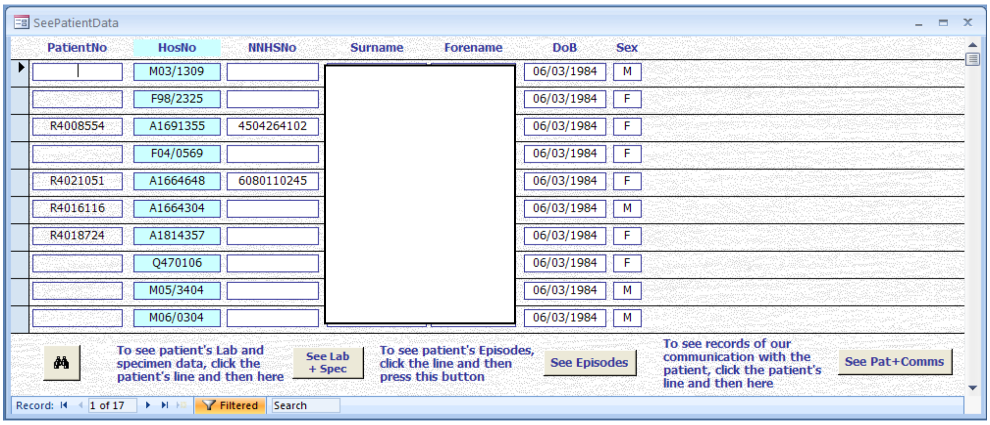


Figure 1.5: Patient Data

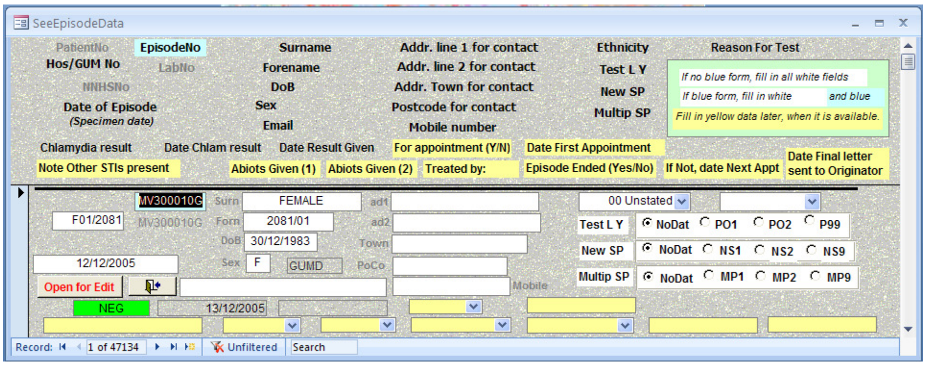


Figure 1.6: Episode Data (Blue Form and Treatment)

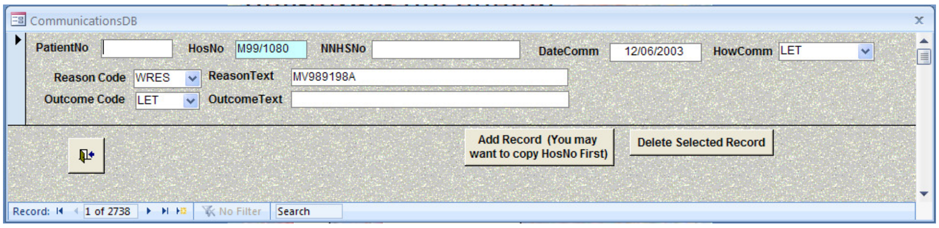


Figure 1.7: Communications Record

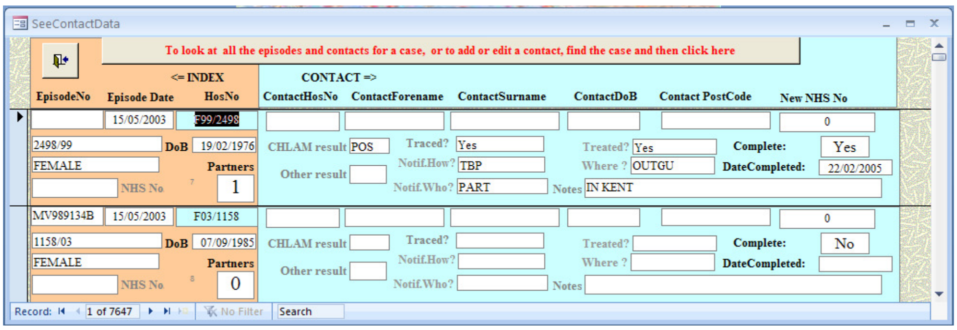


Figure 1.8: Contact Data

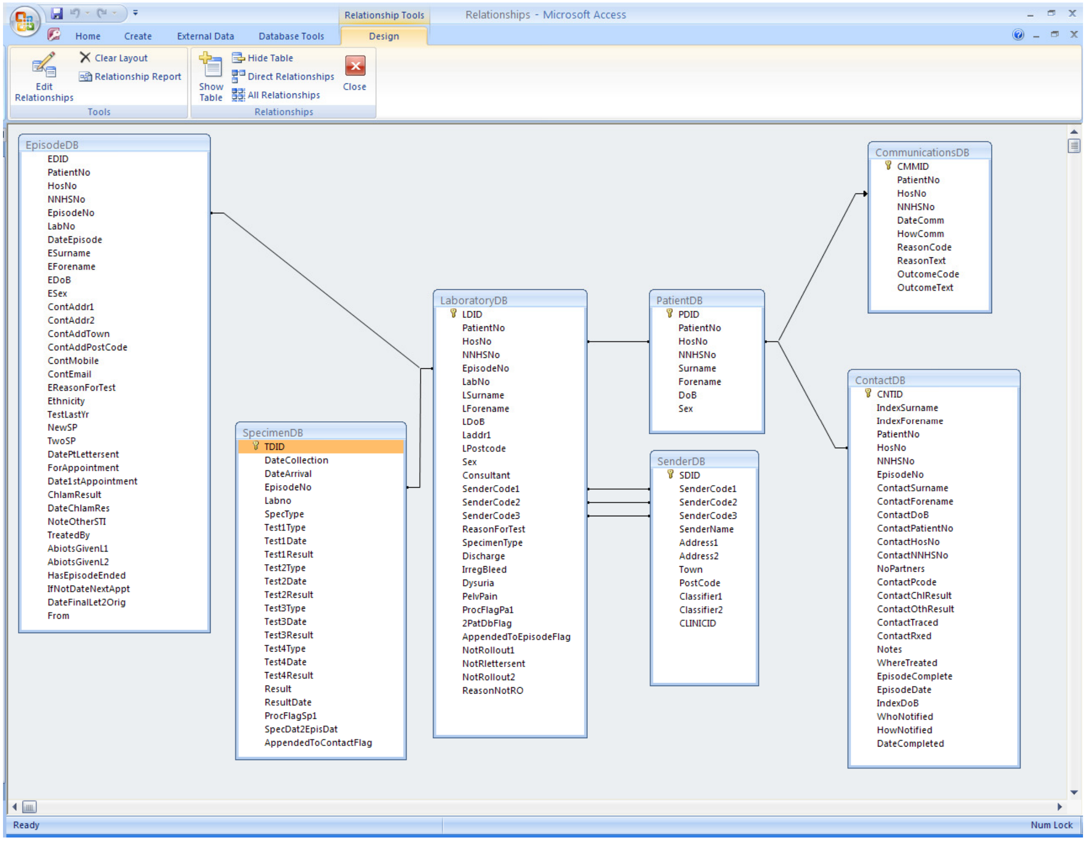


Figure 1.9: Relationships between tables within previous Chlamydia screening database

2.0 – New System

The original Chlamydia screening access database system was replaced with a system developed called Geoclinic System. Examples of the type of data that were available from the new system are shown in figures 2.1 and 2.2.

Figure 2.1: Clinical Reports available from system

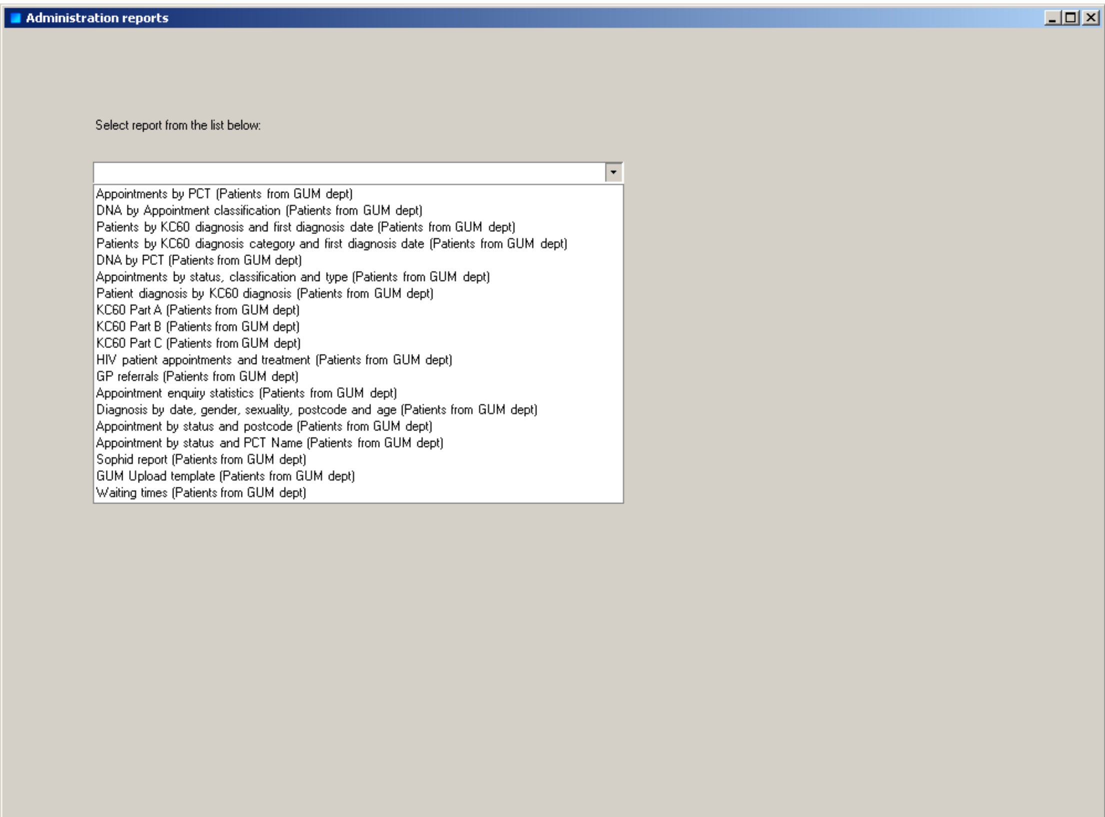


Figure 2.2: Admin reports available from Maintenance tab

C. Socioeconomic datasets

CASWEB (http://casweb.mimas.ac.uk/)

Data	Source
CS105: Age by Highest Level of Qualification	2001 Census
CT005: Theme Table on All People	2001 Census
KS005: Country of birth	2001 Census
KS006: Ethnic group	2001 Census
KS14a: National Statistics – Socio Economic Classification – all persons	2001 Census
KS017: Cars or vans	2001 Census
UV006: Dependent Children	2001 Census
UV020: General Health	2001 Census
UV058: Persons Per Room	2001 Census

Neighbourhood Statistics
(http://www.neighbourhood.statistics.gov.uk/dissemination/)

Data	Source
Notifiable Offences, 2006/07	Home Office
Benefit Data: Summary Statistics, August 2006	Department for Work and Pensions
Child Benefit Families, 2006	HM Revenue and Customs
County Court Judgements – Personal Consumer Debt, 2005	Registry Trust Ltd
Conceptions – Under 18's, 2006	Office for National Statistics
Homelessness, 2004/05	Department for Communities and Local Government
UV93: Same-Sex Couples	2001 Census
UV81: Armed Forces	2001 Census
Deaths, 2006	Office for National Statistics
UV04: Age	2001 Census

D. Participant Information Sheet and Consent Form

Participant Information Sheet – Over 18

Portsmouth Hospitals NHS NHS Trust

UNIVERSITY OF Southampton

Participant Information Sheet

Sexual Behaviour, Attitudes and Knowledge Survey

Study Title – STIGMA – Sexually Transmitted Infection GUM MAnagement toolkit

I am Joe Viana, a PhD student from the School of Management at the University of Southampton. I am conducting research that aims to use computer models to reduce the spread of Sexually Transmitted Infections (STIs). The research is being carried out in collaboration with the Genito-Urinary Medicine (GUM) clinic at St Mary's Hospital Portsmouth. The survey which I am asking you to complete will contribute towards the completion of my PhD, as well as expand the current knowledge about STIs.

Before you decide whether to take part in the research you need to understand why the research is being done and what it would involve for you. Please take the time to read the following information carefully. Talk to others about the study if you wish.

What is the purpose of the Study?
The purpose of this study is to increase our understanding about STIs and to reduce the number of people who have STIs. Computer modelling will be used in this research. This involves representing a situation such as the GUM clinic in a computer program, similar to a computer simulation game. The program is used to test out proposed changes to the clinic system and see how they affect the imaginary patients in the computer program. This enables us to discover what works best before putting any changes into practice for real patients in the actual clinic environment.

The principal research objective of this study is:

How can levels of Sexually Transmitted Infections (STIs) in the UK be decreased?

The study aims to answer the following specific questions:

1. What work has already been done, in Hampshire and elsewhere, to assess the most efficient and effective way(s) to reduce the levels of STIs?
2. How can computer modelling approaches be used to assist the GUM clinic to plan potential improvements?
3. How can computer modelling approaches be used to increase understanding about the spread of STIs within a computer simulated population?
4. Are there specific geographical areas within a region which require focused attention from the GUM clinic?
5. Are certain behaviours, attitudes or knowledge associated with particular STIs?

Why have I been chosen?
Two groups of people have been asked to fill in the questionnaire:

i. Patients who attend the GUM clinic at St Mary's Hospital, Portsmouth.
ii. Students at the University of Southampton.

Patients of the clinic and students of the University of Southampton have been chosen to complete this survey to determine if a person's level of education is associated with a greater level of knowledge and awareness about STIs and risky sexual behaviour or if experience of STIs is.

You have been chosen to complete this questionnaire as you are in one of the two groups, patient at the GUM clinic or University student.

Do I have to take part?
It is up to you to decide. We will describe the study through this information sheet, which you can keep and take away with you. We will then ask you to sign a consent form to show you have agreed to take part.

What will happen to me if I take part?
If you choose to take part:

i. Patients at the GUM clinic
   a. You will be asked to complete a paper based questionnaire with the paper work you collect from reception on entry to the GUM clinic. Alternatively you may take the questionnaire home, where you can complete it and return it by post or in person to the clinic at a later date.
   b. The questionnaire should take around 10 minutes to complete.
   c. The questionnaire results will be linked with your clinical record at the clinic.
   d. Please only complete the questionnaire once.

ii. Students at the University of Southampton
   a. You will be asked to complete an online questionnaire.
   b. The online questionnaire should take around 10 minutes to complete.
   c. The online questionnaire needs to be completed in one sitting.
   d. Please only complete the online questionnaire once.

What will I have to do?
We would be grateful if you could spend around 10 minutes to fill in this questionnaire as accurately as possible. We must stress that your participation is voluntary and you don't have to complete this questionnaire or any question in it if you don't want to – it's entirely your choice

Once you have filled in the questionnaire:

i. Patients at the GUM clinic: please return the questionnaire to reception or post it back to the clinic in the stamped addressed envelope.
ii. Students at the University of Southampton: please complete the questionnaire online.

Students who complete the questionnaire online: please ensure that you complete the questionnaire only once, as it is possible to take the questionnaire multiple times as it is completely anonymous.

All questionnaires (paper and electronic) and information provided will be stored securely either in locked cabinets or on a password protected computer in a secure location.

What are the possible disadvantages and risks of taking part?
The questionnaire is about a sensitive topic that may cause embarrassment. Remember that you don't have to answer any question(s) if you don't want to.

What will happen if I don't want to carry on with the study?

You are free to withdraw at any time, without giving a reason. This would not affect the standard of care you receive. Data that you have provided which is not identifiable to the research team may be retained. Any identifiable data would be anonymised or disposed of. Please see "What if there is a problem?" section if you wish to contact someone about withdrawing from the study.

What if there is a problem?
If you have any concerns about the questionnaire, the researcher or you wish to withdraw, you have the opportunity to do this through an independent body separate to the study:

Research Governance Office
George Thomas Building 37
Rooms 4007/9
University of Southampton
Highfield
Southampton SO17 1BJ
rgoinfo@soton.ac.uk

Will my taking part in the study be kept confidential?
Your taking part in the study will be kept confidential, unless the information you provide on the questionnaire indicates that you have been sexually abused or have sexually abused someone, or you have taken illegal drugs. If the above information is provided then confidentiality cannot be upheld and your information will be passed on to the GUM clinic to take the matter further following the procedures they have in place to deal with such instances.

What will happen to the results of the research study?
The information you provide will be used in an unidentifiable format in the modelling process and in the PhD thesis which is to be produced at the end of this study. Unidentifiable data may be used in other publications that might come out of this study. The information used as stated will be in an unidentifiable format and in no way can be linked back to you.

Results will be displayed in poster format at the GUM clinic at St Mary's hospital on completion of the study.

Who is organising and funding the research study?
The project is funded by the Engineering and Physical Sciences Research Council (EPSRC).

Who has reviewed the study?
All research in the NHS is looked at by an independent group of people, called a Research Ethics Committee to protect your safety, rights, wellbeing and dignity. This study has been reviewed and given a favourable ethical opinion for conduct by the Berkshire Research Ethics Committee

Further information and contact details
The research is being carried out by Joe Viana, a PhD student from the University of Southampton and contributes towards his PhD qualification. Further information can be obtained from:

Joe Viana
School of Management,
University of Southampton,
Southampton
SO17 1BJ
Email: J.Viana@soton.ac.uk

Participant Information Sheet – Under 18

Portsmouth Hospitals NHS
NHS Trust

UNIVERSITY OF Southampton

Participant Information Sheet

Sexual Behaviour, Attitudes and Knowledge Survey

Study Title – STIGMA – Sexually Transmitted Infection GUM MAnagement toolkit

I am Joe Viana, a student from the University of Southampton. I am conducting research to reduce the spread of Sexually Transmitted Infections (STIs). The research is being carried out with the Genito-Urinary Medicine (GUM) clinic at St Mary's Hospital Portsmouth. The questionnaire which I am asking you to complete will contribute towards the completion of my University degree, as well as increase knowledge about STIs.

Before you decide whether to take part in the research you need to understand why the research is being done and what it would involve for you. Please take the time to read the following information carefully. Talk to others about the study if you wish.

What is the purpose of the Study?
The purpose of this study is to increase our understanding about STIs and to reduce the number of people who have STIs. Computer modelling will be used in this research. This involves representing a situation such as the GUM clinic in a computer program, like a computer simulation game. The program is used to test out new ideas in the clinic system and see how they affect the imaginary patients in the computer program. This enables us to discover what works best before putting any changes into practice for real patients in the actual clinic environment.

The reason for the research is to see:

How can the number of people who have Sexually Transmitted Infections (STIs) in the UK be decreased?

The study aims to answer the following questions:

6. What work has already been done, in Hampshire and elsewhere, to assess the most efficient and effective way(s) to reduce the number of people who have STIs?
7. How can computer modelling approaches be used to help the GUM clinic plan potential improvements?
8. How can computer modelling approaches be used to increase understanding about how STIs spread within a computer model containing imaginary people?
9. Are there specific areas within the city which require more attention from the GUM clinic?
10. Are certain behaviours, attitudes or knowledge associated with particular STIs?

Why have I been chosen?
You have been chosen as you are attending the GUM clinic at St Mary's Hospital Portsmouth

Do I have to take part?

It is up to you to decide. We will describe the study through this information sheet, which you can keep and take away with you. We will then ask you to sign a consent form to show you have agreed to take part.

What will happen to me if I take part?
If you choose to take part:

iii. You will be asked to complete a questionnaire with the paper work you collect from reception on entry to the GUM clinic. You may take the questionnaire home if you want to, where you can complete it and return it by post or in person to the clinic at a later date.
iv. The questionnaire should take around 10 minutes to complete.
v. The questionnaire results will be linked with your clinical record at the clinic.
vi. Please only complete the questionnaire once.

What will I have to do?
We would be grateful if you could spend around 10 minutes to fill in this questionnaire as accurately as possible. We must stress that your taking part is voluntary and you don't have to complete this questionnaire or any question in it if you don't want to – it's entirely your choice.

Once you have filled in the questionnaire please return the questionnaire to reception or post it back to the clinic in the stamped addressed envelope. All questionnaires and information provided will be stored securely in locked cabinets in a secure location.

What are the possible disadvantages and risks of taking part?
The questionnaire is about a sensitive topic that may cause embarrassment. Remember that you don't have to answer any question(s) if you don't want to.

What will happen if I don't want to carry on with the study?
You are free to withdraw at any time, without giving a reason. This would not affect the standard of care you receive. Data that you have provided which is not identifiable to the research team may be retained. Any identifiable data would be anonymised or disposed of. Please see "What if there is a problem?" section if you wish to contact someone about withdrawing from the study.

What if there is a problem?
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Rooms 4007/9
University of Southampton
Highfield
Southampton SO17 1BJ
rgoinfo@soton.ac.uk

Will my taking part in the study be kept confidential?
Your taking part in the study will be kept confidential, unless the information you provide on the questionnaire indicates that you have been sexually abused or have sexually abused someone, or you have taken illegal drugs. If the above information is provided then confidentiality will be broken and your information will be passed on to the GUM clinic to take the matter further following the procedures they have in place to deal with such situations.

What will happen to the results of the research study?
The information you provide will be used in an unidentifiable format in the modelling process and in Joe's degree thesis which is to be produced at the end of this study. Unidentifiable data may be used in other publications that may come out of this study.

The information used as stated will be in an unidentifiable format which in no way can be linked back to you.

Results will be displayed in poster format at the GUM clinic at St Mary's hospital on completion of the study.

Who is organising and funding the research study?
The project is funded by the Engineering and Physical Sciences Research Council (EPSRC).

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All research in the NHS is looked at by an independent group of people, called a Research Ethics Committee to protect your safety, rights, wellbeing and dignity. This study has been reviewed and given a favourable ethical opinion for conduct by the Berkshire Research Ethics Committee

Further information and contact details
The research is being carried out by Joe Viana, a PhD student from the University of Southampton. This research contributes towards his PhD qualification. Further information can be obtained from:

Joe Viana
School of Management,
University of Southampton,
Southampton
SO17 1BJ
Email: J.Viana@soton.ac.uk

Consent Form

Portsmouth Hospitals NHS
NHS Trust

UNIVERSITY OF Southampton

Consent Form

Title of Project: **Sexual Behaviour, Attitudes and Knowledge Survey**

Name of Researchers: **JOE VIANA and DR V HARINDRA**

Please enter your clinic number: ☐☐☐ / ☐☐☐☐ Example: M 0 8 / 1 2 3 4

Please initial Box

1. I have read and understood the Participant Information Sheet dated 02/06/2008 (version 2) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. ☐
3. I agree that the data I provide once analysed can be published in an unidentifiable format. ☐
4. I understand that relevant sections of my medical notes and data collected during the study, may be looked at by individuals from the University of Southampton, from regulatory authorities or from the NHS Trust, where it is relevant to my taking part in this research I give permission for these individuals to have access to my records. ☐
5. I agree to take part in the above study. ☐

Name of Patient	Date	Signature

REC Reference Number: 08/H0505/71

Clinic Consent form (version 1) – 27/03/2008

E. GUM and student questionnaire

GUM paper based questionnaire

Portsmouth Hospitals NHS Trust

UNIVERSITY OF Southampton

Sexual Behaviour, Attitudes and Knowledge Survey

Sexual Behaviour, Attitudes and Knowledge Survey

GUM Clinic Version 2 - 02/06/2008

REC Reference Number: 08/H0505/71

Portsmouth Hospitals NHS Trust

UNIVERSITY OF Southampton

Sexual Behaviour, Attitudes and Knowledge Survey

Definitions of terms used in questionnaire

PARTNERS OR SEXUAL PARTNERS:

People who have had sex together - whether just once, or a few times, or as regular partners, or as married partners.

GENITAL AREA:

A man's penis or a woman's vagina - that is, the sex organs.

VAGINAL SEXUAL INTERCOURSE:

A man's penis in a woman's vagina. This is what people most usually think of as 'having sex' or 'sexual intercourse'.

ORAL SEX (oral sexual intercourse):

A (*woman/man's*) or a (*man/woman*'s) mouth on a partner's genital area.

ANAL SEX (anal sexual intercourse):

A man's penis in a partner's anus (rectum or back passage).

SEXUAL INTERCOURSE, OR 'HAVING SEX':

This includes vaginal, oral and anal sexual intercourse.

GENITAL CONTACT NOT INVOLVING INTERCOURSE:

Forms of contact with the genital area NOT leading to intercourse (vaginal, oral, or anal), but intended to achieve orgasm, for example, stimulating by hand.

ANY SEXUAL CONTACT OR EXPERIENCE:

This is a wider term and can include just kissing or cuddling, not necessarily leading to genital contact or intercourse.

WITHDRAWAL:

Withdrawal is sex without using contraception and where the man withdraws before ejaculation (cumming)

Portsmouth Hospitals NHS Trust

University of Southampton

Sexual Behaviour, Attitudes and Knowledge Survey

Remember all your answers are strictly confidential, and you don't have to answer any questions you don't want to.

1. Please enter your clinic number. For example M08 1234 ☐☐☐ / ☐☐☐☐

2. What is your postcode? For example PO17 1BJ ☐☐☐☐ ☐☐☐

3. Which of the following best describes your sexual orientation?

Heterosexual (straight) ○ Homosexual (gay/lesbian) ○ Bisexual ○ Not sure ○

4. What is your ethnic background?

Asian (British) ○ Asian (Other) ○
Black (British) ○ Black (Other) ○
White (British) ○ White (Other) ○

Other *Please Say:* ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

5. Who do you live with? *Please mark all answers that apply to you:*

Parents ○ Husband/wife ○ Friends ○ Older sibling(s) ○ Number ☐☐
Single Parent ○ Partner ○ On your own ○ Younger sibling(s) ○ Number ☐☐
Other guardian(s) ○ Own children ○

6. Please mark the **one circle** which best describes you

In full time education: School ○ College ○ University ○

In paid employment: Part-time ○ Full-time ○ Unemployed ○

House Wife ○

7. What Qualifications do you have? *Please mark all that apply to you:*

Postgraduate Degree ○ Undergraduate Degree ○ 'A' level ○ Currently at University ○
GCSE Grades A-C ○ GCSE Grades D-G ○ GCSE Grades U ○ Currently at School ○

8. How often have you had an alcoholic drink of any kind during the last 12 months?

Five or more days a week ○
Three or four days a week ○
Once or twice a week ○
Once or twice a month ○
Once or twice in the last 12 months ○
Not at all in the last 12 months ○ ***(if marked please skip to question 10)***

9. About how many drinks do you usually have on the days when you have any, apart from parties or special occasions?

One or two ○ Three or four ○ Five or six ○ More than six ○

10. Have you ever had sex whilst being drunk? Yes ○ No ○

11. Do you ever smoke cigarettes? Yes ○ No ○ ***(if No please skip to question 13)***

REC Reference Number: 08/H0505/71 Clinic questionnaire (Version 2) – 02/06/2008

Portsmouth Hospitals NHS Trust

University of Southampton

Sexual Behaviour, Attitudes and Knowledge Survey

Remember all your answers are strictly confidential, and you don't have to answer any questions you don't want to.

12. About how many cigarettes do you smoke a day?

Less than 10 ○ Between 10-20 ○ Between 20-40 ○ More than 40 ○

13. Have you ever injected yourself with any drugs or other substances, which have not been prescribed?

Yes ○ No ○

14. Have you ever shared a needle – used for injecting — with someone else?

Yes ○ No ○ Don't know ○

15. Have you ever had sex with someone who takes or shoots street drugs using a needle?

Yes ○ No ○ Don't know ○

16. Have you ever had sex whilst being under the influence of drugs? (including other non injected drugs)

Yes ○ No ○

17. For how long have you lived in this (city/town/village)?

Always (i.e. since birth - never lived elsewhere) ○
1 year or less ○
Over 1-5 years ○
Over 5-10 years ○
Over 10-20 years ○
Over 20 years (but not always) ○

18. Were you born in?

United Kingdom ○ Africa ○ Asia ○ Australasia ○
Europe (not UK) ○ North America ○ South America ○ Other please state below ○

(if you stated United Kingdom please go to question 20, else go to 19)

19. How old were you when you (first) came to live in the United Kingdom? ☐☐ years old

20. At what age did you first have vaginal sexual intercourse? ☐☐ years old

Never had vaginal sexual intercourse ○

21. Which of the following best describes your current sexual relationship status?

Please read all the options before making your selection.

I'm not currently in any kind of sexual relationship ○
I'm not in a regular sexual relationship but I'm having casual sex with people ○
I'm in a regular sexual relationship with one person ○
I'm in a regular sexual relationship with one person but I also have sex with another person / other people ○

22. In the last 3 months, how many sexual partners have you had?

☐☐ Person/people

REC Reference Number: 08/H0505/71

Clinic questionnaire (Version 2) – 02/06/2008

Portsmouth Hospitals NHS Trust

University of Southampton

Sexual Behaviour, Attitudes and Knowledge Survey

Remember all your answers are strictly confidential, and you don't have to answer any questions you don't want to.

23. Which of the following best describes the age difference between yourself and the last person you had sexual intercourse with?

More than 4 years younger ○
2-4 years younger ○
About the same age (within about 1 year of my age) ○
2-4 years older ○
More than 4 years older ○

24. The last time you had sexual intercourse with someone how far from you did that person live?

Within 1 mile ○
Between 2 miles 5 miles ○
Between 5 miles and 10 miles ○
A different city ○
A different country ○
Don't know ○

25. The last time you had sexual intercourse, did you use a condom?

Yes ○ No ○ ***(if No please skip to question 29)***

26. The last time you had sexual intercourse, which of the following best describes when the condom was put on?
Please read all the options before making your selection.

Before intercourse had started - before any penetration occurred ○
After we had started intercourse – pulled out after some penetration and then put the condom on ○

27. If the condom was put on after penetration, was it being used for ejaculation only (i.e. just for cumming)?

Yes ○ No ○

28. The last time you had sexual intercourse, when was the condom removed?

Before ejaculation (i.e. cumming) ○ After ejaculation (i.e. cumming) ○

29. If you have had unprotected sex (no condom), what have the reasons been for not using a condom?
Please mark all that apply to you

Drunk/drugged up ○
Wanted to but didn't say anything ○
Didn't want to spoil the moment ○
Wanted to get pregnant ○
Didn't have any ○
Didn't think of it ○
Partner didn't want to ○

30. In the past year have you used condoms (mark all that apply):

to prevent pregnancy ○
to protect against HIV and other sexually transmitted infections ○
None of the above ○ ***(if marked please skip to question 32)***

31. Which was the main reason: to prevent pregnancy or to protect against infection? Please mark the one answer that applies to you

To prevent pregnancy ○
To prevent infection ○
Both equal ○
Depends on who the partner is ○
Don't know ○

REC Reference Number: 08/H0505/71 Clinic questionnaire (Version 2) – 02/06/2008

Portsmouth Hospitals NHS Trust

University of Southampton

Sexual Behaviour, Attitudes and Knowledge Survey

Remember all your answers are strictly confidential, and you don't have to answer any questions you don't want to.

32. Which method of contraception do you use now?

Condom ○	Injection ○	Withdrawal ○	None ○
Pill ○	Implant ○	Diaphragm ○	

33. Since you had sexual intercourse for the first time, have you or your partner(s) ever used emergency contraception?

Yes ○ No ○

34. Have you ever given oral sex (*woman/man*) - by you to a partner, that is your mouth on a partner's genital area?

Yes ○ No ○

35. Have you ever received oral sex (*woman/man*) - by a partner to you, that is a partner's mouth on your genital area?

Yes ○ No ○

36. Have you ever had **ANAL SEX** with a (*woman/man*)?

Yes ○ No ○

37. ***For WOMEN ONLY men go to question 38***
Have you ever had any form of sexual contact with another woman?

Yes ○ No ○

38. Have you ever met a new sexual partner on the internet, dating or social websites?

Yes ○ No ○

39. We would like to know what you think the risks of becoming infected with any STI are in the following groups...	Greatly At Risk	Quite A Lot	Not Very Much At Risk	Not At All	Don't Know
a) the risks to you, personally, with your present sexual lifestyle?	○	○	○	○	○
b) People who have sex with many different partners of the opposite sex?	○	○	○	○	○
c) Married couples who only have sex with each other?	○	○	○	○	○
d) Married couples who occasionally have sex with someone other than their regular partner?	○	○	○	○	○
e) Male homosexuals?	○	○	○	○	○
f) Female homosexuals?	○	○	○	○	○

40. Have you ever been told by a Doctor or Nurse you have: (mark those that apply)

Chlamydia ○	Genital Warts ○	HIV infection or AIDS ○	Gonorrhoea ○
Syphilis ○	Genital Herpes ○	Pelvic Inflammatory Disease (PID) ○	Other STI ○

	Not at all worried	A little worried	Quite worried	Very worried	Extremely worried
41. How worried are you about becoming infected with HIV?	○	○	○	○	○
42. How worried are you about becoming infected with a sexually transmitted infection (STI) other than HIV?	○	○	○	○	○
43. How worried are you about unintentionally falling pregnant/making someone pregnant?	○	○	○	○	○

Thank you for taking the time to fill in this questionnaire

REC Reference Number: 08/H0505/71 Clinic questionnaire (Version 2) – 02/06/2008

Student online questionnaire

Portsmouth Hospitals NHS
NHS Trust

UNIVERSITY OF Southampton

REC Reference Number: 08/H0505/71
Student Version 2 - 02/06/2008

Sexual Behaviour, Attitudes and Knowledge Survey

Consent Form

The questionnaire investigates highly sensitive information about you the participant, and as such requires you to agree with the statements below, by selecting yes on the consent form at the bottom of the page if you wish to take part.

- I have read and understood the Participant Information Sheet, and would like to take part in this research project.
- I have read and understood the Definition of terms used in the questionnaire.
- I agree for the answers that I give in the questionnaire to be stored on a password protected computer for analysis.
- I agree for the answers that I give in the questionnaire to be analysed to increase the understanding about how Sexual Behaviour affects levels of STIs.
- I agree that the data I provide once analysed can be published in an unidentifiable format.
- I agree to only complete the questionnaire once.

The information provided can in no way be linked back to you and is stored on a secure server at the University of Southampton.

YOU HAVE THE RIGHT TO WITHDRAW FROM THE STUDY AT ANY TIME EVEN IF YOU HAVE SELECTED "YES" ON THE CONSENT FORM

IF YOU WOULD LIKE TO WITHDRAW PLEASE EMAIL YOUR REF NUMBER IN THE BOTTOM RIGHT OF THE PAGE TO:

rgoinfo@soton.ac.uk

☑ Yes, I agree to take part in the survey

Startsurvey

Ref: **BAHVZFFGW**

1 of 1 17/08/2009 10:0(

Portsmouth Hospitals NHS
NHS Trust

UNIVERSITY OF Southampton

REC Reference Number: 08/H0505/71
Student Version 2 - 02/06/2008

Ref: BAHVZFFGW

Sexual Behaviour, Attitudes and Knowledge Survey

Remember all your answers are strictly confidential, and you don't have to answer any questions you don't want to. To withdraw from the study please email your reference number above to rgoinfo@soton.ac.uk

1. Gender

○ Female ○ Male

2. What is your term time postcode? e.g. SO17 1BJ

3. Please enter your Date of Birth (in the format DD/MM/YYYY, e.g. 31/01/1990)

4. Which School are you based in?

--- SELECT SCHOOL ---

5. Which of the following best describes your sexual orientation?

○ Heterosexual (straight) ○ Homosexual (gay/lesbian) ○ Bisexual ○ Not sure

6. What is your ethnic background?

○ Asian (British) ○ Asian (Other)
○ Black (British) ○ Black (Other)
○ White (British) ○ White (Other)
○ Other - please say

7. Who do you live with? *Please mark <u>all</u> answers that apply to you*

☐ Parents ☐ Husband/wife ☐ Friends ☐ Older sibling(s)
☐ Single parent ☐ Partner ☐ On your own ☐ Younger sibling(s)
☐ Other guardian(s) ☐ Own children

If you selected older or younger siblings above, please tell us how many

8. Please mark the one option which best describes you

○ In full-time education: School ○ In full-time education: College ○ In full-time education: University
○ In paid employment: Part-time ○ In paid employment: Full-time ○ Unemployed
○ House wife

9. What Qualifications do you have? *Please mark all that apply to you*

1 of 2 17/08/2009 10:07

- ☐ Postgraduate Degree
- ☐ Undergraduate Degree
- ☐ 'A' level
- ☐ Currently at University
- ☐ GCSE Grades A-C
- ☐ GCSE Grades D-G
- ☐ GCSE Grades U
- ☐ Currently at School

10. How often have you had an alcoholic drink of any kind during the last 12 months?

- ○ Five or more days a week
- ○ Three or four days a week
- ○ Once or twice a week
- ○ Once or twice a month
- ○ Once or twice in the last 12 months
- ○ Not at all in the last 12 months

If you answered "not at all in the last 12 months", please skip to question 12

11. About how many drinks do you usually have on the days when you have any, apart from parties or special occasions?

○ One or two ○ Three or four ○ Five or six ○ More than six

12. Have you ever had sex whilst being drunk?

○ Yes ○ No

13. Do you ever smoke cigarettes?

○ Yes ○ No

If you answered "No", please skip to question 15

14. About how many cigarettes do you smoke a day?

○ Less than 10 ○ Between 10-20 ○ Between 20-40 ○ More than 40

15. Have you ever injected yourself with any drugs or other substances, which have not been prescribed?

○ Yes ○ No

16. Have you ever shared a needle – used for injecting — with someone else?

○ Yes ○ No ○ Don't know

17. Have you ever had sex with someone who takes or shoots street drugs using a needle?

○ Yes ○ No ○ Don't know

18. Have you ever had sex whilst being under the influence of drugs? (including other non injected drugs)

○ Yes ○ No

Next

Page 1 of 3

Portsmouth Hospitals NHS
NHS Trust

UNIVERSITY OF Southampton

REC Reference Number: 08/H0505/71
Student Version 2 - 02/06/2008

Ref: **BAHVZFFGW**

Sexual Behaviour, Attitudes and Knowledge Survey

Remember all your answers are strictly confidential, and you don't have to answer any questions you don't want to. To withdraw from the study please email your reference number above to rgoinfo@soton.ac.uk

19. For how long have you lived in this (city/town/village)?

- 1 year or less
- 1-5 years
- 5-10 years
- 10-20 years
- Over 20 years (but not always)
- Always (i.e. since birth - never lived elsewhere)

20. Were you born in?

- United Kingdom
- Africa
- Asia
- Australasia
- Europe (not UK)
- North America
- South America
- Other (please state)

If you answered "United Kingdom", please go to question 22, else go to 21

21. How old were you when you (first) came to live in the United Kingdom (in years)?

22. Have you ever had vaginal sexual intercourse?

- Yes
- No

If you answered yes, at what age did you first have vaginal sexual intercourse?

23. Which of the following best describes your current sexual relationship status?
Please read all the options before making your selection

- I'm not currently in any kind of sexual relationship
- I'm not in a regular sexual relationship but I'm having casual sex with people
- I'm in a regular sexual relationship with one person
- I'm in a regular sexual relationship with one person but I also have sex with another person / other people

24. In the last 3 months, how many sexual partners have you had?

1 of 3 17/08/2009 10:0

25. Which of the following best describes the age difference between yourself and the last person you had sexual intercourse with?

- More than 4 years younger
- 2-4 years younger
- About the same age (within about 1 year of my age)
- 2-4 years older
- More than 4 years older

26. The last time you had sexual intercourse with someone how far from you did that person live?

- Within 1 mile
- Between 2 miles 5 miles
- Between 5 miles and 10 miles
- A different city
- A different country
- Don't know

27. The last time you had sexual intercourse, did you use a condom?

- Yes
- No

If you answered "no", please skip to question 31

28. The last time you had sexual intercourse, which of the following best describes when the condom was put on? *Please read all the options before making your selection*

- Before intercourse had started - before any penetration occurred
- After we had started intercourse – pulled out after some penetration and then put the condom on

29. If the condom was put on after penetration, was it being used for ejaculation only (i.e. just for cumming)?

- Yes
- No

30. The last time you had sexual intercourse, when was the condom removed?

- Before ejaculation (i.e. cumming)
- After ejaculation (i.e. cumming)

31. If you have had unprotected sex (no condom), what have the reasons been for not using a condom?

- Drunk/drugged up
- Wanted to but didn't say anything
- Didn't want to spoil the moment
- Wanted to get pregnant
- Didn't have any
- Didn't think of it
- Partner didn't want to

32. In the past year have you used condoms *(mark all that apply)*:

- to prevent pregnancy
- to protect against HIV and other sexually transmitted infections
- None of the above

If you answered "none of the above", please skip to question 34

33. Which was the main reason: to prevent pregnancy or to protect against infection?

- To prevent pregnancy
- To prevent infection
- Both equal
- Depends on who the partner is
- Don't know

34. Which method of contraception do you use now?

- Condom
- Injection
- Withdrawal
- None
- Pill
- Implant
- Diaphragm

Next

Page 2 of 3

Portsmouth Hospitals NHS Trust

UNIVERSITY OF Southampton

REC Reference Number: 08/H0505/71
Student Version 2 - 02/06/2008

Ref: **BAHVZFFGW**

Sexual Behaviour, Attitudes and Knowledge Survey

Remember all your answers are strictly confidential, and you don't have to answer any questions you don't want to. To withdraw from the study please email your reference number above to rgoinfo@soton.ac.uk

35. Since you had sexual intercourse for the first time, have you or your partner(s) *ever* used emergency contraception?

○ Yes ○ No

36. Have you ever given oral sex (*woman/man*) - by you to a partner, that is your mouth on a partner's genital area?

○ Yes ○ No

37. Have you ever received oral sex (*woman/man*) - by a partner to you, that is a partner's mouth on your genital area?

○ Yes ○ No

38. Have you ever had ANAL SEX with a (*woman/man*)?

○ Yes ○ No

WOMEN ONLY please answer question 39, men go to 40

39. Have you ever had any form of sexual contact with another woman?

○ Yes ○ No

40. Have you ever met a new sexual partner on the internet, dating or social websites?

○ Yes ○ No

41. We would like to know what you think the risks of becoming infected with any STI are in the following groups...

a) the risks to you, personally, with your present sexual lifestyle?

○ Greatly at risk ○ Quite a lot ○ Not very much at risk ○ Not at all ○ Don't know

b) People who have had sex with many different partners of the opposite sex?

○ Greatly at risk ○ Quite a lot ○ Not very much at risk ○ Not at all ○ Don't know

c) Married couples who only have sex with each other?

○ Greatly at risk ○ Quite a lot ○ Not very much at risk ○ Not at all ○ Don't know

d) Married couples who occasionally have sex with someone other than their regular partner?

F. Variable short names matched to questions from questionnaires

Short Name	Question	Question Number
3month_partners	in the last 3 months how many sexual partners have you had	22
A_level	What qualifications do you have	7-3
Age	NA - Calculation	NA
age_difference	Age difference between yourself and last sexual partner	23
age_entered_country	How old were you when you entered the UK	19
age_vaginal	At what age did you first have vaginal sex	20-1
amount_alcohol	How many drinks do you usually have	9
amount_smoked	How many cigarette do you smoke a day	12
anal	Have you ever had anal sex	36
at_school	What qualifications do you have	7-8
at_univeristy	What qualifications do you have	7-4
chlamydia	Have you ever been told by Doctor/Nurse you have	40-1
cigarrettes	Do you smoke cigarettes	11
condom	Last time you had sex did you use a condom	25
condom_ejaculation	Was the condom being used just for ejaculation	27
condom_main_reason	Which was the main reason for condom use	31
condom_removal	When was the condom removed	28
condom_timing	When was the condom put on	26

Short Name	Question	Question Number
contraception	Which method of contraception do you use now	32
country_born	Were you born in	18-1
date_questionnaire_completed	NA	consent form
didn't_have_any	What have been the reasons for not using a condom	29-5
didn't_think	What have been the reasons for not using a condom	29-3
DOB	Date of Birth	u3 and clinic record
drunk	Have you ever had sex whilst being drunk	10
drunk_drugged	What have been the reasons for not using a condom	29-1
emergency_contraception	Have you or your partner used emergency contraception	33
ethnic	Ethnic background	4-1
female_contact	Have you ever had any contact with another woman	37
female_homosexuals	Risks of becoming infected with any STI in the following groups	39f
frequency_alcohol	How often do you drink alcohol	8
friends	Who do you live with	5-3
GCSE_grades_A-C	What qualifications do you have	7-5
GCSE_grades_D-G	What qualifications do you have	7-6
GCSE_grades_U	What qualifications do you have	7-7
Gender	Gender	u1
genital_herpes	Have you ever been told by Doctor/Nurse you have	40-6
genital_warts	Have you ever been told by Doctor/Nurse you have	40-2

Short Name	**Question**	**Question Number**
gonnorrhoea	Have you ever been told by Doctor/Nurse you have	40-4
guardians	Who do you live with	5-9
HIV_AIDS	Have you ever been told by Doctor/Nurse you have	40-3
HIV_STIs	In past year have you used condoms for	30-2
how_long_in_city	How long have you lived in this place	17
husband_wife	Who do you live with	5-2
ID	Clinic Number	1
injected_drugs	Have you ever injected yourself with drugs	13
internet_socialwebsite	Have you ever met a new sexual partner on the internet	38
location	NA	u4
male_homosexuals	Risks of becoming infected with any STI in the following groups	39e
married_couples_sex_each_other	Risks of becoming infected with any STI in the following groups	39c
married_couples_sex_with_others	Risks of becoming infected with any STI in the following groups	39d
needle_share	Have you ever shared a needle	14
No_old_siblings	Who do you live with	5-12
No_old_young_siblings	Who do you live with	5-13
No_young_siblings	Who do you live with	5-11
none	In past year have you used condoms for	30-3
older_siblings	Who do you live with	5-4
oral_given	Have you ever given oral sex	34
oral_recevied	Have you ever received oral sex	35
other_country	Were you born in	18-2

Short Name	Question	Question Number
other_ethnic	Ethnic background	4-2
other_STI	Have you ever been told by Doctor/Nurse you have	40-8
own	Who do you live with	5-7
own_children	Who do you live with	5-10
parents	Who do you live with	5-1
partner	Who do you live with	5-6
partner_didn't_want_to	What have been the reasons for not using a condom	29-6
partner_proximity	How far did last sexual partner live from you	24
people_many_partners	Risks of becoming infected with any STI in the following groups	39b
personal_risk	Risks of becoming infected with any STI in the following groups	39a
PID	Have you ever been told by Doctor/Nurse you have	40-7
postcode	Postcode	2
postgraduate	What qualifications do you have	7-1
pregnancy	How worried are you about unintentional pregnancy	43
prevent_pregnancy	In past year have you used condoms for	30-1
relationship_status	Current Sexual relationship status	21
sex_drugs_other	Have you ever had sex with someone who takes injected drugs	15
sex_drugs_yourself	Have you ever had sex under the influence of drugs	16
sex_orien	Sexual orientation	3
single_parent	Who do you live with	5-5
spoil_moment	What have been the reasons for not using a condom	29-7

Short Name	**Question**	**Question Number**
status	Participants Status, working, education or neither	6
syphilis	Have you ever been told by Doctor/Nurse you have	40-5
to_get_pregnant	What have been the reasons for not using a condom	29-2
Umbrella Location	NA	NA
undergraduate	What qualifications do you have	7-2
vaginal_sex	Never had vaginal sex	20-2
wanted_to_but_didn't say	What have been the reasons for not using a condom	29-4
worried_HIV	How worried are you about becoming infected with HIV	41
worried_other_STI	How worried are you about becoming infected with other STI	42
young_siblings	Who do you live with	5-8

G. GUM data collection instruments

Reception Timing Information

Day ______________________

No.	Patient ID	Time Form Issused	Time Form Returned	Type of Form
eg	MO8/12345	09:30	09:34	New/Return
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				

Reception Phone Calls

Day ________________________________

No.	Time Phone Call Started	Time Phone Call Ended	Time Call Forwarded
eg	09:30	09:34	
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			

Patient Examination

Date: ____________________ Grade: ____________________

					History		Examination/Specimens		Blood		Management/Treatment	
No.	**Patient ID**	**N**	**O/N**	**FUP**	**Start**	**Finish**	**Start**	**Finish**	**Start**	**Finish**	**Start**	**Finish**
eg	MO8/12345	✓			09:30	09:34	09:34	09:45	09:47	09:55	10:05	10:15
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Lab Specimens

Date: ______________________________

Grade: ______________________________

No.	Patient ID	Start	Finish
eg	M08/12345	09:30	09:34
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Lab Phone Calls

Date: ___________________________

No.	Time Phone Call Started	Time Phone Call Ended
eg	09:30	09:34
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

H. Labels used in the GUM model

Name	Type	Group	Purpose
lbl_A_ID	Number	Unique ID	Unique patient identifier
lbl_A_Pat_Type	Number	Patient Type	Patient Type be that New (N), Follow Up (FUP) or Old/New (ON)
lbl_I_All_Clear	Number	Conditions	All Clear – patient does not have any of the conditions of interest
lbl_I_Chlam	Number	Conditions	Chlamydia status (infected or not)
lbl_I_Gon	Number	Conditions	Gonorrhoea status (infected or not)
lbl_I_Herp	Number	Conditions	Herpes status (infected or not)
lbl_I_HIV	Number	Conditions	HIV status (infected or not)
lbl_I_NSU	Number	Conditions	NSU status (infected or not)
lbl_I_Syp	Number	Conditions	Syphilis status (infected or not)
lbl_I_War	Number	Conditions	Warts status (infected or not)
lbl_M_1_His	Text	Task Duration	Duration – History medical stage
lbl_M_2_Exa	Text	Task Duration	Duration – Examination medical stage
lbl_M_3_Blo	Text	Task Duration	Duration – Blood medical stage
lbl_M_4_Lab	Text	Task Duration	Duration – Lab medical stage

Name	Type	Group	Purpose
lbl_M_5_Man	Text	Task Duration	Duration – Management medical stage
lbl_Medical	Number	Task Duration	Used in the assignment of medical duration labels
lbl_P_Lab	Text	Task Duration	Duration – of Lab Phone Calls
lbl_P_Recep	Text	Task Duration	Duration – of Reception Phone Calls
lbl_R_Appoint	Number	Routing Patients	Route patients before leaving GUM to make an appointment or not
lbl_R_Blood	Number	Routing Patients	Route patients to return to management or to wait until lab test results available before returning to management
lbl_R_Exit	Number	Routing Patients	Route patients to leave the clinic on entry if certain conditions are met, Patient has probability of ignoring this and entering the clinic
lbl_R_Gender	Number	Routing Patients	Route patients based on gender
lbl_R_Manage	Number	Routing Patients	Route patients directly to management stage missing diagnoses stages
lbl_R_Room	Number	Routing Patients	Route patients back to medical room they were seen in during first medical stage
lbl_R_Shared	Number	Routing Patients	Route patients to specific queue if resources shared between genders
lbl_R_Test	Number	Routing Patients	Route patients to Blood, lab or both tests

Name	**Type**	**Group**	**Purpose**
lbl_Re_1_IssueF	Text	Task Duration	Dist Issue Forms
lbl_Re_2_ComF	Text	Task Duration	Dist Complete Forms
lbl_Re_3_EntF	Text	Task Duration	Dist Enter Details
lbl_Re_4_Appoint	Text	Task Duration	Dist Make Appointment
lbl_W_Med	Number	Waiting Time Limit	Patient's waiting time limit in the medical stages
lbl_W_Recep	Number	Waiting Time Limit	Patient's waiting time limit in the pre-form part of reception
lbl_W_Recep2	Number	Waiting Time Limit	Patient's waiting time limit in the post-form part of reception

I. User interface manual

User interface manual

1.0 – Introduction

As the models were produced with simulation packages which many may be unfamiliar with a user, an interface was constructed in Microsoft Excel, to capture a more familiar windows environment. Figure 1.1 is the main screen of the interface enabling: model variables to be amended; to control the models produced; and, view the results from the model(s).

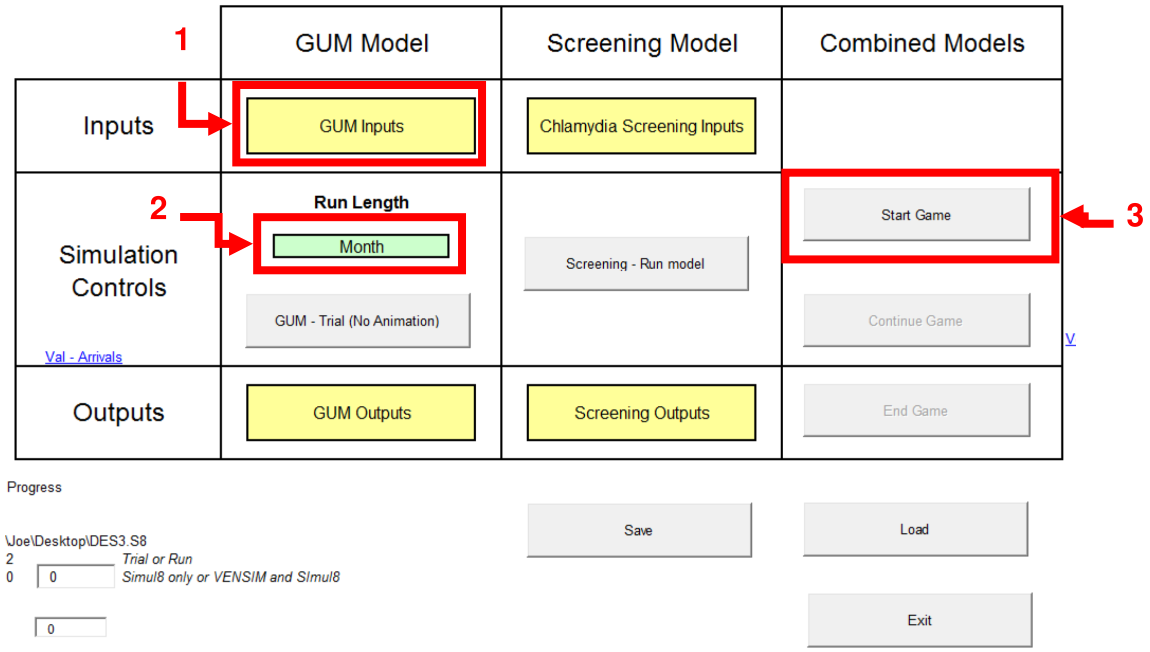


Figure 1.1 – Main page of User Interface, highlighting key features

The key features of the interface design have been highlighted in red in figure 1.1. A brief description of these features is provided below:

1. Yellow buttons are navigation buttons leading to further screens, either: input or output.
2. Green boxes are fields (representing the variables) which can be manipulated.
3. Grey boxes are command buttons which start the models with the specified parameters.

2.0 – GUM model

The GUM model controls are highlighted below, in figure 2.1. It can be run for a day, a week or a year and this can defined by selected the green box under the “run length” option and choosing the time scale from the drop down list. The default time scale for the GUM model is a month. The key aspects have been highlighted in red. These will be discussed in sequence in more detail in the remaining parts of section 2. In short: 1 is the inputs for this model; 2, starts the model; and, 3 displays the outputs from the model.

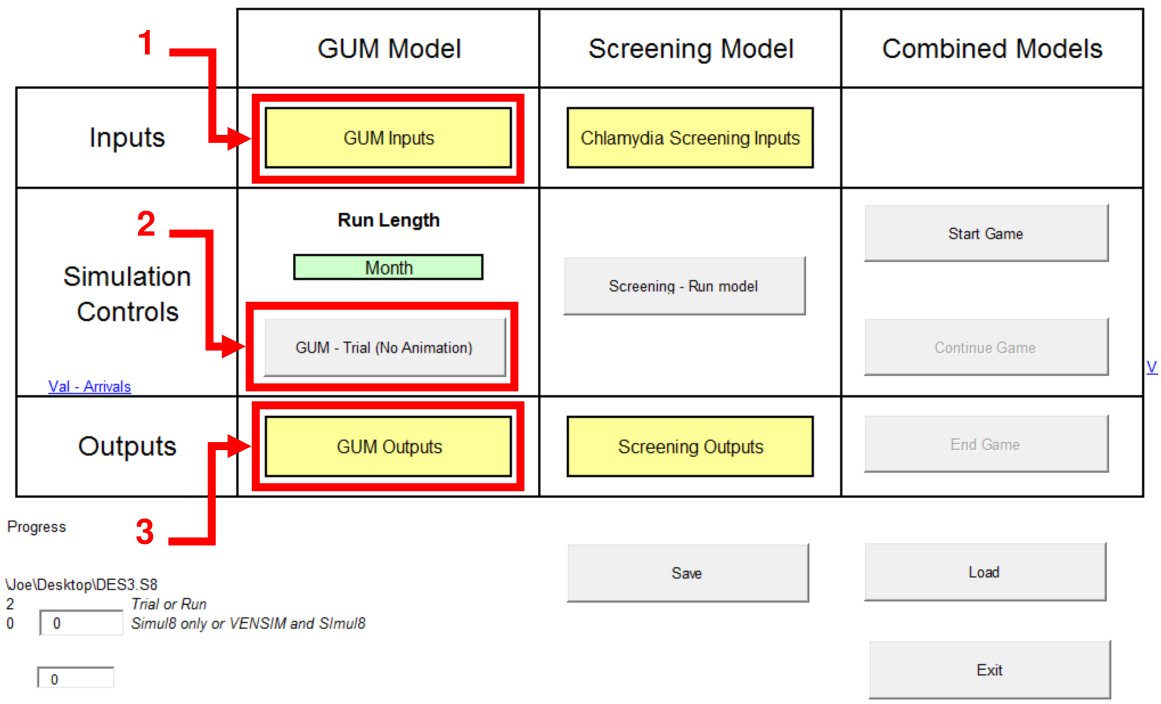


Figure 2.1 – GUM model related user interface controls

2.1 – Entering the data

Figure 2.2 is the next level down from the GUM input highlighted as 1 in figure 2.1. Each button in figure 2.2 takes the user to the corresponding variables to be entered. Figure 2.3 is a typical input form with the areas where the users can enter values are highlighted in green.

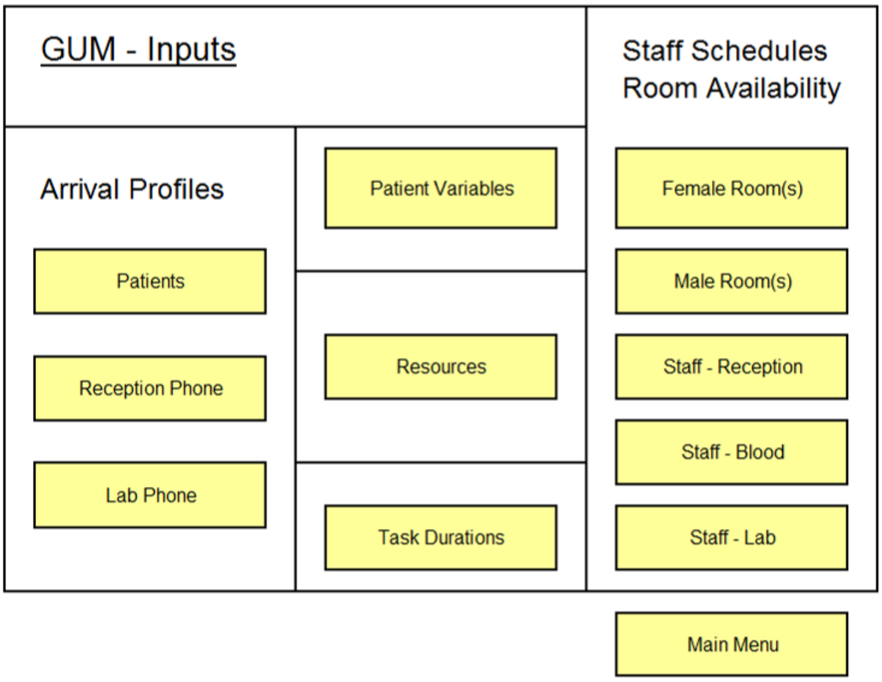
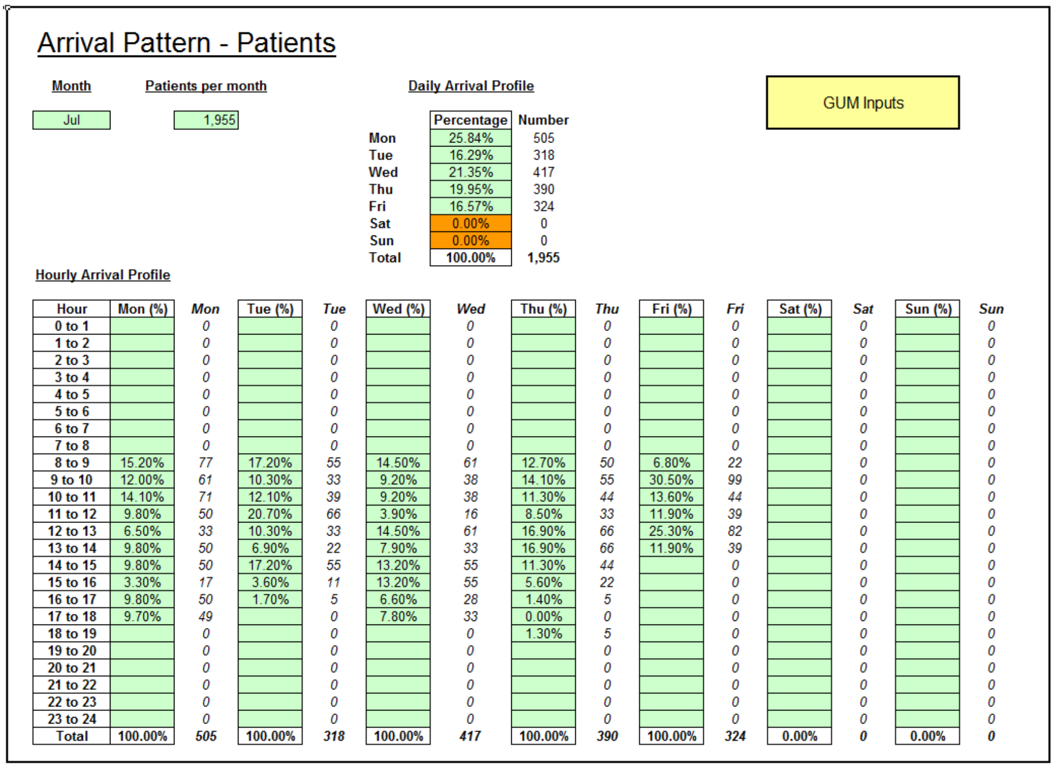


Figure 2.2 – GUM related user interface controls



Arrival Pattern - Patients

GUM Inputs

Month	Patients per month
Jul	1,955

Daily Arrival Profile

	Percentage	Number
Mon	25.84%	505
Tue	16.29%	318
Wed	21.35%	417
Thu	19.95%	390
Fri	16.57%	324
Sat	0.00%	0
Sun	0.00%	0
Total	100.00%	1,955

Hourly Arrival Profile

Hour	Mon (%)	Mon	Tue (%)	Tue	Wed (%)	Wed	Thu (%)	Thu	Fri (%)	Fri	Sat (%)	Sat	Sun (%)	Sun
0 to 1		0		0		0		0		0		0		0
1 to 2		0		0		0		0		0		0		0
2 to 3		0		0		0		0		0		0		0
3 to 4		0		0		0		0		0		0		0
4 to 5		0		0		0		0		0		0		0
5 to 6		0		0		0		0		0		0		0
6 to 7		0		0		0		0		0		0		0
7 to 8		0		0		0		0		0		0		0
8 to 9	15.20%	77	17.20%	55	14.50%	61	12.70%	50	6.80%	22		0		0
9 to 10	12.00%	61	10.30%	33	9.20%	38	14.10%	55	30.50%	99		0		0
10 to 11	14.10%	71	12.10%	39	9.20%	38	11.30%	44	13.60%	44		0		0
11 to 12	9.80%	50	20.70%	66	3.90%	16	8.50%	33	11.90%	39		0		0
12 to 13	6.50%	33	10.30%	33	14.50%	61	16.90%	66	25.30%	82		0		0
13 to 14	9.80%	50	6.90%	22	7.90%	33	16.90%	66	11.90%	39		0		0
14 to 15	9.80%	50	17.20%	55	13.20%	55	11.30%	44		0		0		0
15 to 16	3.30%	17	3.60%	11	13.20%	55	5.60%	22		0		0		0
16 to 17	9.80%	50	1.70%	5	6.60%	28	1.40%	5		0		0		0
17 to 18	9.70%	49		0	7.80%	33	0.00%	0		0		0		0
18 to 19		0		0		0	1.30%	5		0		0		0
19 to 20		0		0		0		0		0		0		0
20 to 21		0		0		0		0		0		0		0
21 to 22		0		0		0		0		0		0		0
22 to 23		0		0		0		0		0		0		0
23 to 24		0		0		0		0		0		0		0
Total	100.00%	505	100.00%	318	100.00%	417	100.00%	390	100.00%	324	0.00%	0	0.00%	0

Figure 2.3 – GUM related user interface controls

2.2 – Running GUM model only

After the parameter values have been set by the user the model can be run, by selecting the command button highlighted as 2 in figure 2.1. Once this button has been selected the GUM model will run. The screen will switch from the interface to the simulation package illustrated in figure 2.4. This screen contains a progress bar. Once the simulation has been completed this screen will close and return the user to the interface screen.

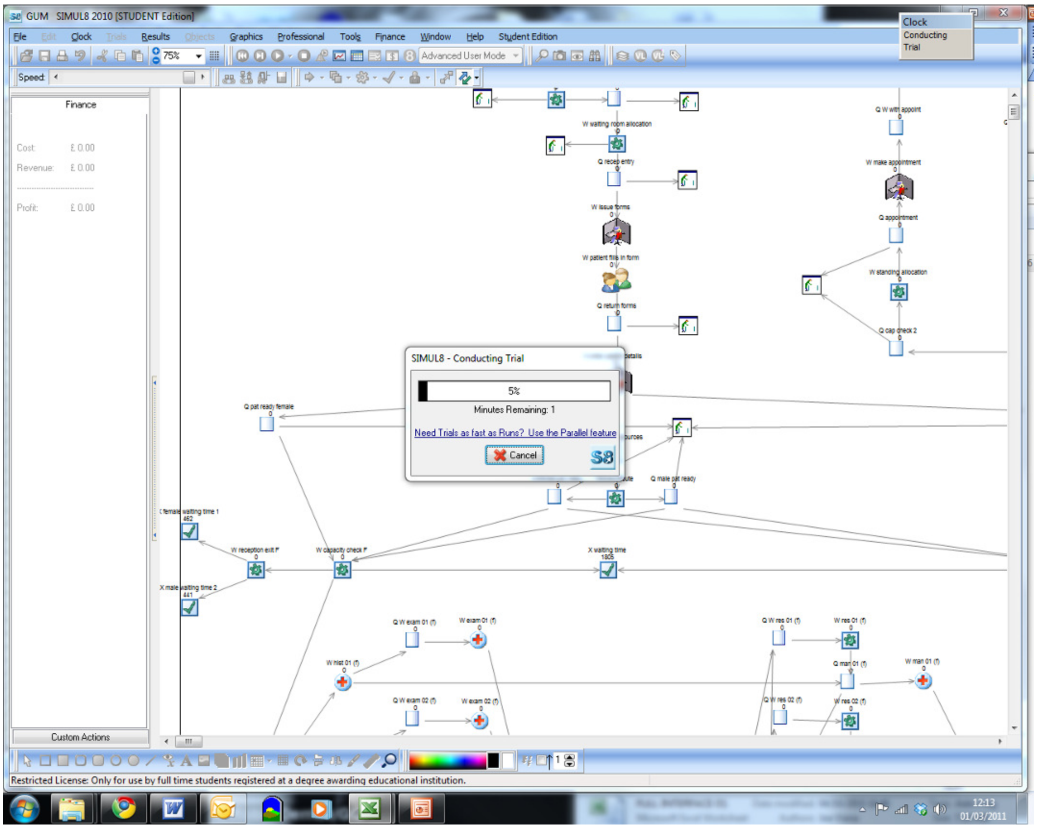


Figure 2.4 – GUM related user interface controls

2.3 – Results from the model

Following the running of the GUM model results can be obtained through the interface. This can be obtained through the button highlighted as 3 in figure 2.1. This takes the user to the screen shown in 2.5. From this screen the user can get results on the topics stated. Figure 2.6 is an example of the results available from the model. They are average results with confidence intervals.

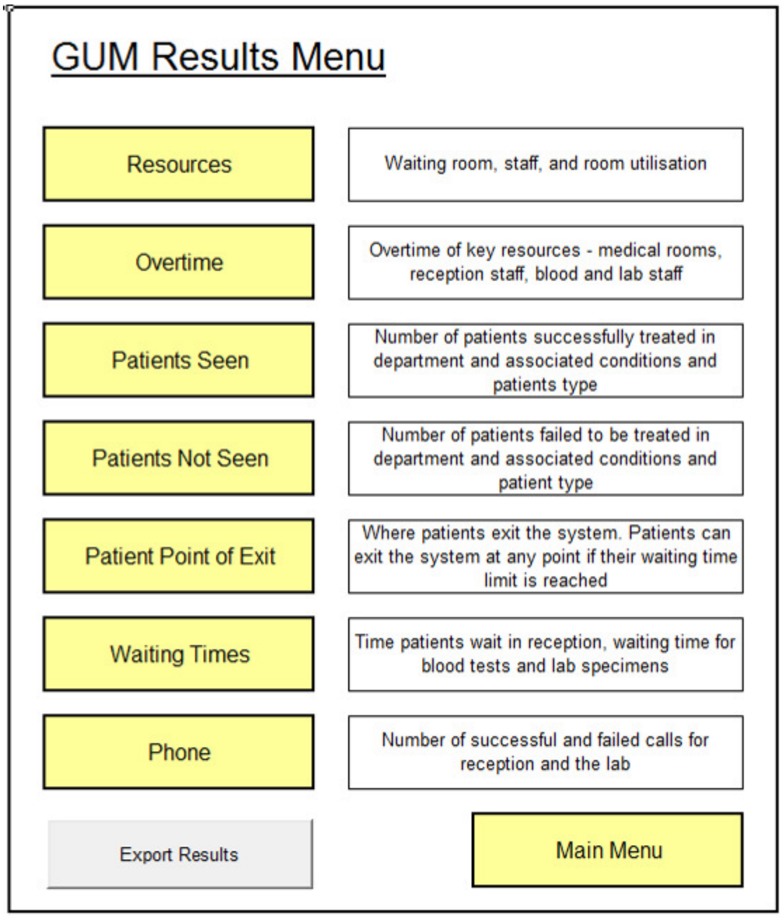


Figure 2.5 – GUM model related user interface controls

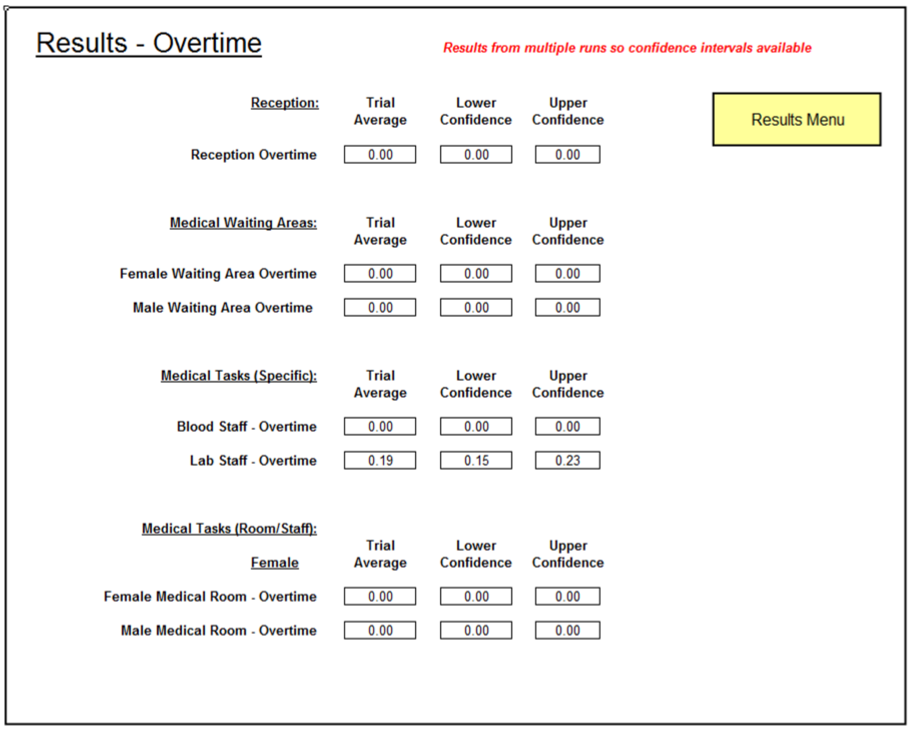


Figure 2.6 – GUM model related user interface controls

3.0 – Screening Model

The Screening model controls are highlighted below, in figure 3.1. The key aspects have been highlighted in red. These will be discussed in sequence in more detail in the remaining parts of section 2. In short: 1 is the inputs for this model; 2, starts the model; and, 3 displays the outputs from the model.

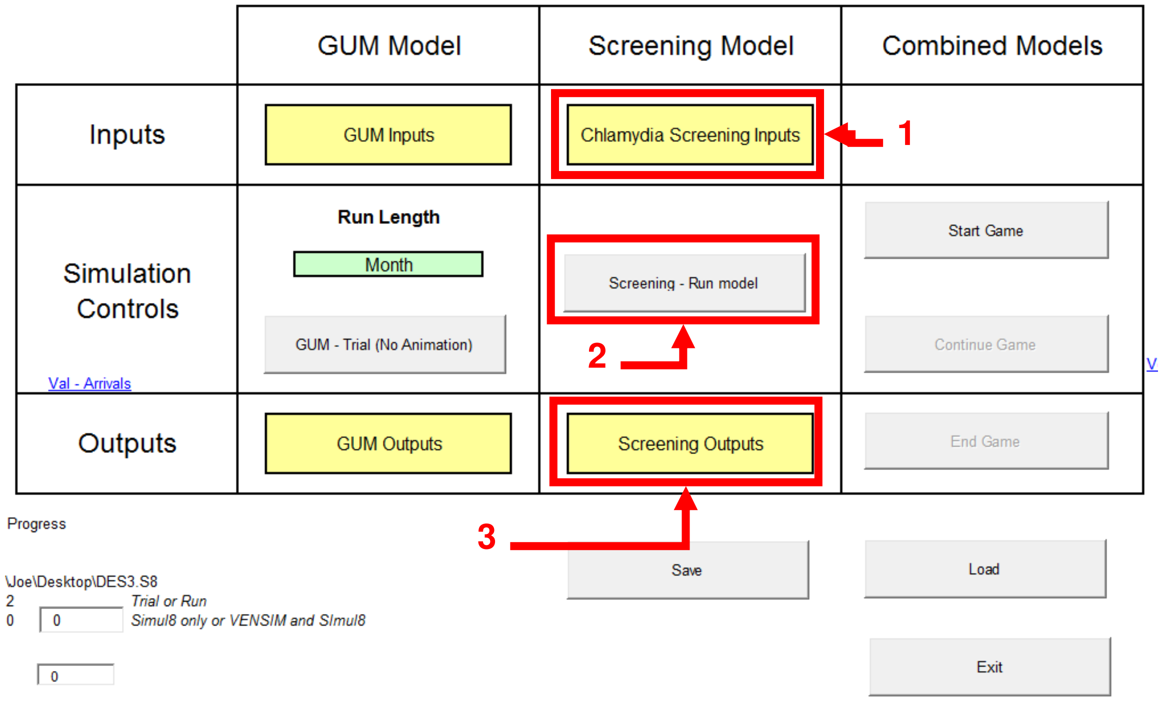


Figure 3.1 – Screening model related user interface controls

3.1 – Entering the data

Figure 3.2 is the next level down from the Screening input highlighted as 1 in figure 3.1. Each button in figure 3.2 takes the user to the corresponding variables to be entered. Figure 3.3 is a typical input form with the areas where the users can enter values.

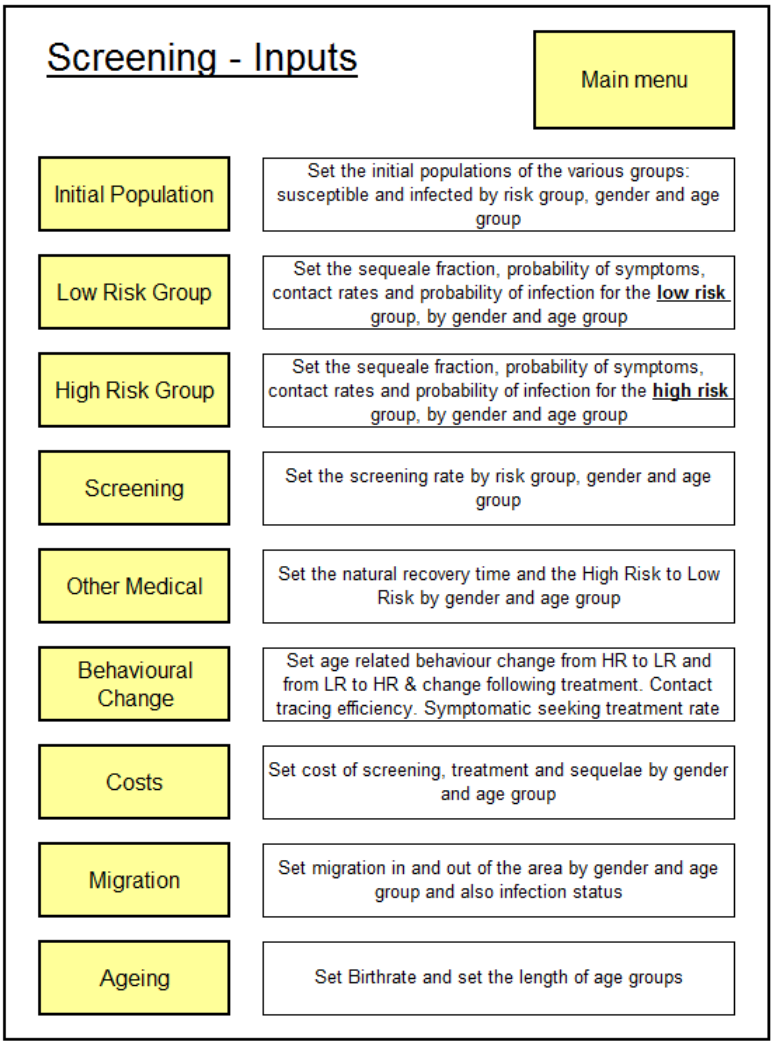
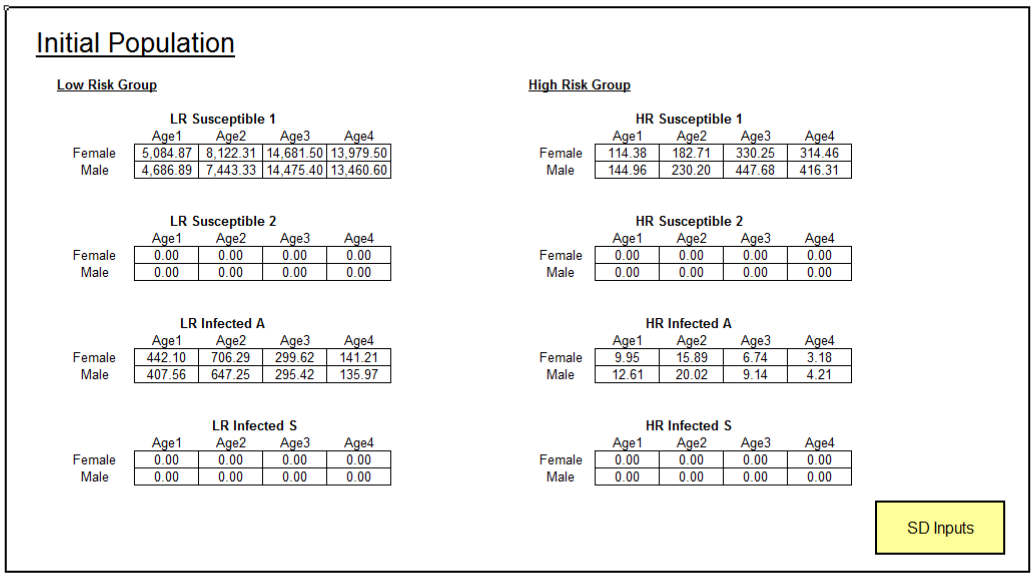


Figure 3.2 – Screening model related user interface controls



Initial Population

Low Risk Group

LR Susceptible 1

	Age1	Age2	Age3	Age4
Female	5,084.87	8,122.31	14,681.50	13,979.50
Male	4,686.89	7,443.33	14,475.40	13,460.60

LR Susceptible 2

	Age1	Age2	Age3	Age4
Female	0.00	0.00	0.00	0.00
Male	0.00	0.00	0.00	0.00

LR Infected A

	Age1	Age2	Age3	Age4
Female	442.10	706.29	299.62	141.21
Male	407.56	647.25	295.42	135.97

LR Infected S

	Age1	Age2	Age3	Age4
Female	0.00	0.00	0.00	0.00
Male	0.00	0.00	0.00	0.00

High Risk Group

HR Susceptible 1

	Age1	Age2	Age3	Age4
Female	114.38	182.71	330.25	314.46
Male	144.96	230.20	447.68	416.31

HR Susceptible 2

	Age1	Age2	Age3	Age4
Female	0.00	0.00	0.00	0.00
Male	0.00	0.00	0.00	0.00

HR Infected A

	Age1	Age2	Age3	Age4
Female	9.95	15.89	6.74	3.18
Male	12.61	20.02	9.14	4.21

HR Infected S

	Age1	Age2	Age3	Age4
Female	0.00	0.00	0.00	0.00
Male	0.00	0.00	0.00	0.00

SD Inputs

Figure 3.3 – Screening model related user interface controls

3.2 – Running Screening model only

After the parameter values have been set by the user the model can be run, by selecting the command button highlighted as 2 in figure 3.1. Once this button has been selected the Screening model will run. The button once pressed will go grey indicating that the model is currently running in the background. When the button returns to black the simulation model has finished running and the results have been imported into the user interface.

3.3 – Results from the model

Following the running of the GUM model results can be obtained through the interface. This can be obtained through the button highlighted as 3 in figure 3.1. This takes the user to the screen shown in 3.4. From this screen the user can get results on the topics stated. Figures 3.5 and 3.6 are examples of the results available from the model. Both graphical and tabular results are available for variables associated with people and costs. Due to the type of simulation confidence intervals are not available.

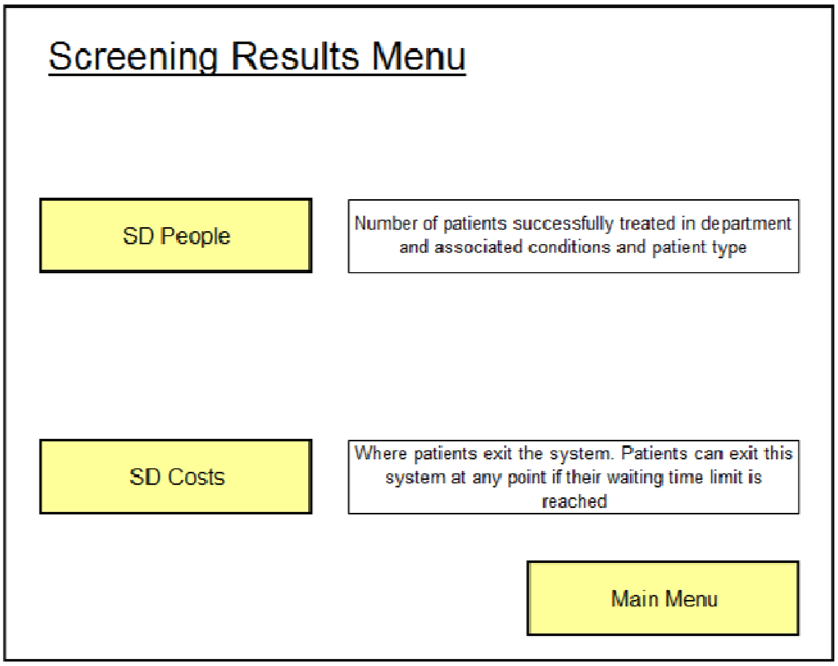


Figure 3.4 – GUM related user interface controls

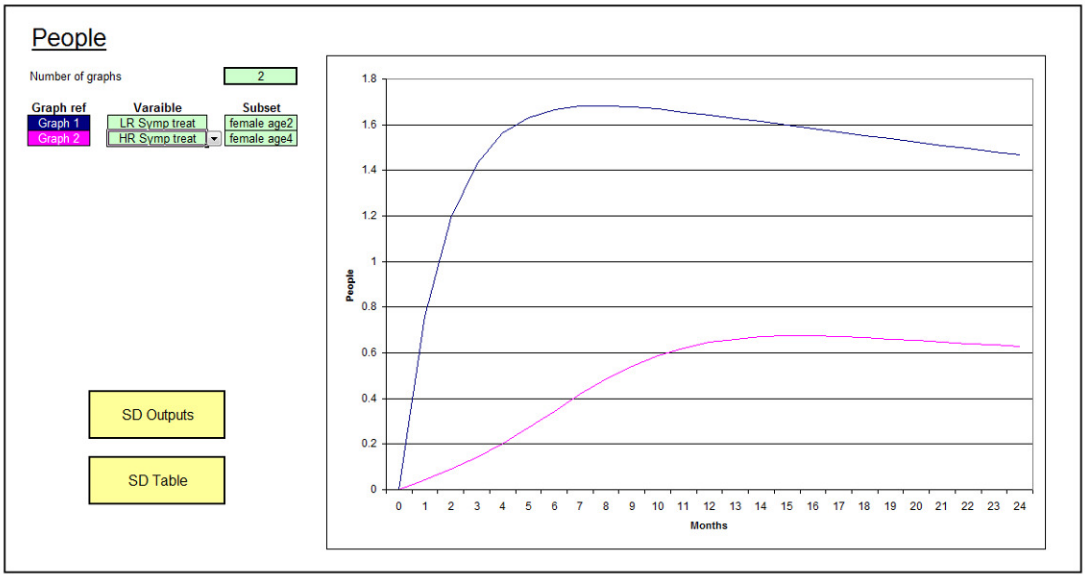


Figure 3.4 – GUM related user interface controls

People Table

Variable	Subset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LR Symp treat	female age2	0	0.76331	1.191	1.4298	1.5614	1.6318	1.6666	1.6807	1.6826	1.6773	1.6679	1.6559	1.6425	1.6281	1.6133	1.5983	1.5831	1.568	1.553
HR Symp treat	female age4	0	0.04407	0.0894	0.1413	0.2019	0.2706	0.3438	0.4165	0.4836	0.5412	0.5872	0.6216	0.6457	0.6612	0.6699	0.6735	0.6735	0.6708	0.6664

Figure 3.5 – GUM related user interface controls

4.0 – Combined Models

The GUM and screening models are combined to produce a combined model. The inputs for the combined model are entered as previously discussed for the models run in isolation. Likewise, this is similar for the results of the combined model are obtained from the outputs already discussed for the individual models. The purpose of the composite model is to replace an aspect of the screening model with the more detailed and GUM model. The composite model can be controlled from the buttons highlighted on the right of figure 4.1.

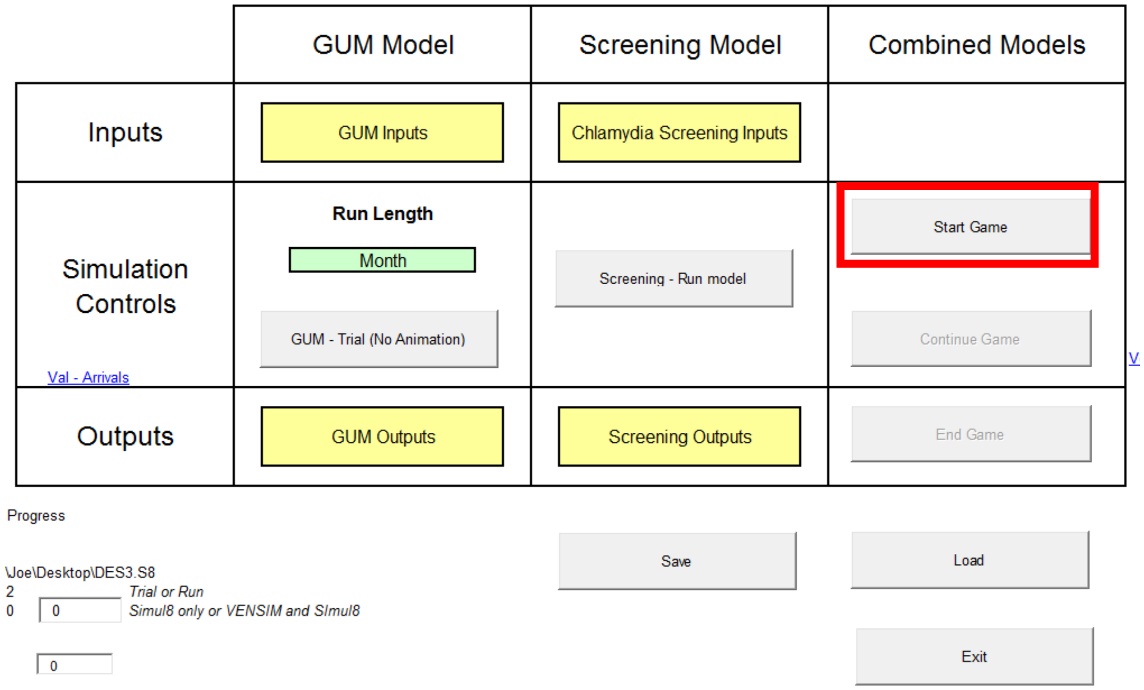


Figure 4.1 – GUM related user interface controls

J. Chlamydia screening database data

K. Collinearity of socioeconomic data

L. Questionnaire results

M. GUM Discrete Event Simulation model

N. Screening System Dynamics model

O. Microsoft Excel user interface

P. Interface VBA

Q. GUM model variables

R. GUM model distributions

S. GUM model Visual Logic

T. GUM model experiments and results

U. SD formulas

V. SD model experiments and results

W. Composite model experiments and results

An electronic version is available in the attached media of the appendices above. Each appendix has a corresponding folder containing the pertinent information.

It should be noted in order for the composite model the Microsoft Excel user interface, the Simul8 model and the VENSIM model need to be in the same location, i.e. folder or desktop