Exploring data sharing in pathology through investigating the concept of a National Pathology Handbook system.

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Summary

Currently the United Kingdom Pathology Service is a disaggregated system with no formal communication between different laboratory entities. This project looks to current informatics techniques to manage pathology information in better ways and to investigate data sharing throughout the Pathology Service. This project looks towards and develops the concept of a National Pathology Handbook to elicit data sharing throughout the Pathology Service. It provides the output of a prototype system and suggested architecture and then goes to provides recommendations for further work in this area.
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Chapter 1

Introduction

1.1 About the author.

1.2 Introduction to the project.

This project is linked to the current large scale project the National Program for Information Technology (NPfIT) linked to the National Health Service (NHS). This project is being run for the Pathology Service in the NHS. There are currently no formal methods of data sharing within the United Kingdom Pathology Service. This project will be looking to this and addressing if the area of informatics can be used to create structures and systems to share pathology information throughout the United Kingdom Pathology Service.

1.3 Relevance to degree program studied

This project holds relevance to modules studied throughout the authors degree program. Knowledge from the following modules will be used throughout this project.

- PATH 1001 - Introduction to Medical Informatics
- PATH 2001 - Clinical Informatics: Standards and Technologies
• PATH 2003 - System Usability in Clinical Practice

• COMP 2400 - Database Principles and Practice

• COMP 2670 - Object-Oriented Software Engineering

• COMP 2680 - Practical Software Development

• COMP 2480 - Internet Systems and Technologies

• COMP 3470 - People-Centred Information Systems Development
1.4 The Problem.

The National Health Service (NHS) is a UK organisation that provides free health care at point of use for the United Kingdom population [25]. In previous years the NHS has started to show its age and a need for information technology has become apparent. This was addressed in October 2002 with the appointment of a Director General of IT in the NHS [11]. This lead onto the forming of the National Program for IT (NPfIT), a program that would aim over ten years to revolutionise the NHS throughout the use of information technology.

This project leads on from the current high levels of investment in the information technology provision in the NHS, many areas of the NHS have undergone intense change programs focusing upon management change and technology introduction. This project focuses upon the work that is being performed in the National Pathology Service. The National Pathology Service has so far not been addressed by the NPfIT but analysis is just about to begin.

The National Pathology Service is currently seen as a disaggregated service; in September 2005 Lord Carter Coles was appointed to produce a review of the pathology services in the United Kingdom. The outcomes of this report was that there is now a need for change within the organisation, leading to the launch of pilot projects to test reform throughout the service [6].

This project leads on from the findings of the Carter Report and the current investment in IT throughout the NHS. This project aims to assess the feasibility of the implementation of a system to allow information sharing throughout the Pathology Service [13]. This project in particular addresses a current issue that there are no formal channels for data sharing within the NHS Pathology Service. The project looks to explore data models and architectures for sharing of data between laboratories where currently no formal communication structure exists. In particular it looks towards this through the creation of a National Laboratory Handbook system.

A national catalogue of pathology data and the sharing of this information has been brought up recently by many pathologists. The most recently notable occasion of this were the discussions held at Cambridge at the recent Diagnostic summit. The outcomes here pointed towards the creation of a national
pathology catalogue database [24]. This project will pick up on some of these discussions and go to investigate them from a technical perspective.

1.5 Aims of the project

There has been calls for a structured system to be created that will allow sharing of information throughout the Pathology service. This project will focus upon the feasibility of this system and what data is required to be shared between different entities in the Pathology Service. The focus will be upon the creation of a service and method for sharing information through the concept of a national laboratory handbook see sections 3.2.5 and 3.2.6. This project is sponsored by Dr Richard Jones, Associate clinical director of Yorkshire and the Humber Strategic Health Authority.

1.6 Project Requirements and Possible Extensions

The minimum requirements for this project are to investigate the feasibility of implementing an architecture for data sharing in the National Pathology Service. Then to suggest a appropriate architecture to support this and to prepare a prototype system. Possible extensions are:

- Explore scalability of system for the entirety of the National Health Pathology Service.
- Implementation of knowledge management to map disease types to test types.
- Explore options of implementing a machine to machine XML information request system.

1.7 Project deliverables

This project aims to deliver the following:

- A data model concept to share information throughout the Pathology Service.
- A prototype database.
- A prototype abstraction layer to show this architecture working.
- The report detailing the work.
Chapter 2

Project Management

This chapter will deal with any project management tasks and decisions that occurred during this project. It is very important to plan and monitor projects to check that they are on track and will deliver requirements. Project management happened throughout the project with most of the planning being the inception iteration and monitoring happening throughout all iterations.

2.1 Initial Project Issues

Some issues were faced at the beginning of this project. Primarily the project was going to be performed for an external company that the author had worked for in an industry year. It became evident early in the project planning stage that it would not be feasible. This was due to a member of staff who was interested in leading the project leaving the firm and there being no internal support. A recommended project was then chosen from the School of Computing news groups. Yet this was found to be not feasible due to issues with the computing content and also the fact that two other students were found to be working on this project. By this point time was quickly passing and a decision had to be made to find a project to undertake. The author decided to contact Mr Owen Johnson from the School of Computing for advice. He was then referred onto Dr Richard Jones (Associate clinical director Yorkshire and the Humber Strategic Health Authority) who put forward the National Laboratory Handbook project. This
was a attractive project due to the authors interest and experience in the Health Informatics area. This impacted project progress in 2007 as this project was not even confirmed until 01/11/2007. Some time was lost at the start of the project but this was kept in mind when all later planning was performed.

2.2 Project Constraints

As a student project there were constraints placed upon this project, these were taken into consideration at the project planning stage. All projects have unique characteristics that may cause constraints and distinguish them from other projects. The following constraints were identified characterise this project:

- Limited time due to this being an academic project and not being the developers sole focus.
- Limited user involvement.
- No funding due to this being done as research for a non funded academic project.
- Primarily only one developer.
- Some decisions may have to be made by clinical staff at a high level so some assumptions may have to be made.

2.3 Initial Plan

In any project it is very important to plan ahead and to set mile stones. This allows a high abstraction view from a project management perspective to see how the project is progressing with regards to the plan and completion dates. The author needed to do this as to plan around other commitments and work. See fig 2.3 for a Gantt chart showing the initial plan for this project. This was then reviewed throughout the project to check progress.

It can be observed from fig 2.3 that this project will iterate through certain stages until the stage is complete. The analysis and design and the build stage will take up the most time in this project. Fig 2.3 is the first draft of the plan and was set out after the requirements of the project had been gathered. This allowed a rough estimate to be made of how long certain tasks would take in the project and also as to how much emphasis should be put into each task.
2.4 Plan Changes

Figure 2.4 shows how the project actually ran. Some of the stages within the initial project plan were not needed ‘Initial Testing’ was first thought to be a stage where any early thoughts on design would be assessed, this was found not to be needed. Some of the stages merged into one stage. On execution there was no split between the build and the testing stage as it was found it was easier with a UCD approach to test each function on completion forming smaller iterations.

In the evaluation phase many of the activities were also merged into one stage. This was found to be an easier approach as there was no iteration needed on the evaluation activity. Towards the end of the project it was realised how much time the report write up was going to take so the entire shift of the project was moved onto this and another four days were assigned for it.
Chapter 3

Background Research

This chapter contains research that was performed for this project. This related to the work that was performed in the inception phase of this project under the background research activity.

3.1 Methodology Research

Planning and execution of projects should be a meticulously planned and stage driven process. A methodology defines a structured method for the execution of a project, from the inception through to post-completion. A methodology sticks through a project through staffing changes and sometimes structural changes, so serious thought should be put into the choice of methodology. There are different methodologies dependent upon the characteristics of a project so it is good to define these early as to assess what has best fit with this project.

- This is a feasibility study so staff participation throughout is not guaranteed.

- Only one developer is working on this project so work should be broken down into manageable chunks with not many concurrent tasks.

- The outcome will be a prototype system, not a deployable system.
This section will now review three methodologies and aim to make a choice as to which one will be the best methodology for this project.

### 3.1.1 DSDM Dynamic Systems Development Methodology (DSDM)

DSDM takes a view to fix resources for the project and then sets out to deliver only what is available within these resources. Most methodologies do not operate on this basis, they look out to elicit the end users requirements and then aim to provide these. This methodology heavily focuses upon the inclusion of users all the way through the process. As with other methodologies DSDM has distinct stages that a project passes through [29]. These stages are *feasibility study, business study, functional model iteration, design and build iteration and implementation*. Of these stages the latter three are the only iterative stages see fig 3.1.1.

![Figure 3.1: The typical stages of the Dynamic Systems Development Methodology [29]](image)

As this methodology sets requirements early in the project and does not iterate this stage it leads a developer to have a clearer and fixed view as to what is required from the project. This allows the developer more time to look towards how the software should function and the design of the whole system without constant pressure from the requirements side. It should also be considered that using this methodology would cause a loss of requirements flexibility, as changing requirements will not be an option. When considering the use of this methodology for a project such as the one planned here it must be noted that this methodology relies heavily upon user involvement [29]. This project is not going to be able to attain user involvement throughout the project.
3.1.2 James Martins Rapid Application Development (JMRAD)

A Rapid Application Development (RAD) approach aims to build a working system rapidly [29]. As with any process stakeholders want things quicker and better. This has led on to the creation of many methodologies that concentrate a RAD approach. James Martins Rapid Application Development (JMRAD) is one of these methodologies [4].

JMRAD has four distinct stages it devotes time early in the project assessing the user’s needs. The first stage is the Requirements Planning, this stage focuses upon meetings with key stakeholders empowered to make decisions in the project. These users are from various levels in the organisation, some being higher management and some being standard level employees. The second stage is known as User Design within this stage key stakeholders are engaged in modelling activities to map data flows within the organisation and to design a system around them [4]. Modelling languages such as UML are used heavily in this stage (see section 3.4.1). The third stage is the Construction stage this moves on to build the system primarily in prototypes that are reviewed by users and iterative change is performed upon feedback. Due to this method of active user involvement users will know what to expect from the system on delivery. Cut Over is the final stage this involves the full testing of the system and training of the users, then the system is then phased into the organisation [4]. From the information presented here we can see that this methodology needs a lot of user participation but promises to produce a product that will have correct fit with an organisation fast.

3.1.3 Agile Unified Process

The Agile Unified Process is a both iterative and incremental process. This methodology breaks down the project into activities and phases. Activities are standard stages that are not entirely dissimilar from most other methodologies e.g. requirements capture and testing. There are then four phases throughout the project, in each phase different activities are concentrated on for example in the inception phase requirements gathering and business modelling are concentrated on. The project phases are the iterative element of this methodology, this leads the phases to allow flexibility and the secondary iteration may address an activity that did not have the required outcome on the primary iteration. Please see fig 3.1.3. This shows a graphical representation of this methodology.
3.1.4 Methodology Choice

Three methodologies were considered to support this project. As time was a constraint and there was only one developer available JMRAD and DSDM seemed initially to be good for fit with this project. When researching further into the DSDM methodology it was found that the primary stage of this methodology is concerned wholly with checking if the project and the methodology fit with each other. For the purpose of this project this would not be an applicable stage. DSDM was considered due to the fact that this project has no sponsorship so there are only certain resources and time that can be applied to it. DSDM fixes the resources for the project and then sets out to deliver only what can be achieved within these constraints this approach fits well with this project [29]. Yet on investigation it was found that active user involvement is regarded as imperative [29]. Due to the nature of this project, user involvement will be sparse throughout, so it was decided that DSDM would not be used. The decision was made to pursue with the AUP to perform this project. It would be a modified AUP methodology where the transition and deployment phases would be removed due to this project aiming to assess feasibility of a proposed solution. Another stage will be inserted for the evaluation of the project. This will allow the flexibility of this project to iterate through certain stages based upon feedback.

3.2 Domain Research

This project will have to take into account the complex area of the UK health sector. The complexity of the UK health service goes some way to attributing to the cause of the issue that this project aims to address. The Health Sector in the UK is split up into the private health sector and the National Health
Service (NHS). This project is concerned with the NHS and in particular with the Pathology Service within it.

### 3.2.1 National Health Service

Health care systems vary from country to country and also area to area. When contrasting the system that has been adopted in the United Kingdom to the system that is used in North America and other countries there are startling differences between the two. A whole project could be written upon these differences, yet for the purposes of this report it is sufficient to know that there are differences dependent upon government and country health provision.

The NHS is a unique system that supplies health care to the citizens of England through public taxation funding. The NHS is designed to be free at the point of use, and is based on a patients clinical need, not their ability to pay [26]. In this respect it is very different to other countries health care models where care has to be paid for by patients when needed. For this reason health insurance is a regular and expensive outgoing for most citizens.

The NHS is a complicated and large organisation in 2004 it was reported that it was the fifth largest employer in the world, employing 1.3 million employees and still growing [16]. Due to its sheer size and also the complexity of the job it performs the structure of the NHS is not simple. Firstly at the top of the Structure is the Department of Health (DOH) this is a governmental department that oversees the management of the health services of the whole country. There is then nine Strategic Health Authorities (SHA), these are authorities governing the health service they are split up into geographical areas and answer directly to the Department of Health. Within each SHA there are many organisations called trusts, these trusts all manage different types of patient care the main types of trust are listed below [26].

**Primary Care Trusts (PCT)** are the first instance of care that most patients see when they have an issue this includes General Practitioners, walk-in centres and services such as direct phone line health care support services.

**Secondary Care Trusts (Acute Trusts)** manage the hospitals in the NHS, these are specialised services and patients are normally referred here by primary care services.
Ambulance Trusts manage the transportation in emergencies of patients and also staff to any point of emergency that they are required.

3.2.2 The National Program for IT (NPfIT)

The National Program for IT (NPfIT) was launched in 2002, it represents the largest IT investment in the United Kingdom to date [7]. The NPfIT aims to revolutionise the operations of the NHS by implementing large scale IT systems to modernise the operations. The NPfIT is creating a multi-billion pound technology infrastructure, which will improve patient care by enabling clinicians and other NHS staff to increase their efficiency and effectiveness [11]. Due to this large scale funding and change many NHS departments out of scope of the direct program are looking to see how systems could be implemented to support their activities. This project will look towards the creation of a National Laboratory Handbook infrastructure something that has been supported by Connecting for Health (see section 3.2.3) and many professional pathologists [14].

3.2.3 Connecting for Health

Connecting for Health are an organisation created by the Department of Health, they are charged with the overseeing of the NPfIT. Connecting for Health came into operation in April 2005 [11]. CFH make all the decisions upon the direction of the NPfIT and also manage communication of information to all of the stake holders and the public regarding the program. They are the driving force for the whole of the IT investment within the NHS, and have supported the idea of a National Laboratory Handbook [14].

3.2.4 The Pathology Service

The definition of pathology is the branch of medicine that studies disease [30]. Within the NHS most secondary care trusts have pathology laboratories associated with them. This is a department where samples such as urine, blood and saliva can be sent to be tested to attain certain results that may indicate conditions. There is a range of different tests that each laboratory will perform, each laboratory may perform completely different tests. The method for each test will be different as will the requirements and reasons for each test [13]. Each test will have many different pieces of information associated with it, this data is currently not uniform. Yet tests also contain characteristics that will be the same throughout the NHS.
3.2.5 Laboratory Handbooks

A Laboratory Handbook is a collection of information related to a laboratory. It stores information about services that are provided by a laboratory. There is no set form of laboratory handbook in most cases a handbook will list the tests that a laboratory performs and all the relevant information on these tests. Currently there is no standardised form for this, some handbooks may be in electronic form e.g. spreadsheets, some are published in booklet form. This was observed at a Pathology Workshop when representatives of the Ashford and St. Peters Hospitals NHS Trust presented their current printed solution (see Appendix B) handbook solutions [10]. There are many different forms that these handbooks are published in. Currently there is also no standard content that is stored in handbooks at every pathology laboratory content is different.

3.2.6 National Laboratory Handbook Concept

The National Pathology Handbook concept has talked about by many of the more IT aware pathology professionals [13]. It is a idea that a system could be created to allow information sharing throughout different pathology laboratories in the NHS. This project fits in with the current large scale IT change in the NHS and could be integrated with all of the current system change. CFH are currently working on a ‘National Pathology Catalogue’ (see 3.2.7 this aims to be a definitive list of tests that are performed throughout the country.

The National Laboratory Handbook concept started off as a very lose idea. In the early stages of the project thought was put as to what this would mean. Use case modelling was performed to see what services this handbook could provide to the NHS. After analysis the following definition of a National Laboratory Handbook was formed and seemed appropriate.

‘A national system holding all services and exceptions that a pathology laboratory will provide from a national list (national pathology catalogue). Creating a national information system storing what services each laboratory will offer countrywide. This system will be customisable from each laboratories system including a provision for localised data from chosen fields on certain tests’.
3.2.7 The National Catalogue

The national pathology catalogue is a concept that is currently being worked on by CFH (see section 3.2.3). They are looking to provide a definitive list of tests that laboratories throughout the country provide. Currently there is no standard list of tests in their entirety so this will be a push for standardisation in the NHS. The idea of a national catalogue will fit well with information system development within the NHS.

3.3 Research Techniques

SQIRO techniques are used for requirements gathering within system design projects. Four of these techniques will be discussed here as they are expected to be used within the project.

3.3.1 Sample Documents

Sample documents from the organisation under investigation can be used. The collected documents can be used in two ways, statistical analysis can be performed to identify data patterns. Documents can also be used by the analyst to determine the information that is used by end-users in their current work [29]. This is a type of as-in system modelling as it is using the current system to assess the needs and purpose of a project. This will be used within the analysis and requirements stage of this project to help to understand the data needs of the organisation from a laboratory handbook.

3.3.2 Questionnaires

Questionnaires can produce very rich data if designed properly, but it is a hard task to design a good questionnaire and much thought must be put into it. A well designed questionnaire may be a good way to evaluate what would be expected from the identified users of the system.

3.3.3 Interviews

Interviews are meetings normally with relevant stake holders in the system, most commonly these being end users or management who have positive agenda for the systems integration. The degree of structure may vary some interviews are planned with a fixed set of questions that the interviewer works through, while others are designed to cover certain topics but are open ended [29]. This will be a very important
fact finding technique for this project as the main method of communication with users is based upon
direct stake holder meetings.

3.3.4 Reading

When approaching a problem with no understanding of the domain it is very hard to understand what the
problem is and construct relevant solutions. It is important that certain aspects are understood before any
change is considered. Reading will be very important in this project as understanding of the Pathology
Service in the NHS will need to be a focus to begin with.

3.4 Requirements Gathering Techniques

Discussion will take place here of research of methods that could be used in the requirements gathering
stage.

3.4.1 Universal Modelling Language (UML)

UML modelling is a technique that can be used to set and explore many ideas within a system develop-
ment life cycle. The analyst may be looking to find out what the requirements of the finished product
could be, or the analyst may be using a model to discover what the organisation is currently doing.
UML is a powerful technique used for creating real world abstractions to create understanding and doc-
umentation of the organisation the system. UML is not only used to create understanding of the current
systems it can also be used to design the new system and present it before the build stage is completed.
It is a technique used for the modelling and presentation of information in computational projects. [29].

3.4.2 MoSCoW Technique

MoSCoW is a method of requirements prioritisation, it attributes labels to each of the use cases within a
system design. Must have requirements are the base of the system and must be included. Should have
are necessary but the system will operate without them. Could have are good requirements to include in
the system but may not add much value. Won’t have are requirements that could perfect the system but
are not needed. This will be a good method to use within this project as this project has time constraints
and can only develop certain use cases [29].
Chapter 4

Requirements Analysis

This chapter describes the process that was used to recognise the requirements for this project. It takes in stages the work that was performed in the inception and elaboration stages with regards to the requirements activities.

It was decided that the requirements analysis stage would be split into stages. Each stage will focus upon different aspects of understanding the problem better and matching a solution to this problem.

4.1 Stage One: Understanding the Data

Throughout this project consideration had to be given to the dataset that the system would contain. At the first user requirements meeting with Dr Richard Jones it was made clear that the data modelling was no trivial matter in this project.

Including pathology experts in the process was a key factor to understanding the data. Much like the computing field pathologists use many acronyms to describe things. When the author was looking through the sample laboratory handbooks it was noticed immediately that extensive research was needed into the items contained in the handbook. Some of the fields were self evident but then others were not and work had to put into decipher these. A visit was organised to Leeds and Bradford Pathology Labs.
with Dr Richard Jones and Paul Richardson a CFH analyst working within the area of the NHS Pathology Service.

On discussion with Paul Richardson it was found that he had also been working on the issue of understanding the data within the Pathology Service. By this time most of the data fields in the handbooks had been elaborated on and understood by consulting Dr Richard Jones and other health care professionals.

It was decided to check that these meanings were correct and it was agreed that Paul would swap a spreadsheet of terms he had been working on with the author as to compare see Appendix C for these spreadsheets.

The next consideration was what data should be put into the system. At the most basic level the question that had to be asked was ‘What should a National Laboratory Handbook contain?’ There is no right or wrong answer to this question but a decision had to be reached with regards to the design of the data set that the prototype system would contain. The method that was used for this was assessment of four different laboratory handbooks and rationalisation through an expert user. Four pathology sites were identified and the pathology handbooks were accessed from the sites shown below.

- Leeds
- Liverpool
- Ashford and St Peters (see Appendix B)
- Nottingham

The handbooks were all assessed using the sample reading technique. Each one was read through carefully and the data sets were collected from them. The outcome of this was a list of data fields that had appeared throughout the sample set of handbooks.

From the collected dataset the information was concentrated on. Information was also modelled about contacts at laboratories but certain data fields such as opening times were out of scope of this system.

The second consideration was that if a national system was deployed then it would have to be recognised that some of the data in this system would have to be uniform throughout the country and some would be local to each laboratory. The decision as to what fields would be national was not an easy decision.

On evaluation it was also found that these laboratories should not be allowed to type in whatever values they wished into these local fields. Each local field should have a set number of options this is following
A method had to be designed to get feedback on this information from professionals. A spreadsheet was designed with all of the identified fields. Assumptions that had been made were put into this spreadsheet and then they were sent off via email channels to different health care professionals. Please see fig 4.1 for a snapshot of this spreadsheet, the full spreadsheet can be viewed in Appendix C.

**Figure 4.1: Spreadsheet used for the assessment of handbook data.**

This spreadsheet contained fields that had been chosen for inclusion by the means of the assessment. Health care professionals were asked to make comments upon this fields. They were asked to comment upon the understanding of the field and also if this should be a laboratory specific (local field). As there is currently no standardisation in the NHS this was asked for as to make sure that understanding was all at the same level please see Appendix C for requirements gathering spreadsheets.

**4.1.1 Stage One: Outcome**

From this stage there were three main outcomes.

- A list of data fields that would be included in the final system.
- Understanding of the meanings of the data that had been assessed.
• An initial attempt to separate local and national data.

• A realisation that this is not a definitive data set (this will be discussed in recommendations).

4.2 Stage Two: System Requirements Analysis

Stage one looked to the data that was currently handled within laboratory handbooks. The aim of stage two was to learn about the requirements of a handbook and to decide upon the services a national laboratory handbook could provide. A meeting was organised with Dr Richard Jones and Mr Keith Gailer (Pathology IT Operations Manager for Leeds Teaching Hospitals). Within this tour the workings of a laboratory were observed and how a laboratory handbook fitted into staffs day to day workings was observed and understood. Please see Appendix D for information of this visit.

Laboratory handbooks are used throughout secondary care, in the Leeds Teaching Hospital Trust a web electronic version of a handbook is the standard version. As has already been established handbooks come in different formats throughout trusts some are physical form handbooks and some are computerised such as spreadsheet and web interfaces. It is important to understand how handbooks are used by understanding this it will help to understand how a national handbook. Also by identifying any issues with the current system it will help to design how a new system will improve current operations.

4.2.1 Current Use

A informal interview was held between the author and laboratory staff to find out the current usage of handbooks within the Leeds and Bradford Pathology Partnership please see Appendix D.

• The main function is fact finding for clinical staff about the tests that a laboratory provides.

• Non clinical staff use the system to find out information about tests e.g. secretary’s answering questions about tests.

• Clinical staff use the system to find out if a test is provided by their lab and information on ordering.

• Staff can use the systems to check Turn around times on tests as to plan patient care.
• *(not all)* Provide external access so other trusts can see what tests labs perform.

• *(not all)* Provide public information so that the public can find relevant information on tests.

• Find laboratory / department contact details.

It was found from this investigation that the primary function of a laboratory handbook within a trust is to be a tool for the distribution of data too a organisation that may have hundreds of staff. Pathology is a very important function within a trust as much of the medical service relies on running tests to ascertain what is wrong with patients and what the most appropriate form of treatment will be. The importance of pathology in trusts was illustrated in this meeting with the description by Dr Richard Jones of when a IT failure caused the Leeds Teaching hospital to grind to a halt as no diagnosis could be confirmed.

Also from this meeting the identification of issues with the current handbook solutions were a key finding and helped to understand what the National Laboratory Handbook could provide.

• Currently there are no standards for data sharing of test information between laboratories within the pathology service.

• Some laboratories wish to share handbook data but do not have the solution to facilitate information sharing (some may outsource tests to other labs so allowing access would be a good feature).

• Lots of data in handbooks is uniform throughout the pathology service yet all laboratories store this information on a laboratory by laboratory basis.

• With many disaggregated systems it is very hard to keep data standards. There is currently a large push in the NHS for standardisation of data.

• Physical handbooks can only be updated at most once a year due to cost.

• Physical books can get lost or damaged in a clinical environment.

• If tests are withdrawn throughout the whole of the service due to clinical risk this is extremely problematic to withdraw when so many handbooks have to be updated.

It would have been more conclusive if more laboratory staff could have been accessed to give insights into the use of handbooks. It is felt that this investigation has found all of the major uses and issues but it not and exhaustive list due to the non availability of users.
4.2.2 Concept Elaboration

Throughout the project interest was seen from CFH (see 3.2.3) the organisation contacted Dr Richard Jones to ask if the author and Dr Jones would be free to attend a meeting on 28/01/08. Some very important information with regards to the design of the national laboratory handbook system came out of this meeting. This was a meeting of the CFH Pathology Project team, they explained that they were currently working towards creating a definitive list of coded information within the pathology service [23] see section 3.2.7. On more elaboration it was found out that this was a concept that has since been recognised as a ‘National Pathology Catalogue’ this will be a listing of all tests that the NHS provides.

This session helped to understand better what a National Laboratory Handbook would offer to the pathology service as a whole. As in the future a ‘National Pathology Catalogue’ would exist it made sense that the handbook would operate off this national directory of tests. The project now took on the task of modelling the National Laboratory Handbook system around the concept of a national list of tests. CFH were at a very basic stage with their data models and they were very interested see the data models for the National Laboratory Handbook design as they would contain roughly the same data. At this point in the project the design stage has not begun, so nothing could be passed on. A presentation followed showing all of the current projects that are being run in the Pathology Service, at this point it was realised by the author that it would make more sense if all these systems could run off one main pathology data set.

It is out of the scope of this project to model the data for the whole of the Pathology Service. But it made sense that the creation of a flexible data model could be evolved to allow other systems to use it also. This could lead the the creation of a central data repository for the whole of the pathology service. CFH were very interested in this concept and wished to have the findings of the project presented to them. It can be observed how many of these projects conceivably connect together in see Appendix F. An example of the fitting together of these projects can be illustrated with the following example. Currently a large project that is going on within the CFH organisation is the ‘Order Communications Project’ this will allow primary care doctors and secondary care doctors to order tests electronically. The National Laboratory Handbook concept could plug into this as the proposed order communications system will be able to ascertain from this system what tests are provided by a laboratory and information upon requesting them.
4.2.3 Outcome

The following points came out of this meeting.

- The data model will need to run from a central list of tests (‘National Catalogue’).
- The model should allow each laboratory to maintain a list of tests that they provide from the national list (Allowing a perceived local laboratory catalogue).
- The model should allow each laboratory to maintain exceptions that they do not provide from the national list (Allowing a perceived local laboratory catalogue).
- The model should allow certain test data to be stored on a local basis for laboratories from a list of choices.
- The model should allow the storage of clinical data linked to tests.
- As many decisions will need to be made by clinical boards later on the model should be flexible to change.

4.3 User Evaluation

Consideration of users is very important when trying to understand a current system. With this project a use case approach to development is going to be followed as standard with any unified process [29].

The understanding of users is very important as the development will be based around what functions users need. From the meetings held with the labs and research a number of users of handbooks had been identified. These included Doctors (Primary care), Doctors (Secondary care), Surgeons, Nurses, Secretaries, Lab Staff, Patients, Pathologists, Laboratory Technicians and in cases where electronic solutions were already used there had to be administrators to look after the solution.

The current access levels to handbooks for users were assessed as to understand the user base. In trusts where paper based systems are prevalent only people who are given hard copies of the handbooks have access [27]. Whereas in the current Leeds system the public have access to the basic information and then the clinical information is accessed via a password. A finding from this meeting was that within most trusts irrespective of role all staff with handbook access will have access to the same information as none of it is patient information so privacy is not governed as long as staff authentication is confirmed.
It was decided after assessing all the users roles that all current users fall into one of four categories. The analysis of this can be seen in Appendix G, it was decided that the following user groups would exist within the new system.

**Public User** a public user will be able to gain the most basic access to the system. This will not show any lab specific data and will be more like an information system of basic test information.

**Laboratory User** a laboratory user will be the standard authenticated user, they will be attached to a lab and will be able to view all information about laboratory services at their respective laboratory.

**Laboratory Admin** a laboratory admin will be able to manage a laboratory that they are assigned to. They will manage the information that is held on laboratory per laboratory basis.

**National Admin** a national admin will manage the system as a whole e.g. adding and removing tests, laboratories and users.

Each of the user classes above were assessed individually by using a use case method. Firstly the functions that each user would need within the system was identified. Then this was mapped onto a use case diagram as seen in figure 4.3. This gave a structured method to run the design and build stages of the project. This set the project ready to move into the build stage.

4.4 Stage Two: Outcome

This stage has investigated some of the current handbook systems that are in place. It has looked to how the current solutions are used within a clinical setting and also investigated any weakness’s that these have. The stage then looked to identify user groups and how their needs can be served by the system as to allow the developer to understand how to best facilitate these in the new system.

At this stage in the project a good overall understanding of the domain and the current system was held. The project was now ready to move onto the design stage to assess how a national replacement for the current systems could be implemented. The use case created in the analysis stage will drive the projects design and development stages please see 4.3 for the use case diagram.
Figure 4.2: A use case model derived from the Analysis and Requirements Gathering
Chapter 5

Design and Build

This chapter will discuss the decisions that were made throughout the design process of this project. This section refers to the work that was performed primarily in the elaboration phase with regards to the analysis and design activity. It will then go on to address the build of this project that was performed in the construction phase in the build activity and how to was performed and driven.

5.1 Introduction

This project is addressing the architecture of a solution so design was split into layers as each part of the system could be addressed in turn. The presentation layer is concerned with what the user can see when they are working with the system. The business logic layer of the application deals with the operation of the system it shifts the data around and controls the functions. Within the data layer the data is all stored for retrieval by the application. This is a commonly used approach in software design called the three tier architecture.

A main focus of this project is the accessibility of this data from one central source by many different users non dependent upon geography. With this in mind it made sense for the system to have a web front end forming the presentation layer, this would allow for easy accessibility by many parties. As there was also going to be data stored in the system and many transactions a database was the obvious
choice for the data layer. A technology would be needed to sit in between these two layers to perform logic functions. Due to the choice of the presentation and data layers it was decided that this would be a web server. This chapter will also look at the concepts of the system this is the part of the system that the user will relate with.

5.2 Technology and Tools Review

Many technologies are available that could form a solution to the identified problem. A layered design will be the outcome of this project and a mix of technologies will be needed to facilitate this. Within this section discussion will occur upon technologies and choices will be made in section 5.2.4.

5.2.1 Database Technologies

Databases act within computer systems as a layer of data storage to primarily provide persistence. Most information systems operate upon some form of data set. It is very important that the correct technology is chosen to store this data. These systems are called Relational Database Management Systems (RDBMS) and provide functionality for the storage and upkeep of data. The industry standard language for accessing this data is Structured Query Language (SQL) this is a language used for the retrieval and editing data when communicating with a RDBMS. [28]

5.2.1.1 PosgreSQL

PostgreSQL is an open source RDBMS. It is known as being one of the best established open source projects as it has been run now for over 15 years. For this time period the system has been in active development allowing real user participation in the direction of the software. It has all the features that are expected of any RDBMS with the added advantage that it is free software. It runs on all major operating systems and servers [20].

5.2.1.2 Microsoft SQL Server

Microsoft SQL server (MSQL Server) is Microsoft’s RDBMS offering to the industry. As with all Microsoft software it proprietary software with most version having a cost associated with them [19]. A key feature of MSQSL Server is that it is designed around usability allowing database administrators to
have the functionality that they need to perform day to day tasks with ease. As MSQL Server is a Microsoft offering it only supports the Windows operating systems meaning the system has less portability and narrows down server operating system options. After research it was found that there is a free version of MSQL Server called Microsoft SQL Server Express Edition this has less functionality than the full version but can offer a good platform for a developer tool as it would be a good tool to test database designs [18].

5.2.2 Web Server Technologies

A web server performs key functions within any web based application. Typically a web server will provide the hosting of the system on line allowing the system to be available to anyone with access to the World Wide Web (WWW). When considering a web server technology for this system it should be recognised that this will not simply be displaying static pages. This web server will need to process documents and react to user input also.

5.2.2.1 Apache Web Server

Apache is a free open source web server supplied by the Apache Software Foundation. It is primarily focused upon the Linux operating system but the package can also be used on other operating systems such as the Windows Server operating system [15]. As it is a open source technology is claimed to be more reliable than most commercial systems due to the belief that more people will have looked over the source code and revised it [15].

Apache is scalable to need, a single personal page can be run on it or a large corporate site serving millions of regular visitors [15]. It has offerings of modules for most server side languages including JSP, Python and PHP. Yet it does not support the commonly used ASP server side language.

5.2.2.2 Internet Information Services (IIS) Web Server

IIS is Microsoft’s web server, IIS is bundled with the Windows Server operating system family that has a cost associated with it. It supports many technologies such as ASP, ASP.NET and PHP. The system is well known for ease of use with a very simple graphical user interface. IIS is the only web server that is known to have full support for the ASP.NET technology stack as these are both Microsoft products.
5.2.3 Server Side Technologies

Server side technologies were explored as to see what would provide the best technology to provide server side processing within this system.

5.2.3.1 ASP.NET

ASP.NET is a Microsoft server side programming technology. This technology was specifically designed to allow the construction of rich web applications with a wide range of design flexibility. The developers of ASP.NET assessed what the needs of most web applications were and then designed it to have pre built items to perform some of these tasks. These items or ‘objects’ are very flexible for developers to customise them to suit the need of the application. ASP.NET helps to overcome the issues with static HTML pages of not being dynamic, a web server will dynamically produce .aspx pages (the standard ASP.NET format) dependent upon the ASP.NET code in them. ASP.NET supports many scripting languages that sit behind it such as VBscript, Java Script and the C# language [22].

5.2.3.2 PHP

PHP is a open source server side scripting language. It is primarily UNIX based but also now has support on the Windows Server operating systems. PHP supports an extensive list of databases and web-servers. PHP is known as one of the best maintained open source projects and it fits in very nicely with the use of the Apache web server technology. Security is a common issue for PHP it is commonly known as having many exploits. Of the vulnerabilities listed in the National Vulnerability Database in the first month of 2008 38.4% were linked to PHP [17].

5.2.4 Technology Choices

After reviewing technologies decisions had to be made as to what would be used to develop and support this system. As the choices that are being made here will define the overall architecture of the system there are three decision that had to be made at this point. Yet these decisions cannot be seen as isolated. The architecture needs to fit together so that each layer will serve the other layers. From looking at the technologies researched two distinct options come out.

One of these is a decision to take the open source route using the Apache/PHP/PostgreSQL stack whereas
the other is to use the commercial Microsoft stack of IIS/ASP/SQL Server.

Both of these architecture choices have pros and cons and the health domain that this system will eventually work within needs to be looked to as to see which choice is best suited.

Using the open source stack would make sense from a cost perspective for the NHS, as the software is all free and can be easily deployed. Yet the project had no access to the tools and servers needed to support this architecture. Professional support is also an issue within the NHS. This system is envisaged to be deployed into a health domain and through business change reliance will be put upon this system. This needs to be considered that there is no professional support for these systems, if the system goes down then there is no organisation you can call on to have responsibility for the upkeep of this and assurance of up time as the system will be supporting decisions concerning lives. The PHP language has also been recognised as a extremely insecure language so is not an appropriate choice for development.

The use of the Microsoft stack would cost the NHS money to acquire and upkeep the licences, but as money is paid for this product Microsoft hold a responsibility to troubleshoot problems if they arise. The systems are also designed for use in large environments so if this system is nationally rolled out it would cope well from a scalability stance.

From a development perspective this seems the sensible option as access to the tools are readily available. The Yorkshire Centre for Health Informatics are willing to supply an IIS server, Visual Studio 2008, the IDE for ASP writing is free to students and Microsoft SQL Server Express edition is a free robust option for database development.

After careful consideration it was decided to use the commercial option also the sponsors preferable option was the Microsoft stack as in the Pathology Service this was already used for some functions so the staff has experience with it.

5.3 Concept Design

Not all design for this project was technical the user base for this project were mostly going to be non technical users so it is important to address the concepts that would be created and used by this project. As with many computer systems metaphors are used for example the windows operating system uses
a desktop metaphor to relate computer concepts to real world concepts. With the National Laboratory Handbook the following metaphors were created.

**National Catalogue** a national list that contains all of the tests that are offered by the NHS.

**Lab Service** a service that is offered by the respective laboratory.

**Lab Exception** a test from the national catalogue that is not supplied by the respective lab from the list.

**Local Data** information that is only applicable to one lab and is set locally by them.

**National Data** data that is uniform throughout the NHS.

**Local Catalogue** the amalgamation of services, exceptions and local data creating a laboratories own catalogue.

These concepts will be created throughout the use of the national laboratory handbook system.

## 5.4 Presentation Layer

Due to the nature of this project it was evident that a web front end would be the best option for the presentation layer. A web front end would allow access throughout the whole of the country to the system through a single non geographically dependent entry point.

### 5.4.1 Structural Design

System structure was a primary design concern for the system as the system that the users would interact with. Once the structure of the system was defined the navigation system and web structure would be able to be designed. This would also allow decisions regarding access controls to the system with reference to the use case discussed in Fig 5.4.1. A hierarchical structure was designed that set out where all the features would be placed in the structure of the presentation layer of the system.

### 5.4.2 Interface Design

ASP.NET was new to the developer in this project so a book was used to teach the main functionality. This was Beginning ASP.NET 2.0 with C# [5]. The first thing that was learnt was the use of a
Figure 5.1: A first pass design of the structure of the presentation layer.

The interface for this site should be intuitive as to allow users to easily navigate around and find the information that they want. In this system there is no need for a extravagant looking interface as this system is not provided to sell a product or advertise a product such as online stores. It will be used as a information system, users that use this service will access it with a specific goal in mind. When this site was designed a basic level of HCI was considered by keeping in mind Shneiderman’s eight golden rules of interface design [2].

The interface design was roughly drawn on paper in a technique called storyboarding to start off with then more and more parts were added to it iteratively until there was a solid foundation existed for development. A simple clean design was decided with navigation and login features on the left hand side of the site and a logo in fitting with the NHS at the top. A feature in ASP.NET would be used called a site map file. A site map is an XML file that contains information about all the aspx file within

the website forming a map of the site. Then controls can be added that will interface with this. For example in this interface a navigation system was added that read all of this information from the site map and built a menu system that could be used for navigation of the site [5]. Styles would be added to the site through the use of a CSS file this would set the look and feel of the website. It was decided that bold plain colours should be used in keeping with current NHS websites with a blue and white colour scheme.

5.5 Data

The data modelling was one of the most complex parts within this project. This system had to be able to cope with two types of data that had been identified.

**National Data** - data that was available to all laboratories throughout the NHS and has been identified as unified throughout the country

**Local Data** - data that each laboratory would want to store on laboratory by laboratory basis.

Databases have tables and fields within them, these had to be designed as to model the data that would be stored in the system. Two different designs were drawn up for the data layer of this system, they were both done using agile modelling methods on a whiteboard see Appendix E. The developer created quick designs on a whiteboard and refined designed until a design that was satisfactory was created. Two designs came out of this method and these are both described below.
5.5.1 Data Model 1: Local Database Method

The local database method designed a data model that would require each laboratory to have their own database. These would all be stored on one server and with a central database storing national data. The local databases would contain fields that had all of the laboratory specific choices in, these would be contained in the format of id numbers. The national database would then contain mapping tables that would map the Id’s from the local database to data items within the national set. This would allow the advantage of the database sizes staying relatively small. A problem was identified that as there is approximately 120 labs in the country [13] causing the upkeep of this system to be hard concurrent connections would have to be managed between two databases per user that would not be scalable with hundreds of users. The data models as designed for this can be viewed in Appendix I.

5.5.2 Data Model 2: National Database Method

This model was a design that would use one large database for the whole of the country. This database would contain a mix of the local and national types of data. The method of separating local from national data would be coped with using a mapping method. For each test that a lab wanted to store lab specific data there would be a central table that they could record their options in. This table would then contain Id’s that could be resolved to the in the national set to entries. Fig 5.5.3 shows how a central table will be linked up to mapping tables contains options here you can observe how the department tube and storage options of a test can be customised per lab.id and test.id. Each of the other fields in the TESTLOCALDATA table would also have mapping tables associated with them. An agile design method was used to design this scheme a whiteboard was used and worked on until the design was satisfactory, pictures of this and the final schema can be seen in Appendix I.

5.5.3 Model Choice

It was decided that the national database method should be used. The main positive from this approach is the single database making the upkeep easier. It was also identified that if there was more than one database the system would have to make connections to multiple databases, there would be over one hundred databases (one per laboratory). This would not be a efficient way to design a system as the
database server would have to cope with multiple connections to multiple databases and it would make the logic layer very complicated and not completely efficient. Primarily the decision was made to go with the Local Database Method due to the thinking that one large database may be unmanageable. But on further thought and on consultation with Dr Richard Jones it was recognised that the national database method would be a much better solution and by the use of mapping tables there would not be multiple instances of the same item stored.

![Diagram showing the concept of mapping tables.](image_url)

**Figure 5.3:** Diagram showing the concept of mapping tables.

### 5.5.4 Normalisation

When discussing database design normalisation is a topic that has to be considered [9] describes normalisation as ‘a process of analysing the given relation schema’s based on their functional dependencies and primary keys to achieve the desired properties of (1) minimising redundancy and (2) minimising the insertion, deletion and update anomalies’. There are four main normal forms used in database design 1NF, 2NF, 3NF and BCNF. An attempt was made to normalise the data scheme that was designed for the data layer within this system and it was found that most of the fields were already decomposed to a
level good enough to maintain good normalisation principles. Some of this data schema was left non-normalised for example the test_id fields. This was allowed due to the opinion of the developer that this model is robust enough without any more decomposition and also that relations may be left in a lower normalisation status such as 2NF for performance and functionality reasons [9].

5.6 Business Logic Layer

This section will work through and discuss design decisions regarding the Business Logic Layer.

5.6.1 Security and authentication

To allow users to see the ‘Local Catalogue’ for their laboratory there must be a explicit link between user and laboratory. A authentication system needed to be designed that would allow a user to have a laboratory attributed with them and also have access controls attributed with their user credentials. The ASP.NET membership controls proved a easy way to implement the access controls meaning that certain functions could only be accessed by users with the correct rights. This did not solve the problem of lab membership though. After research [5] it was found that a way to associate users with labs would be a technique called profiles. A profile can associate additional information fields with users, profiles are set up in a file called web.config. The web.config file defines all the settings for the ASP.NET system, it was decided each user would be associated with a lab_id meaning that the system could identify what lab the logged in user was a member of.

Using this profile manager it was decided that a field would be added into the users profiles called lab-Member this field would be populated with the lab_id of the laboratory that the user is associated with to allow the system to know what laboratory they belong too. This would allow the system to dynamically produce output dependent upon laboratory.

The access system also had to be modelled this was decided to be done on a process of roles. Roles are specific user groups that users sit inside within the ASP.NET login system. Three roles would be created a labadmin, labuser and national admin. As the structure had been defined it was possible to design what user roles would have access to which parts of the system. Please view Appendix H to see how the access rights would be set up. The access rights would all be defined in the web.config file, this would use the membership system to work out what user role a logged in user had and display the
appropriate navigation options.

5.6.2 Data Access Layer (DAL)

A method had to be implemented to access the data from the data layer and to bring it into the application layer. It was first considered that this would be a trivial task by setting up a database connection and coding some SQL Query’s to retrieve data into the business logic layer. After some research into data access in ASP.NET it was found that this was not a good method as it would leave the system open to SQL Injection. SQL injection is an attack in which malicious code is inserted into strings that are later passed to an instance of a DBMS for parsing and execution [21]. By using this method the normal operation of a program can be changed, the most common attack with SQL injection is to create a query that will make the database return all rows. This is an example of a information disclosure attack as a user who should not have access to certain data fields will gain it.

The best method to implement a secure data connection layer would be the implementation of a Data Access Layer (DAL) [1]. The implementation of a DAL allowed a easy set of methods to be written to retrieve data from the data layer dependent upon arguments passed to it. This could be done by creating a XSD file which forms a object called known as a data set. A data set contains items called table adaptors a table adaptor provides a object to reference a database table. Querys can be added to table adaptors and these form methods that can be used in code to retrieve chosen data from a database.

5.6.3 Functions

The system should provide functions to users to allow them to complete certain tasks. These functions needed to be identified and designed as part of the system. The language that would be used for this would be the C# language. Each .aspx file has a .cs file sitting behind it with the the program code in it that is executed on the server. Querys would also need to be written in SQL for the C# to call and interact with. The functional design was driven by the designed use case see Fig 4.3. This section will discuss how the design was performed for for one of the functions within the system for a full list the designed functions please see Appendix K. At times this section will refer to the database model please refer to Appendix I to see the schema for the database that the code would be operating on.

[View My Lab Catalogue Function]
When designing the functions it was important to first state exactly what this function would do. First thinking about ‘what’ instead of ‘how’ is important to get a solid design. The view my lab catalogue function would allow a user to view their laboratories local catalogue. The laboratory catalogue would have to be generated using data from the database and manipulating this data within the code.

It was first identified what data would be needed to perform this function. The business logic layer would need to know the users lab_id and know what exceptions the laboratory holds from the national list. From this data the system would be able to generate the users laboratory catalogue and display it. This function would also need to be able to retrieve the clinical data that is held about a selected test (national data) and the lab specific data (local data).

The data tables that were going to need to be accessed were identified and what specific parts of the information the business logic layer would need to perform its task. Using this information a plan was made for the methods that would be needed to be programmed into the DAL to retrieve the data. SQL code would be needed to be added into the DAL to retrieve the data, the SQL code would have variables put into it so that the business logic layer would be able to interact with the data layer. This SQL business logic layer in the DAL would then be presented within the code as a method call so that it could be used throughout the program. This section now follows on to discuss the DAL methods needed for this function and how they were designed.

Retrieve the list of all services a lab provides from the lab_id This was identified to be one of the most important functions within the system. As the database schema was complicated it was decided that most of the work to retrieve this list would be done at the SQL level. The database holds a list of exceptions with lab_id and test_id and also a list of tests with test_id the most efficient way to create the ‘local catalogue’ would be to retrieve a list of all tests but take away the tests that a laboratory holds as a exception. SQL operators were explored to see which operators could be used to support this function and after research the EXCEPT statement was found this this would help to support this concept. ‘The third set operator is the EXCEPT operator. If two table expressions are combined with the EXCEPT operator, the end result consists of only the rows that appear in the result of the first table expression but not appear in the result of the second’ [8]. A SQL query was designed that would fetch the national list and then compare it to the exceptions list and only show items that did not have exceptions to the queried lab_id. Please see Appendix J Fig J.1.1 for the code that was designed for this. The output was a function called ‘GetLabServices(@lab_id)’ that could be called at any time in the program to return a
list of services dependent upon lab_id. Anything followed by a ‘@’ in the method body of this defines the input that is needed for this method.

**Retrieve clinical data for a test from the test_id** Clinical information needs to be derived for a test when it was selected. Two tables were identified that would need to be joined to retrieve this information and a SQL INNER JOIN was an appropriate method to facilitate this [8]. A method was designed called GetClinicalByTestID(@test_id). This method would supply the clinical information for a test dependent upon what test was supplied as an argument at the end of the method please see Appendix J Fig J.1.2.

**Retrieve local data for a test from the test_id and the lab_id** A method had to be designed to retrieve the local lab data that was associated with a test. This would form the display for localised information that was a major part of this computer system. By selecting the test_id and lab_id it would be possible to retrieve all the customised entries for this information. Yet as this is all stored as identity numbers many SQL INNER JOINS had to be created to resolve what the id number was associated to. A method was designed called GetLocalTestData(@lab_id, @test_id) this using an SQL statement resolved all the local Id’s associated with a test to the information that the Id’s related to and returned them please see Appendix J Fig J.1.1.

**Retrieve lab_name from lab_id** Early in the design a decision was made to associate certain user groups with laboratory’s. This is in the form of each user having a lab_id associated with them. A method needed to be designed to resolve a lab_id to a laboratory name so that this can be displayed to the user so that the human user know they are associated with the correct laboratory. A method was designed called GetLabNameByID(@lab_id) this method took the lab_id as an argument and then ran a SQL query that looked for this ID and returned the lab that the lab_id was associated with. To view the code for this please see Appendix J Fig J.1.3.

Now that these methods had been designed the function could be created as to interact with these and to facilitate the ‘View Lab Catalogue’ function. Pseudo code was written around the methods to design how the function would be coded in the build stage see fig 5.6.3.

Pseudo code was created for all of the use cases that would be assembled to create the system as a whole all of these use cases are described in Appendix K. Each one of these functions was then coded into the system.
5.7 Build

5.7.1 Data Layer Build

The design for the data layer had been performed on a whiteboard with agile modelling techniques. Because of this the output of the design stage was a large model on a whiteboard, photos were taken of this to record it. When the build stage was moved onto this model was used to create a database script that could be run on the database server to create the data layer. This proved to be a very easy way to create the database by moving a graphical representation of the data layer into a text based creations script a section of the database creation script can be viewed it Appendix J Fig J.3.

Test data had to be put into the system also as to show the operation of the system. An access database had been supplied with a list of all tests in it, there was around 600 tests in this database but none of them were structured. The only way to get the data out of this in the kind of format that could be useful was by a method of exporting certain rows in certain tables to Comma Delimited Files. These files were then used to create a data insertion script that inserted test data into the database as to show the operation.
of the system.

5.7.2 Use Case Driven Approach (UCD)

A UCD approach would be used to develop this system. A UCD approach will take each use case and work to develop this into the system. Throughout the build stage each use case was addressed and built from the output of the design phase. This approach worked very well as the design had already been done for all of the must have and should have use cases the developer could just look at the design and translate it into code. Firstly the data functions would have to be coded by programming SQL statements into the DAL and then the function was built around that in C# code. These simple steps were followed for each of the use cases that were built. An example of one of the use cases that was coded into the system is the ‘View my lab catalogue’ function some of the code can be seen for this in Appendix J. If there was time left then the other features could be addressed by the use of another iteration. An example of this is the extended feature mentioned in section 5.7.3. It was decided there was time to put this feature in so it was designed and then built towards the end of the build stage.

Each use case was subjected to a MoSCoW rating allowing the developer to prioritise what would be the priority to be worked on. Due to time constraints a few features were not completed, these were most of the edit features of the site. The edit features allowed database records to be edited. This was not a problem as the system demonstrated the architecture that would work throughout the NHS and with time edit features could be easily included.

5.7.3 Extension Work

As there was time left towards the end of the build stage one of the extension features was created for this system to demonstrate the flexibility of the data model. A knowledge management system for disease to test mapping was added to the system. This allowed the linkages of tests and diseases as to give access to a public accessible database to show what tests are commonly used to identify what conditions.

5.7.4 Build Issues

The build presented no major issues as extensive planning had been performed prior to the commencement of the build stage. The C# language was new to the developer so to begin with getting grips with this impacted the speed of the build. As the build gained momentum the developer found that the C#
language was picked up quickly and the IDE Visual Studio 2008 was a relatively intuitive program to use.

5.8 Testing

Active testing was performed throughout the development of the system. Each time a use case neared completion the use case was tested to see that it performed the job it was designed to. The table shown in Appendix K holds a description of what functions the use case should perform on completion and the use cases were tested with reference to this.

Upon deployment testing was repeated to check that the solution worked when hosted on IIS all of the functions described in Appendix K were tested with satisfaction.

5.9 Conclusion

The output of the design and build was a prototype system and database schema’s. The system was built on the developers laptop and then transferred over to the Yorkshire Centre for Health Informatics IIS server which would form a good base for the evaluation. The architecture functioned well upon deployment and a system was deployed that functioned correctly upon all functions being tested.
Chapter 6

Conclusions and Recommendations

6.1 Project Findings

Throughout this project there have been various findings that that should be taken away. These aim to provide key guidelines to anyone who is going to carry on with the national pathology handbook project, or systems integration into the Pathology Service. Many obstacles have been encountered through this project these are described below.

The primary problem was found that there was no rigid definition of a test. A test could be described as a method that is used to retrieve an outcome, a chemical that is tested on?, a indicator of a condition? or a service that is supplied by a laboratory. Within the design of this system each individual test was described by it’s own analyate (chemical measured) name.

There is currently no list of all tests that are available throughout service. Test data was used in this project but for any future development a definitive list needs to be developed.

As there is no current nationalised systems for data sharing throughout the pathology service there is a lack of current standards to define exactly what should be stored and shared. The identification of a representative population was aimed to be achieved by this project. Only four laboratory handbooks could be accessed for analysis causing this project not having a representative proportion.

Data that is stored within this system needed to be classified as either local or national information. What
data should laboratories allowed to store on a per test level and what data should be clinically stored throughout the whole of the service is a question that was continually asked throughout this project. Assumptions had to be made for this but the model developed had the flexibility to adapt to needs. A final meeting was organised with Paul Richardson from CFH to discuss the findings of this project and present the system. The findings were discussed and all were agreed that they were valid points that need to be addressed before any computer systems implemented.

6.2 Project Recommendations

The outcome of this projects investigation has come up with some of the following recommendations for the finalisation of the design of a National Laboratory Handbook. These recommendations will also lead to more understanding of the area for other computer systems projects that are currently being worked on for the Pathology Service.

Define a national test list  The definition of a national list of services/tests needs to be defined throughout the country. Define what constitutes a test or a service.

Data to be stored? What is required information to be stored about a test/service e.g. what should every laboratory throughout the country know about tests. A board of subject matter experts should be set up to define what should be stored about a test.

Identification of data storage  What fields of the identified test data should be localised and should be national a board of subject matter experts should be set up to define of the selected fields what should be national and what a laboratory should wish to store about tests.

Who Owns the Data?  Who holds ownership of the national data and who is responsible for vetting it to make sure it is up to date?

Who will manage this system and be responsible for it?  Who will hold ownership of the national systems?

By deciding upon definitive answers to these questions and developing some of the concepts mentioned here the path would be set to deploy a national laboratory handbook system to the pathology service and it to act as a information system for the whole of the NHS.
Chapter 7

Evaluation

7.1 Evaluation Criteria

An evaluation criteria was set out to help to monitor how well the project went overall and to critically evaluate it. Below are the points that will be used to perform this evaluation.

Have the aims of this project been achieved?

Does this project set out a realistic route for handbook development in the NHS?

Does the data modelling performed go to suggest realistic and scalable models for using within the pathology service?

Has the solution met the minimum requirements?

Have any of the extended requirements been met?

Have the main functional requirements of the system been met?

How did the methodology choice work with this project?
7.2 Evaluation Methodology

The evaluation of this product will be performed by two main parties. A evaluation will be performed by the author of the project using the evaluation criteria and commenting upon how these have been met throughout the project and any issues encountered. Then stakeholder involvement will be asked for, from Dr Richard Jones who has been the effective sponsor of this project throughout and is a pathology professional.

More formal methods of evaluation were suggested, the use of a survey method and some user groups were thought of being held. Unfortunately the response rate for professional evaluators was not high. The feedback from CFH and Dr Richard Jones is satisfactory as both of these parties are key drivers in the modernisation of the Pathology Service, with Connecting for Health managing all future projects and implementation.

7.3 Authors Evaluation

Has the aim of this project been achieved?

The main aim of this project was to assess the feasibility of a national laboratory handbook solution. The project firstly went to ask the question ‘What is a laboratory handbook?’ and to assess the current forms of these items. The project then went to look at the data contained within these and via of rationalisation decided what data could be and would be used in the national laboratory handbook system. Decisions were then made as to if this data was local to certain laboratories or national and applied to all laboratories around the country. This was the user requirements phase of the project to see what would be required from a national solution and how this could be facilitated.

A prototype architecture was designed suggesting a way that this system could be built to provide evidence for how a system could be built ontop of the suggested data models.

The author is of the opinion that the aims of this project have been achieved as the project has gone to assess the feasibility of implementing this system within the health service and has then gone to design a prototype system that will provide the future basis for this system.
Does this project set out a realistic route for handbook development in the NHS?

The NHS is one of the most complicated organisations in the world. The almost organic growth of the organisation over the past sixty years has led to the development of a disaggregated system causing the implementation of computer systems to be a complex and troublesome task. This is something that was recognised by issues encountered throughout the project. This project goes on to recommend steps for the NHS for standardisation to allow future implementation of computer systems and to help to increase management efficiency within the Pathology Service. See section 6.2 for recommendations.

This project sets out a realistic road map for the implementation of the national laboratory handbook solution into the NHS. Issues have been identified that first need to be overcome, this project does to go recommend a way to firstly overcome the issues faced and secondly develop a solution to be used for the health service.

Does the data modelling performed go to suggest realistic and scalable models for using within the Pathology Service?

The data modelling is one of the main aspects of this project. After the project had identified data fields that were common within handbooks and chosen which to include in the system it followed on that modelling must be done to facilitate the storage of this information. This was complex as methods had to be devised to allow the storage of information that is national to the health service and local to the specific laboratory. Decisions that had to be made towards what data fell into either of these categories was not straight forward so flexibility had to be built into the data model to allow other fields to be added as local and national pending later changes.

The outcome of this was two data models that would facilitate the storage of this data in different ways. A decision was made on which data model would be used for the the prototype system but either of the models presented in this project would have worked. This project has suggested two scalable and flexible models that could be implemented into the Pathology Service.

Has the solution met the minimum requirements?

Within the inception of this project there were four minimum requirements that were identified these were

- Create a database model for the storage of unified and localised pathology data.
• Propose an architecture for the NHS to implement this.

• Create a database upon this architecture.

• Create an abstract layer to provide services from the database.

All of these requirements were met by the design and build of this project leading to the solution meeting the minimum requirements.

**Have any of the extended requirements been met?**

One of the extended requirements was to look at the implementation of a knowledge management system to allow explicit links to be added between tests and diseases. This feature was added into the system as it presented the stakeholders with the fact that this data model was flexible enough to allow modular extensions like this.

An extended requirements of the project was also to look to scalability of this solution. The model that was designed from the design chapter in this project will support scalability as the mix of design and architecture would have no issues with supporting all of the laboratories in the country. As the abstract layer is a prototype more work would be needed upon this aspect of the project.

**Have the main functional requirements of the system been met?**

A use case development approach was taken with this project, each of the use cases were implemented in turn. The use cases were labelled using a MoSCoW approach leading to usecase prioritisation helping with time management. The measure of the completion of all functional requirements is the successful implementations of all the Must Have use cases. These were all successfully implemented leading to all the main functional requirements of the system being met.

**How did the methodology choice work with this project?**

The methodology chosen for use in this project was the AUP this allowed a rigidly planned process with iteration to ensure completeness to the best standard. The initial plan was stuck to part with a few changes when the project fell behind. The plan was followed until the end of the build stage with the build and test merging into one stage with each use case being built and then tested. Delay with the implementation stage was encountered due to the fact that the external server supplied by the Yorkshire
Centre for Health Informatics was only available when the server technician was around to allow access to it. This did not cause a major problem but delayed the system evaluation by one week as the system was not externally accessible. This methodology was a good choice for this project as it allowed flexibility for a shift in some of the timings when things fell behind and the iterative approach helped the project to deliver what it could in the time frame allowed. One issue noted is due to this project being a prototype certain iterative stages did not require iteration, due to a prototype system being created not a solution for widespread use.

7.4 Stakeholders System Evaluation

Dr Richard Jones Evaluation

Chris Harris’s project has been to design a prototype dataset architecture for a national catalogue of laboratory tests and implement this into a national handbook solution. Since starting this work Chris’s work has taken on significant national importance since the creation of such a catalogue was endorsed by the Diagnostic Summit and has become a major requirement of the NHS National Programme for IT Order Communications Project.

The prototype developed by Chris more than meets the initial expectations of me as project sponsor. Chris has worked diligently on the analysis of the problem space and has understood the requirements for a robust and scalable architecture. He has identified the need for this to map into national and international ontologies for test specifications and to allow for appropriate localisation.

He has also taken into account the user requirement to be able to use this catalogue for decision support in test selection from the viewpoint of providing a mapping between clinical conditions and the list of tests which would be appropriate for use in particular clinical contexts.

Throughout the project Chris has attended meetings with members of the Connecting for Health team working in order communications. They have confirmed his design philosophy and his work has already been adopted within some elements of the technical framework being developed by CFH. What has become clear is that Chris’s methodology is ahead of their own thinking. They are currently compiling flat lists of available test catalogues using Microsoft Excel and have created what they recognise as an unmanageable Excel spreadsheet of 5000 potential tests which contains many duplicates and has limited scope for normalisation.

As an indicator of the quality of Chris’s work he was invited to present his prototype to the stakeholder
group of the CFH project at a workshop help at the Wellcome Trust in London. This group included clinical users, NHS IM&T staff, IT industry representatives and academics. Chris gave a very professional and mature presentation and he and his work was highly praised by the group. Subsequent follow-up has confirmed major interest by the team in progressing the prototype to a formally adopted version, in particular moving from their flat file approach to a formally modelled database version.

Overall, Chris has demonstrated an ability to work professionally and independently on a complex problem and to produce a solution which has utility in an applied filed of health care information systems.

7.5 Conclusion

This project set out to look towards data modelling in the health service and to show this throughout the creation of a ‘National Laboratory Handbook’. Overall this project has been extremely successful it has met stated aims and feedback from the involved parties has been overwhelmingly good. A issue that was constantly met throughout this project was the complexity of the pathology sector due to lack of standardisation. This led to each of the laboratory entities being completely different from a management perspective. The project has gone to suggest some steps that need to be addressed to allow the ‘National Laboratory Handbook’ concept to be developed further, and addressing the bigger picture of helping the wider deployment of computer systems to this area. Something that this project has missed out due to time, technology and knowledge constraints is the implementation of a machine to machine solution. This would seriously set this project apart from the work currently going on in the Pathology Service and would show how these data models could be central to widespread system development and deployment. The architecture designed will support this well and for a developer with this knowledge will be a trivial task. A key success of this project was the presentation to CFH towards the end of the project showing the projects findings and deliverables CFH took this on board and it helped them to realise that the current route they were working on is unmanageable solution. Overall this project has been a success providing a proposed architecture a prototype system and data models for the service going on to provide recommendations and thought for the future of technology deployment in the Pathology Service.
Bibliography


[12] R.J. Jones. Nhs pathology it projects, a pulative road map. a presentation dealing with all current IT projects in the pathology field.


Appendix A

Personal Reflection

Throughout my university career I have got involved in as many areas as possible, I have directed my degree as to the way that it interests me. This project was no different. Initial issues caused me problems to this project driving me to at a point desperation of not really knowing what to do. I am a pro-active person who always knows when a cause is lost so had to cut two initial project ideas and look for another one.

I was in a very fortunate position to be offered a project by Rick Jones that matched my studies at university better than either of the previous project proposals but the time lost could never be regained. Throughout this project I have proven to myself that I have determination to get something done even when things have gone wrong, this has been the single biggest push for me at university and in my life.

I have really enjoyed learning the new technology for this project. It is testament to the School of Computing that their method of teaching programming allowed me to pick up a book and learn C# within a very short period of time. I had no experience of ASP.NET, C#, or SQL Server before this project and now I have enough of a grasp to create a very advanced architecture and application. This project gave me some real contact with people high up in the health computing field, this was great as I had a lot of ideas for this field and people listened to me and took on board what I said. One huge thing I take
away from this project (and my university career as a whole) is the confidence leap I have in talking to people. When joining university the prospect of presenting to one person would have been very hard for me. This project allowed me to present to 50 subject matter experts, knowledge is always valued but my confidence is something that has really grown throughout my degree.

Since the day I started writing it has been evident that a struggle with this task. I have found the writing of the report hard and I know that still after constant iterations over this report there will be issues with it. This is something I have come to accept throughout my university career but am very happy with the way this report has come together.

I was disappointed towards the end of the project that I did not have time to implement a machine to machine solution for this handbook. I personally lacked the development knowledge for this, the time and the equipment to test this on. The created solution has been widely accept but with a machine to machine system it would sit at the middle of the new systems being created for pathology.

As i look back at this project I realise I made a grave error choosing to do 60 credits worth of modules in my second semester irrespective of my project, if you are reading this pre-project, balance your semesters. I see myself as someone who is good at time management, but this silly decision has caused testing times. My key recommendation for this project is do not underestimate your final year. Previous to my fourth year at university I was out working on a year in industry. I seemed to have some strange thought in my head that my last year was going to be a breeze. It was not, and quite rightly so.

I take Eminence pride from this project and from my degree as a whole and I challenge anyone to undertake a project of this scale and not be proud of their output. A special mention should go to the bright light that was lit on the horizon on the day i started writing the report I heard i had a job at Microsoft, this really drove me through the final two weeks of hard graft to pull this project together.

As a personal conclusion Throughout this project I have tried to take one day at a time, but sometimes a few have snuck up on me at once.
Appendix B

Requirements Gathering Techniques

Figure B.1: An example of a printed version of a pathology handbook.
Appendix C

Communication with CFH

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
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<th>E</th>
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</tr>
</tbody>
</table>

**Table C.1**: The requirements gathering spreadsheet used to investigate the identified data set.

Figure C.1: The requirements gathering spreadsheet used to investigate the identified data set.
Figure C.2: Communication between Paul Richardson and Christopher Harris regarding requirements gathering.

Figure C.3: Connecting for Healths requirements gathering spreadsheet received 16/11/2007.
Appendix D

Notes from Leeds laboratory meeting

The laboratory meeting was held at the Leeds & Bradford Pathology Partnership Leeds laboratory. In attendance were Dr Richard Jones (Associate Clinical Director Yorkshire and the Humber SHA).
Mr Keith Gailer (Leeds Pathology Operations Manager).
Mr Paul Richardson (Connecting for Health Analyst).

This was an informal meeting starting with a tour of the laboratory. Before visiting the laboratory the author had gained access to the laboratory handbook for this laboratory site.

The laboratory uses an online solution called Tests and Tubes (T&T). This can be accessed externally by patients and shows the most basic of information. There is also an option of putting a password in to get into a secure area as to find out clinical and laboratory specific information.

As the tour around the laboratory proceeded it was noticed that people were using the T&T system for information. It was seen at one point a worker on the phone and using it to answer a query. At another point in the tour it was seen being used by a pathologist checking how long it should take for a test to be turned around.
The visit then proceeded to an office where discussion began into the current IT provision within the pathology service. Not all conversation was directed towards the "National Pathology Handbook Project. But some of the following questions were answered.

- **How are handbooks used?** - Handbooks are used for various tasks throughout the health service. The main use of a handbook in a trust is to find out the services that are available from the pathology laboratory that is related to the trust. The main use of a handbook internal to the organisation is to find out information about tests. Sometimes handbooks can be used externally. The Leeds handbook has the option for public users to access it to look basic information on tests.

- **Are handbooks the same in each laboratory?** There are no standards in handbook design, a handbook is a tool to spread information throughout a trust. The importance of this information should be stressed as tests are the basis for most diagnosis within the health service. Handbooks come in many different forms throughout trusts, the example of the Leeds and Bradford Pathology Partnership having an electronic version of the handbook on a web based system where some may have Microsoft Excel documents and many have printed versions of handbooks.

- **Who has a handbook?** Within the Leeds Teaching Hospitals trust anyone who needs information upon tests has access to the clinical side of the handbook. There is no strict governance saying who should have access and who should not. As no patient data is stored within handbooks and it simply information upon tests it does not need heavy regulation. Yet this information may be wanted to be kept secret from the world at a whole so only internal access should be allowed to advanced information.

- **Is there a supplier of handbooks?** No there is no supplier of handbooks the Leeds and Bradford Pathology Partnerships was built internally and anyone using printed solutions will design and have them printed.

- **Are there any current off the shelf handbook systems?** There are no current off the shelf handbook solutions.

Significant information was taken away from this meeting giving a very productive start to the requirements gathering stage of the project.
Appendix E

Agile whiteboard modelling

Figure E.1: Agile modelling for the design of the database structure.
Figure E.2: Agile modelling for the design of the relationships in the database.

Figure E.3: The agile modelling of the use case.
Appendix F

Projects in the area and relationships

Figure F.1: A diagram showing potential links between all current IT projects in the pathology sector [12]
Appendix G

User Modelling

To identify user groups modelling was performed. This was done by the method of writing down identified users on a whiteboard and then putting them into categories. These categories later went to form the user roles within the system. It should be noted that new user roles had to be created to look after the national aspects of the proposed system.

Figure G.1: The first attempt at modelling the identified users.
Appendix H

User Access Modelling

User access models were derived from the usecase and then cross referenced with the structure shown in 5.4.1. The result of this were the user access modelling diagrams shown below. These helped to elicit what users would have access to what when the security features were being implemented.

Figure H.1: The access modelling for the public user role.
Figure H.2: The access modelling for a laboratory user role.

Figure H.3: The access modelling for a labadmin user role.
Figure H.4: The access modelling for the national administrator role.
Appendix I

Designed data models

Within this project there were two main designs that were designed for the data modelling aspect. The diagrams of both of these will be presented in this chapter.

Figure I.1: The local data model schema design.
Figure I.2: The national data model schema design.
Appendix J

Code appendix

The code contained in this Appendix is the code that operated the ‘Get Lab Services’ function within the system. The system is built up of many functions please see Appendix K for a full list. All the code shown in this section is only with reference to the ‘Get lab Services’ function if you wish to see code for any of the other functions please refer to the software deliverable.
J.1 Get Lab Services SQL Methods

This section contains all of the SQL code that was used in the get lab services function. For how this all fitted together please see section J.2.

J.1.1 Get laboratory services

This is the SQL code associated with the method for retrieving laboratory services from the database.

```
GetLabServices(@lab_id) Method

SELECT test_id, analyze
FROM tests
EXCEPT
SELECT exception.test_id, tests.analyze
FROM EXCEPTIONS
INNER JOIN tests ON exception.test_id = tests.test_id
WHERE lab_id = @id
```

Figure J.1: Get laboratory services sql code.

J.1.2 Get clinical test data

This is the SQL code associated with the method for retrieving the clinical (national) data associated with a test.

```
GetClinicalTestByID(@test_id)

SELECT *
FROM clinical
WHERE test_id = @test_id
```

Figure J.2: Get clinical data sql code.
J.1.3 Get laboratory name

This is the SQL code associated with the method for retrieving a laboratory name from laboratory id

GetLabNameById(@lab_id)

SELECT lab_name
FROM labs
WHERE lab_id = @lab_id

Figure J.3: Get clinical data sql code.

J.1.4 Get local test data

This is the SQL code associated with the method for retrieving the laboratory specific data (local) data.

GetLocalTestData(@lab_id, @test_id)

SELECT tanalytate, trm.transport_name, tom.testname,
thtube_name, thtube_supplier, lprotstat.tat_time,
thtube_colour, thtube_pic, dp.dept_name,
storage_name, gprotstat.tat_time, gprotstat.tat_time,

FROM TESTLOCALDATA te
INNER JOIN TRANSPORTmap trm
ON trm.transport_id = te.transport_id

INNER JOIN TESTONmap tom
ON tom.testen_id = te.testen_id

INNER JOIN TUBES tb
ON tb.tube_id = te.tube_id

INNER JOIN DEPARTMENTSmapi
ON dp.dept_id = te.dept_id

INNER JOIN STORAGEmap sm
ON sm.storage_id = te.storage_id

INNER JOIN tmap gprotstat
ON gprotstat.t_id = te.gprotstat

INNER JOIN tmap lprotstat
ON lprotstat.t_id = te.lprotstat

INNER JOIN tmap gprotstat
ON gprotstat.t_id = te.gprotstat

INNER JOIN tmap lprotstat
ON lprotstat.t_id = te.lprotstat

INNER JOIN tests t
ON t.test_id = te.test_id

WHERE te.lab_id = @lab_id and te.test_id = @test_id

Figure J.4: Get local test data sql code.
J.2 Get lab service C# code

Figure J.2 shows the main code that created the get laboratory services function. This used all the functions shown in section J.1.

```csharp
public partial class xsyservices : System.Web.UI.Page
{
    protected void Page_Load(object sender, EventArgs e)
    {
        string lab_id = (Profile.lab_id != null) ? (Profile.lab_id.ToString())); // received lab_id that user is a member of
        ServicesTableAdapter sta = new ServicesTableAdapter(); // creates a new table adapter called sta
        Gridview.DataSource = sta.GetLaboratoryServices(lab_id); // use the sta table adapter to invoke the method to get lab services
        // passing to it the lab_id from the profile manager and
        // pass it to a gridview
        Gridview.DataBind();

        LabNameTableAdapter ln = new LabNameTableAdapter(); // Create a new labname table adapter called ln
        DataTable lname = ln.GetLabNameByLabID(lab_id); // get the lab name using by passing the lab_id to the method.
        string strLabName = Convert.ToString(lname.Rows[0]["lab_name"]); // Convert lab name to a string from a datatable object
        labnamelabel.Text = strLabName; // print the lab name onto the page as a display.
    }

    protected void DataGridView_SelectedIndexChanged(object sender, EventArgs e) // event that is fired when test is selected.
    {
        string lab_id = Profile.lab_id.ToString()); // create a string with the lab_id in from the ToString()
        string strTestId = DataGridView.SelectedCell.ToString(); // retrieves test_id from the selected test
        int test_id = Convert.ToInt32(strTestId); // converts the test_id from string to int type
        LocalDataCatalogTableAdapter id = new LocalDataCatalogTableAdapter();
        LocalInfoView.DataSource = id.GetLocalTestData(lab_id, test_id); // retrieves local test data using lab_id and
        // test_id into a gridview
        localinfolabel.DataBind(); // binds this data into the gridview property.

        CLINICALTableAdapter ct = new CLINICALTableAdapter();
        clinicalInfoView.DataSource = ct.GetClinicalByTestID(test_id); // retrieves the clinical data about the test
        clinicalInfoView.DataBind(); // using test_id and passes it to the gridview controller.

        // Sets data view controls
        Gridview.Visible = false; //
        back.Visible = true; //
        LocalInfoLabel.Visible = true; // Sets the information about the particular test viewable and hides the main
        clinicalInfoView.Visible = true; //
        localDateLabel.Visible = true;
    }

    protected void back_Click(object sender, EventArgs e) // event that is fired when back button is clicked.
    {
        back.Visible = false;
        LocalInfoLabel.Visible = false;
        localinfolabel.Visible = false;
        clinicalInfoView.Visible = false;
        clinicalInfoView.DataBind(); // sets the main test list visible and the retrieved data about the test as hidden.
        back.Visible = false;
        Gridview.Visible = true;
        Gridview.DataBind();
    }
}
```

Figure J.5: Get clinical data sql code.
### J.3 Database creation script

Fig J.3 shows part of the creation script that was designed and built to create the database on the server. This script is cross server compatible so will work on most database servers.

```sql
CREATE TABLE order_item (id INT PRIMARY KEY,
                        product_id INT,
                        order_id INT,
                        quantity INT,
                        price DECIMAL(10,2));

CREATE TABLE order (id INT PRIMARY KEY,
                    customer_id INT,
                    order_date DATE,
                    total DECIMAL(10,2));

CREATE TABLE product (id INT PRIMARY KEY,
                      name VARCHAR(50),
                      description TEXT,
                      price DECIMAL(10,2));
```

Figure J.6: Get clinical data sql code.
Appendix K

Functions appendix

Within the system many functions had to be designed. These functions were all derived from the use case modelling. Please see Fig K to see a full list of functions and what they were all required perform.
<table>
<thead>
<tr>
<th>Use Case Name</th>
<th>Use Case Function</th>
<th>Actor</th>
<th>MoSCoW Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Login</td>
<td>Allows a user to login to the system and be authenticated with a laboratory.</td>
<td>Lab User, Lab Admin, National Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Add laboratory</td>
<td>Add a new laboratory to the national laboratory list.</td>
<td>National Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Remove Laboratory</td>
<td>Remove a laboratory from the national laboratory list.</td>
<td>National Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Edit Laboratory</td>
<td>Edit the information provided by a laboratory.</td>
<td>National Admin</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>Add User</td>
<td>Add a user to the national laboratory handbook system.</td>
<td>National Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Remove User</td>
<td>Remove a user from the national laboratory handbook system.</td>
<td>National Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Edit User</td>
<td>Edit a user in the national laboratory handbook system.</td>
<td>National Admin</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>Add Test</td>
<td>Add a test to the national database.</td>
<td>National Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Remove Test</td>
<td>Remove a test from the national database.</td>
<td>National Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Add Disease Mapping</td>
<td>Create a relationship between a disease and a test.</td>
<td>National Admin</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>Remove Disease Mapping</td>
<td>Remove a relationship between a disease and a test.</td>
<td>National Admin</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>Add Local Data</td>
<td>Add local information to a test for a specific laboratory.</td>
<td>Laboratory Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Clear Local Data</td>
<td>Clear local information from a test for a specific laboratory.</td>
<td>Laboratory Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Add test to catalogue</td>
<td>Add a test to a laboratories catalogue.</td>
<td>Laboratory Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>Remove test from catalogue</td>
<td>Remove a test from a laboratories catalogue.</td>
<td>Laboratory Admin</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>View Clinical/Local test information</td>
<td>View information about a test specific to the laboratory the user is associated with.</td>
<td>Laboratory User</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>View disease mappings</td>
<td>View the diseases to test information.</td>
<td>Public, Laboratory User, Laboratory Admin</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>View public test information</td>
<td>View public test information.</td>
<td>Public</td>
<td>COULD HAVE</td>
</tr>
</tbody>
</table>

Figure K.1: Functions identified for inclusion within the final system with MoSCoW profiles.