Antibiotics Reference Application for Connolly Hospital, Blanchardstown

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DECLARATION

I hereby declare that this project is entirely my own work and that it has not been submitted as an exercise for a degree at this or any other university.

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Name                                           Date
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1.0 Introduction

The corporate sector IT has flourished over recent years. This has seen companies willing to invest millions in software in order to proactively gain competitive advantage or to simply maintain their market position. The vast majority of this IT investment has been focused on office-based work. With the current rise of mobile applications software this investment can now also be applied to non-office-based work and through doing so enable real time management of and access to information.

The healthcare environment is a good example of a non-office-based workplace. An example of this is how doctors and nurses need to make evidence based decisions at the patient bedside. The use therefore of mobile apps is increasing as a ‘point of care’ decision support technology.

This project seeks to develop a customized and relevant mobile application in an area where decision support is required within a hospital environment. To ensure relevance, the project seeks to work in partnership with clinical stakeholders. This approach enables a clear understanding of the specifications of the end user and to support these with the functional capabilities of the mobile technology.

The ultimate success of this venture lies in aligning the objectives and goals in a manner that are clear and agreed by all stakeholders.

1.1 Goal

The goals of the project were
• To design and implement a mobile application which could be used in hospitals to assist doctors to make appropriate choices when prescribing antimicrobials. The importance of such choices has been underlined by the emerging threat of multiresistant organisms such as MRSA.

• To present a hospital’s antimicrobial guidelines in a user friendly manner while ensuring the systems architecture is capable of managing the content as the guidelines are subject to periodic updating.

• To construct an application in a manner that would be adaptable to allow for updates and modifications which could run on both IOS and Android devices.

• To ensure that the application is capable of being accessed offline as not all hospitals have access to Wi-Fi.

• To increase the ease of access to prescribers of the antimicrobial prescribing guidelines by having them in a portable electronic format. This means that they would not have to seek access to these away from the point of decision making (the patient’s bedside)

**Project Benefits**

• General Prescribers within the different hospitals could navigate through these guidelines in an efficient manner and quickly decide the most appropriate antibiotic for the individual patient and the condition they are presenting with.

• Whereas the prescribing guidelines are currently available in hard copy format, if dosing calculations are required then this must be done as a
separate activity. This is a factor which can contribute to medication errors and hence harm to patients. The mobile application will also provide additional features such as dosing calculators, providing prescribers with a more user-friendly experience and increased safety for patients.

- As the guidelines consist of various tables and diagrams these will be displayed in the application in a way that would fit the screen but still be readable.

- The adaptable nature of the application will provide a basis for possible expansion and information therefore is not simply hard coded in. This will allow for both in-hospital updating of guidelines and simplify the customisation and adoption of the application in other hospitals.

1.2 Motivation

Management of infectious diseases in hospitalized patients is both a patient safety and a cost-of-care issue (Smolinski et al 2003, Knobler et al 2003, Centers for Disease Control and Prevention 1998). Healthcare-associated infections or HAIs are prevalent on a global scale and here in Ireland as in other countries they contribute to a strain on the entire healthcare system in terms of patient safety and outcomes, extended lengths of stay, cost of care. Dellit identified that comprehensive stewardship programmes have consistently demonstrated a decrease in antimicrobial use of 22% to 36%, with annual savings of 130,000 to 600,000 in both large academic and smaller community hospital settings. (Dellit et al, 2007)
Therefore both from the perspective of reducing the risk of emerging resistance of pathogens and the economic use of limited funding the reduction in use and more accurate targeting of antimicrobials used is of paramount importance to the health system at both a hospital and community level.

In this section I will discuss how appropriate antibiotic prescribing can reduce resistance rates and detail how correct antimicrobial stewardship can be beneficial on a broad scale in the healthcare system. Finally I will outline how the availability of a hospital's antimicrobial guidelines to prescribers at the point of care delivery in the format of a mobile application can assist in achieving this objective.

The Effectiveness of Antibiotic Policies as a Means of Reducing Resistance:

Antibiotic resistance has direct linkages with the excessive and inappropriate use of antibiotics. The Guidelines for Antimicrobial Stewardship in Ireland identified that the antimicrobial consumption in hospitals is a key factor in the emergence of antimicrobial-resistant pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA), Vancomycin-resistant enterococci (VRE) *C. difficile* and the multiple-resistant Gram-negative bacteria. (HSE Health Protection Surveillance Centre, 2009). The Guidelines also identify that the use of certain broad spectrum antibiotic classes appears to particularly strongly associate with the emergence of such pathogens. A number of other research studies (Iosifidis et al 2008, Hsueh et al, 2005, Rogues et al, 2012) identified a close linkage between the level of antimicrobial consumption and the increased prevalence in recent years of resistance to multiple antibiotic classes among Gram-negative hospital pathogens such as *Escherichia coli, Klebsiella pneumoniae and Pseudomonas aeruginosa*. 
Antibiotic use therefore needs to be correctly moderated in order to combat the ever-rising resistance rates.

Antimicrobial restriction policies have been shown, either through formulary limitation or by the requirement of pre-authorisation and justification before use, to be the most effective method of achieving the process goal of controlling antimicrobial use. (Davey et al, 2005). These policies are therefore extremely important and their appropriate use is imperative in minimising this problem.

The antibiotic guidelines which are in place in all hospitals and general practice are designed to directly combat resistance rates as they support appropriate prescribing by informing prescribers in relation to the suitable choice and the correct dosage of each antibiotic. These guidelines are individual to each hospital as the patient profile and resistance rates in each hospital differ. Prescribers, therefore, need to have the individual hospital’s guidelines to hand at all times. When these are only available in a hard copy form their availability at the point of prescribing is not always possible. Human nature being as it is, the prescriber may not have the motivation or time to access them. This is one of the strongest arguments for having a mobile application.

**Antimicrobial stewardship:**

The need to follow correct antimicrobial stewardship is another motivation in the creation of this app. The Infectious Diseases Society of America define antimicrobial
stewardship as: “Antimicrobial stewardship refers to coordinated interventions designed to improve and measure the appropriate use of antimicrobials by promoting the selection of the optimal antimicrobial drug regimen, dose, duration of therapy, and route of administration. Antimicrobial stewards seek to achieve optimal clinical outcomes related to antimicrobial use, minimize toxicity and other adverse events, reduce the costs of health care for infections, and limit the selection for antimicrobial resistant strains.” (IDSA, 2014)

Antimicrobial stewardship is therefore a systematic approach to optimising antimicrobial therapy, through a variety of structures and interventions. Antimicrobial stewardship programmes have been shown to reduce inappropriate antimicrobial use, with resulting reductions in antimicrobial resistance, and also lead to more appropriate antimicrobial therapy for infections where therapy is required, with improved clinical outcomes for patients. Antimicrobial stewardship programmes are highly cost effective, and are capable of saving hospitals many multiples of the cost required to staff and run the programme.

For example, the correct knowledge on when to take a patient off IV antibiotics can be save a lot of money. A daily course of IV antibiotics can cost on average €1,000 whereas if the patient could be switched to a course of oral antibiotics it would cost the hospital as little as €10 a day. This knowledge is often unclear for prescribers and having the guidelines prove an important tool in determining the appropriateness and timing of this switch.
The usefulness of antibiotic policies/guidelines available as an app or other digital format:

With the emergence of technology in Healthcare new technologies such as Clinical Decision Support Systems (CDSS) have also been developed. A CDSS is an application that analyses data to help healthcare providers make clinical decisions. This can be an extremely complex system that has equal intelligence of a human or as simple as online access to formulary restrictions and local antimicrobial prescribing guidelines. Musen et al lay out three key elements of a successful CDSS: Access to accurate clinical data, Access to pertinent medical knowledge and Ability to use appropriate problem solving skills. (Musen et al, 2001)

The antimicrobial application which this report outlines can therefore be defined as a CDSS as it encompasses all three of these elements. It is clear that CDSSs improve patient safety, reduce risk, and save money. CDSSs also reduce diagnostic time and are more interactive than their paper counterparts. They are an excellent utilisation of technology at point of care and not only benefit the prescriber and patient but impact the healthcare system as a whole in a positive way.

The application described in this paper also encompasses multiple facets of the guidelines that are significantly more functional than its paper counterpart. An example of this is the Creatinine Clearance calculator. When using the paper guidelines the prescriber must either do these calculations by hand or through an excel sheet provided on the hospital ward’s computers.

These computers may often be in use by other staff and result in delays to prescribing. Even when they are available bad practice may be followed where the
prescribers do not log into their own account when using it. Apart from being contrary to HSE regulations it may restrict the opportunity to review individual practice. The guidelines in application format will remedy this problem on all these levels as it provides both the guidelines and the necessary access to calculators in a personal hand held format.

The Importance of Attractiveness to the Application:

A major factor of the application was the make the application both user-friendly and attractive. While it is understandable that this may seem surplus to requirements in piece of medical software there are a number of reasons why this is of importance:

- The consultant microbiologist of Connolly and head of the board of Mobile Development Procurement of the region expressed explicit interest in the look and feel of the app being as smooth and “slick” as possible.

- The ISO have published quality standards of mobile-applications in which they list attractiveness as a key facet of quality under both usability and operability (ISO Standards, 2011).

- Junior Doctors are more likely to adapt these guidelines as they will be more encouraged to use the app if it is appealing to them

- Attractiveness can make the app easier to navigate through which can reduce prescribing time at the point of practice (hospital ward).

- This application will be in direct competition with other apps that have the same functionality and can potentially display the exact same information. In order to have a competitive advantage, attractiveness is a key feature to exploit.
1.3 Reader’s Guide

Chapter 2 will give some background to the project, highlighting the rise of health informatics and comparing existing antimicrobial reference guides from both Ireland and the UK.

Chapter 3 describes the detail of planning that went into the project. It describes the various relationships that occurred within the HSE and also discusses the SCRUM methodology and its application in this project. It also discusses the selection of the different technologies that were used to complete this project while providing the reader with the various factors that led to the choice of these technologies.

Chapter 4 describes the manner in which user stories were formulated, architecture was decided and discusses the dynamism which was required of the application.

Chapter 5 discusses the implementation of the application, where each aspect is covered and finally portrays a full user walk through of the application.

Chapter 6 describes the evaluation of the application in which feedback was received by the various HSE liaisons which included most importantly the views of medical students who would potentially be the end users of the app. The chapter also illustrates proposed future testing and overall evaluation of feedback.

Chapter 7 elaborates on the future of the application and where it can be implemented and finally provides overall conclusions on project evaluation.
2.0 Background - what other systems are currently available

The purpose of this section is to discuss the rise of technology namely mobile applications in the healthcare sector and in particular their use in supporting effective and safe use of antimicrobials. This chapter outlines current antimicrobial prescribing mobile applications which are in use in England (the closest guide of reference to the Irish healthcare system) and applications which have been implemented within Ireland and how these have been received.

2.1 The Rising Demand for Mobile Applications within the health sector:

From the perspective of the healthcare sector, the IMS Institute for Health Informatics in their recent report Riding the Information Technology Wave in Life Sciences: Priorities, Pitfalls and Promise (Atkin & Shahni, 2014) provide a view of how the current technology wave—defined in terms of cloud-based storage, new applications, systems integration, and embedded analytics—will be harnessed by life sciences companies in their commercialisation activities. It also identifies why this is necessary if these companies are to succeed in bringing innovative diagnostic and treatment options to patients.

This, combined with, the increasingly termed ‘knowledgeable patient’ will see a revolution in the manner healthcare is perceived and delivered. Hill in her book on this subject identifies the ‘knowledgeable patient’ as taking many forms: patient, carer, consumer advocate, or member of the public interested in health issues. (Hill, 2011) The challenge for clinicians will relate to how they will manage their interactions with the ‘knowledgeable patient’. This will require a considerable shift in culture as the patient now be in a position to ask informed questions about the
evidence base for their treatment, the various choices available and the risks that may attend to making their choices. There is therefore a potential for the development of a more level playing pitch in healthcare delivery, as compared with the paternalism of the past.

The availability therefore, of real time evidence based information to clinicians will become ever more important. The ability to create, store and interrogate large amounts of information will undoubtedly be central to this process. The access provided by mobile applications will increasingly provide an attractive mechanism for delivering this to clinicians at the point of care delivery. It will also become more important in the monitoring of chronic disease by patients as the emphasis on self-care by patients in the community increases e.g. in diabetes and cardiac health.

2.2 **NHS Antimicrobial Applications**

When reviewing best practice in the development and deployment of an antimicrobial application, one must look to the NHS where these have been in use for some time. Within the HSE the NHS is often looked upon when assessing projects as the English healthcare system very similar to Irelands. A study carried out by Imperial College London (Charani et al, 2013) in relation to the use of a mobile application for antimicrobial prescribing found that clinicians rapidly adopted the mobile application for antimicrobial prescribing at the point of care, enabling the policy to reach a much wider audience in comparison with paper- and desktop-based versions of the policy. The study recommended that organisations seeking to optimize antimicrobial prescribing should consider utilizing mobile technology to deliver point-of-care decision support.
The most commonly used commercial antimicrobial application in England at present is called Microguide. Microguide has been developed by Horizon Strategic Partners. Horizon is a technology services firm which specialize in healthcare associated technologies. They have two main applications currently on the market. Microguide and DiAppBetes - a decision support tool for the management of inpatient diabetes in adults.

Microguide is currently their flagship product (see Fig 1.). It is currently employed in 26 trusts across England. It utilises a web-portal in which pharmacists are provided with templates of various pages on which they can display the information. The pharmacists can edit their own guidelines at any stage and update them. Once the update has been finalized this will immediately be sent to devices that will update the next time they are accessed.

While the functionality of this application is undoubtedly quite substantial the layout of the application can feel quite primitive and is often extremely text heavy. It has however, received an overall positive reaction here in Ireland and the company are currently looking to expand further and commence business with hospitals in Ireland.
2.3 Antimicrobial Apps within Ireland

When researching the optimum process for creating an antimicrobial application one must then look to Ireland, where applications have already been created. While the idea of transforming the antimicrobial reference guide into a usable mobile application is a relatively new idea, some companies have developed apps around the country. I will discuss two examples within Ireland and also the current situation in the Irish antimicrobial application market.

R2S: Tallaght Hospital Dublin
An antimicrobial application has recently launched in Tallaght Hospital (Fig. 2). Simply called Tallaght Hospital Meds Guide it is the only application which was surveyed that was not free to the end user, retailing for €5.50 per year. On review it is notable that the menu is not hugely functional as it is presented to the user in a chapter by chapter fashion and therefore not available to be displayed at once. This application also suffers in the same way as Microguide in that it can be quite text heavy at times. This combined with the use of a smaller font to provide more space further hinders the experience of the user. While the application does have a search function it is crude and not very user-friendly. Upon speaking to a junior doctor currently using the application, he reported that the app would occasionally crash and would have be shut down and re-entered.

Fig 2.0 R2S Antimicrobial Application
Maith-u: Galway GAPP

Certainly the most aesthetically pleasing application which was reviewed in the process was the application (GAPP) which is currently deployed in the West Northwest Hospitals Group, which consists of 4 hospitals across the Galway/Roscommon region. GAPP uses a slick interface and is very easy to navigate using the various menus or search function. (Fig. 3) It is laid out in a very user-friendly fashion and has received a positive reception from the prescribers. This did however come at a price with the total cost of the project being €20,000 and is the most expensive app currently in use in public hospitals in Ireland.

Upon further assessment, there are a few pitfalls with its internal architecture. Although it was the West Northwest Hospitals Group intention to have a CMS type of application it wasn't specified in any of the design specification. A major pitfall by the Hospital Group’s commissioning of this app was their failure to sign a contract with the software firm. This has resulted in the Galway is left with the option of approaching the company to not only update the guidelines but also transform its architecture into a more CMS orientated approach. This will undoubtedly cost the hospital another significant amount of money not only for the update but also for the change in architecture.
Different Companies currently bidding for apps

Within the HSE there is currently significant interest by Healthcare Associated Infection and Antimicrobial Committees at National and Regional levels in increasing the deployment of antimicrobial prescribing applications within HSE hospitals. The three companies which have been mentioned above have currently expressed an interest in being considered for any contract that may be available. One regional committee are currently evaluating these three commercial options while also evaluating the application which has been developed for this project. Whilst the application developed as part of this project has been completed in full for Connolly Hospital it has been constructed in a manner that it can easily be
adapted for use in other hospitals. The design of the content management system also means that if procured as an organisational solution all required updates could be carried out by the HSE ICT app team or alternatively it could be purchased on a per hospital basis with any required updates being part of an ongoing contract for service. The flexibility of the app design provides a significant advantage.
3.0 Planning

Throughout the project's lifecycle a significant aspect has been planning. Having an external client was an added layer to the project which contributed to the complexity of the task but also provided the developer with an opportunity to experience a 'live' work environment. From the perspective of the subject matter at hand there was a need to have a close working relationship with appropriate clinical staff in the site where the system was to be deployed. This meant identifying a consultant microbiologist and antimicrobial pharmacist who would contribute to the development of the business requirements. From the perspective of project sustainability there was also a need to ensure that the system architecture was developed using platforms which could be maintained in the longer term. To assist with this it was necessary to develop a working relationship with the app development team in the HSE’s ICT division. The availability of a person to facilitate the introduction to these groups was critical to the process.

This chapter explores this and helps the reader understand the intrinsic aspects of the client-developer relationship while encompassing the planning that occurred.

3.1 Scrum Methodology

During the planning stages of the project, there was a realisation that a proven methodology needed to be applied to the development process. Upon being discussed with the projects supervisor, it was unanimously agreed that an agile method would be most applicable. Upon further discussions with the projects supervisor, the Scrum methodology was proposed. Research into this methodology confirmed its choice as it was felt that it would suit this project well, due to the fact there was an external client involved in the project. The use of Scrum would ensure full stakeholder involvement at various stages throughout the process thus increasing the likelihood of the projects application in the live environment. A full
A description of the Scrum can be found at the website
(https://www.scrum.org/Resources/What-is-Scrum) and a diagram is provided at Appendix A.

3.2 HSE Interaction

There were three stakeholder groups to consult. The initial and main liaison Dr. Michael Carton, Surveillance and Monitoring Officer in the HSE Dublin North East Quality and Patient Safety Department, the Connolly Hospital liaisons were Dr Eoghan O’Neill (Consultant Microbiologist) and Ms Bernie Love (Pharmacist), and the HSE ICT’s App Development Team liaison was Mr Richard Mulholland. Each group dealt with different aspects of the application and therefore had to be met with all on different occasions throughout the project lifecycle.

The original contact was made with Dr. Michael Carton. Dr. Carton was able to provide a broad idea as to what was required of the application. He also made initial contact with the other two stakeholder groups and outlined the roles of both to the developer and the role of the developer to the stakeholders in both Connolly and the ICT Department. Ongoing contact was maintained with Dr Carton to ensure that the project was co-ordinated effectively. Due to the significant nature of the project a decision was made to have it commissioned at a National level. The commissioner was the HSE’s National Director of Quality and Patient Safety Dr. Philip Crowley.

The second stakeholder group was the Hospital liaisons. Both the Consultant Microbiologist and the Pharmacist were considered as end users and their input was directly related to the business requirements of the application. By consulting with these stakeholders a realisation of the user stories was achieved and through
the planning of various sprint meetings the current prototype could be shown to the client. They were also consulted on the deployment of the applications and key features of the testing period.

The final group that were liaised with was the HSE ICT team through Richard Mulholland, a mobile app developer. Richard was consulted on the design of the application. Architectural decisions were influenced by the IT team as they were potentially to take on the application in the aftermath of the project. They were also consulted in troubleshooting problems and assisted in occasional bug fixing.

3.3 Realising user-requirements

In the early stages of the planning process the Hospital team had not been realised and a methodology had not been assigned. An early requirements document was drawn up with the assistance of Dr Carton. These were then refined with the assistance of the Hospital team when assigned. The original requirements document can be found in Appendix B. Subsequently the Scrum methodology was incorporated and the original user requirements were then transformed into user stories with the assistance of both Dr Carton and the project supervisor. Finally, the initial meetings with the Hospital team took place and the user stories could be finalised with the end-user and could be subsequently split into sprints. There were a total of 13 user stories which we subsequently split into 4 fortnightly sprints. A final draft of the user stories can be found in Appendix C.

Realising the user-requirements was a laborious process in which the requirements took many forms before being finalised. It was a significant process within the project. While this was undoubtedly a very time consuming aspect of the project it is not only considered an essential aspect of the scrum methodology but it is through
developing a real understanding of the requirements of the end user that the realisation of a quality product can be developed. It is the attention to detailed stakeholder involvement at all stages that paid dividends as the project progressed.

3.4 Technology Evaluation

The choice of what technology to use was another important aspect in the planning process. It incorporated various different factors:

**Multi-Platform:**

The application needed to be multi-platform as it had to be accessible by all prescribers within the institution.

**Offline:**

The application needed work offline as not all hospitals have full access to Wi-Fi.

**Compatible with HSE ICT Team:**

The application needed to be coded with technologies familiar to the HSE ICT Team as there was a potential that they would take on the running of the application upon completion.

**Timeframe:**

Timeframe also had to be considered as writing a multi-platform offline application could be extremely time consuming for one software engineer and the project needed to be completed within the given timeframe.

**Performance:**
Performance must remain relatively quick. If the application was particularly slow the HSE felt that doctors would be hesitant to use it and therefore the project would be a failure.

All these factors needed to be taken under careful consideration and large amounts of research; planning and consultation went into the choosing of the technology. With all things considered the decision was taken to program the application using Cordova's platform PhoneGap while incorporating jQuery-Mobile within its architecture. The full technology and architecture of the application will be discussed in the Design chapter.
4.0 Design

4.1 User Stories:

As discussed previously the user stories were carefully planned and realised over a long process of formulation and refinement. In the initial stages before the interaction with the Hospital team the basic fundamentals of the application were described. While the majority of these did not make the final user stories they were a helpful indicator in the realisation of the scale and complexity of the project.

The user stories were formulated closely in conjunction with the Hospital team. As all parties involved had little experience with Scrum there was need to fully appraise them of the significance and importance of the user stories.

Through the collaboration of the Hospital team, Dr. Carton and the project supervisor four users were identified:

**Consultant Microbiologist:** Sets out the advice on which antimicrobials are appropriate therapeutics for specific conditions.

**Antimicrobial Pharmacist:** Perform audits of prescribing practice from the prescribers.

**Prescribers:** Medical doctors & nurse prescribers (nurses who have completed nurse prescribing training and can write prescriptions for patients).

**Employee in the IT sector:** Employee in the IT sector of the HSE who will be responsible for the altering and maintenance of the application after it is completed.
Through collaboration with the hospital team the hardcopy of the guidelines were dissected and each chapter became a different user story. Once the guidelines had been covered, external user stories were identified such as a login screen and the adaptability of the applications architecture.

4.2 Choice of Architecture:
The choice of architecture was another task which took careful time and planning. As seen in the above technology evaluation section there was various constraints on what technology to use. The technologies needed to conform to the needs and requirements of each of the stakeholders (external) while meeting all the standards and requirements of the Final Year Project such as time (internal).

Initially, a multi-tiered architecture was decided upon. The initial thought process was to build a native application for the guidelines. However, developing an application for both Android and iOS required developing the application using both Objective-C and Java which given the project timeframe was not considered feasible. As this was ruled out the possibility of a web-based application was then explored. While this seemed to fit the timeframe given it was also deemed unfeasible as access to Wi-Fi in hospitals was limited. It was also considered that there can be various problems that can occur, such as performance and caching difficulties within the device, when developing an offline web-based application.

Having considered the strengths and weakness of the available technologies PhoneGap was decided as the main development framework of choice.
PhoneGap:

PhoneGap is a cross-platform, native development framework that enables the user to write native application for various mobile phone platforms with basic web development languages such as HTML CSS and JavaScript (Ghatol & Patel, 2012). It essentially wraps these languages and uses generated code to compile the code into an offline native application. In the previous section 3.4, four main constraints were identified and the following shows how PhoneGap met avoided these constraints.

Multi-Platform:

PhoneGap uses the web-development languages as a base, and very few alterations are needed to make this code compatible with multiple platforms. This meant that through PhoneGap all prescribers would be able to access the app both on iOS and Android.

Offline:

As PhoneGap creates a native application, connectivity was not an issue as all functionality is conducted offline

Compatible with HSE ICT Team:

PhoneGap is listed as one of the main technologies used by the HSE ICT Team. By using PhoneGap the ICT Team could both assist in the development of the application and maintain the application after the project finished. This was an essential requirement identified by the HSE so that the app could be maintained after interaction concluded.

Timeframe:

Due to multi-platform nature of the application, the success of the app considering the time was much more achievable. Once the application had been developed for
one Operating System, the transfer to a second was relatively effortless and therefore saved hugely on time.

Performance:

A major concern with PhoneGap was performance. Upon review of the framework various reviews had been found stating that its performance levels were not up to standard. However, upon review, the framework suited the nature of the application. The application mainly consisted of content and did not perform any major computations. While PhoneGap would not be optimum for the creation of all apps, it was applicatory to this particular project.

As the application had to be coded in a dynamic fashion, it was decided that the majority of the guideline's text would be stored in external data-sheets that would be displayed on the HTML via JavaScript. The first option was to store the data in XML sheets but the format chosen was JSON as it interacted with JavaScript in a more friendly fashion and was the format of choice by the HSE ICT Team.

**JSON:**

“JSON (JavaScript Object Notation) is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate.”

([JSON.org](https://json.org)). JSON is built on two structures:

A collection of name/value pairs. In various languages, this is realized as an object, record, struct, dictionary, hash table, keyed list, or associative array.

An ordered list of values. In most languages, this is realized as an array, vector, list, or sequence.
The format of the projects JSON files mainly consist of arrays and are usually chapter specific but files still can be quite large (e.g. empirical.json)
The project commenced coding but when the coding was at roughly 20% completion a design decision was taken to adapt the code to work with jQuery-Mobile.

jQuery-Mobile:

“jQuery Mobile is a HTML5-based user interface system designed to make responsive web sites and apps that are accessible on all smartphone, tablet and desktop devices.”, (jquerymobile.com). jQuery-Mobile gave the application a much
better interface to work on. Before the implementation of jQuery-Mobile, the application has consisted solely of HTML and CSS and did not achieve a sophisticated look. While this was a very early screenshot of the Main Menu, it captures the application’s early look and how it failed to look hugely like an app and more like a poorly designed website.

![Fig 6.0 Old list styled menu](image)

jQuery-Mobile added a more professional feel to the application through its various stock buttons, list-views and smooth transitions between pages. Another major benefit which jQuery-Mobile added was its ability to scale pages. This resolved the problem of both different sized screens and different screen resolutions which had previously affected the px attribute in the CSS.

Figure 7 below clearly illustrates the how PhoneGap interacts with the web development languages to form a native application.
Figure 8 below shows the architecture of the project and clearly illustrates how the various files interact with one another to produce the application:

![Diagram Showing Application Architecture]
4.3 Dynamism of Application:

Another major design decision was how to approach the coding of the application. As the majority the guidelines were text based the app could be made relatively quickly by hard coding the information similar to the process Maith-u used when developing GAAP. All stakeholders however, expressed an interest that the application be dynamic and as adaptable as possible.

In keeping with the request of the stakeholders, all information that had the possibility of changing in the future was held in the JSON sheets and introduced into the application externally via JavaScript. This meant that the HTML pages could essentially stay the same and the JSON sheets be edited. This resulted in the code being much cleaner and that the guideline information could be kept separate from the HTML and JQM code.

Keeping the app relatively dynamic was a key design feature and made the likelihood of future adaptation by the HSE much higher. Its implementation proved to be difficult at times as is shown in the next section, implementation.
5.0 Implementation

This chapter depicts the main development phase of the application. It will talk about original set up and then discuss the relationship between the JSON datasheets and JavaScript while showing some examples. Main aspects and features of the application will be explored by referencing the paper guidelines and discussing their implementation into app form with the aid of screenshots of the app and snippets of code. The application has been developed using XCode so for the following chapter all implementation references will be iOS related.

5.1 PhoneGap Implementation

The basic implementation of the PhoneGap framework was extremely simple. The website prompts the user to download Node.js which is a software platform for scalable server-side and networking applications. Once Node.js is downloaded, PhoneGap can be downloaded straight from the command line. The following instructions are taken from PhoneGap’s website:

**Install**

To install 3.4: Ensure that you have Node5 installed, then open your command line and run the following:

```
$ sudo npm install -g phonegap
```

Once installation completes, you can invoke `phonegap` on command line for further help.

**Usage**

```
$ phonegap create my-app
$ cd my-app
$ phonegap run android
```

Learn more at docs.phonegap.com

*Fig 9.0 PhoneGap Implementation*
Once these simple commands are executed PhoneGap will generate a series of files and folders including an Objective-C file to launch in Xcode which generates a sample page to work from (index.html). From there it’s easily edited and coding can commence.

5.2 jQuery-Mobile Implementation

Implementation of jQuery-Mobile is straightforward also. Through the sitejquerymobile.com a zip file is downloaded which contains both a CSS and JavaScript file. These easily slot into the project and are referenced in the HTML by the lines of code below:

```html
<link rel="stylesheet" href="http://code.jquery.com/mobile/1.4.2/jquery.mobile-1.4.2.min.css" />
<script src="http://code.jquery.com/jquery-1.9.1.min.js"></script>
<script src="http://code.jquery.com/mobile/1.4.2/jquery.mobile-1.4.2.min.js"></script>
```

While the installation is straightforward the layout of pages are quite different. All attributes within jQuery-Mobile have unique attributes which are differentiated by identifiers such as:

```html
data-role="X"
data-theme="X"
class="X"
```
jQuery-Mobile also has a multi-page template form which means multiple HTML pages can be included in a single file. Below are screenshots of code snippets taken from the `<body>` tags of empirical.html before jQuery-Mobile implementation and after jQuery-Mobile (without relevant JavaScript):

![Fig 12.1 HTML Before jQuery-Mobile](image1)

![Fig 12.2 HTML After jQuery-Mobile](image2)

As multiple features of the application had already been coded before the jQuery-Mobile implementation, its implementation was quite time consuming and the majority of the code previous to this point was deleted. While this was a big decision in the project's lifecycle it was the correct decision as the application is much more
aesthetically pleasing than before and as jQuery-Mobile has quite strict rules of implementation all the code follows the same path.

5.3 JavaScript and JSON interaction

A major aspect of this project is the interaction between the JSON files and the JavaScript. Through the use of various JavaScript methods, the JSON files are stepped through and the relevant information is pulled. While all the JSON files take the same form (Arrays), the JavaScript differs depending on how it wants to display the content. HTML tags are often embedded in the JSON as this enables the content to be automatically formatted depending on whether the text needs to be in bold or change colour etc.

As described in the previous section, this gives the app its dynamism and information can be added to the external JSON files and this will dynamically change what is displayed on the HTML page without actually changing any of the code. The code below is one of the simpler JavaScript functions in which a JSON file is read in and the contents are displayed in a collapsible form:

```javascript
$(document).on("pageinit", 
"#page1", function(){
var info=""
var imp = "json/malaria.json";
$.getJSON(imp, function(data) {
 $.each(data.Malaria, function(index, item) {
 info += "<div data-role='collapsible' data-mini='true'>
<h3>" + item.Name + "</h3> <p class='infotext'>" + item.Details + "</p> <div data-role='collapsible'>
<h3>Treatment: </h3> <p class='infotext'>" + item.Treatment + "</p>
</div>
});
});

$("#set").empty().append(info).collapsibleset();

});
</script>

Fig 13.0 JavaScript Function
The main function is a pageinit function and is called on the particular page whose id is displayed as the next variable passed in (in this case Page1). The variable info is initialised as an empty string. “info” will be the string which is appended to the HTML’s body. Then the var imp is initialised as the JSON file that the function will access. Then getJSON is called which pulls all the data from the JSON file and main body of the method can be executed.

The JSON file is then passed into another method called each. “each” is a jQuery method and is like a for loop as it steps through each element of the JSON array but is more commonly used in jQuery-Mobile development and provides cleaner code.

In the case of “data.Malaria” Malaria is the array which is stepped through, index is the element which the loop is currently accessing and item is each item in the elements of the array. The next two lines of code are where the collapsible set is fed into “info”. The code indicated in green is HTML which will not differ from element to element. The code indicated in white is the information is each of the elements that need to be printed.

Once all elements have been accessed in the array, “info” is appended to the body of the HTML. “#set” is the div to which “info” will be appended, “.empty()” empties “#set” any time the method is called to avoid duplications and reprints, “.append(info)” appends “info” to “#set”, and “.collapsibleset()” initialises the collapsible set to which “info” is appended. If a jQuery-Mobile widget is created through a JavaScript function it must be initialised like “.collapsibleset()”.

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While this is one of the more simple JavaScript functions most of the code does not differ hugely. The main changes in the app are the variable names and a slight change with a double ".each" if the JSON files contains a 2d array. The main changes occur in the "info+=" line as this is the code that is appended to the text.

While these functions were time-consuming to create, they serve as vital sections of the application and serve to keep the content separate from the code which makes the app significantly more adaptable for both multi hospital use and for the process of updating the guidelines.

5.4 Menu Layout
The menu layout was one of the main aspects in the application and changed hugely throughout the implementation process. Originally it was decided that the menu would be in a list format as seen below:

Fig 14.1 Old List Style Menu
Upon consultation with the Hospital Group in the HSE, they requested the menu be laid out in a tiled fashion, with tiles similar to Galway’s app. Various tweaking and shaping took place with CSS and eventually a tiled menu was created.

![Fig 14.2 Grid Menu pre-colour](image)

However, the clients then also requested that the tiles be coloured. This task was originally difficult as the code was being dynamically generated and stayed the same from element to element. However an array of 7 colours were created and stepped through element by element.

Finally there was an issue with some of the chapter names as they were too long and when shortened to fit inside the tiles, they would become unreadable due to their small size. However upon consolation with the Hospital team, it was agreed that the names could be shortened to fit. See below the final screenshot of the menu, the CSS
used to generate the grid, and the JavaScript function that generates the menu from an external JSON file named "contents.json"

![Fig 14.3 New Menu with Colour, CSS of Grid and JavaScript function for menu](image)
5.5 Empirical Guidelines

Another major step in the implementation was the completion of the empirical guidelines. The empirical guidelines form the main body of the guide. They are divided by clinical condition and then subdivided into tables as seen below:

![Empiric therapy of Infective Endocarditis (IE) (pending blood culture results)](image)

Out of all components these were the most difficult to add dynamically in the application. Initially all information was displayed quite simply. There was a menu for each clinical condition and within each clinical condition all details were displayed on one page.
Lengthy discussions were held with both the main liaison Dr. Carton and the Hospital Group to determine how they should be displayed and while it was agreed that this was sufficient it was also agreed that it could be improved upon and reduce the text on the screen as it was small and difficult to read.

It was agreed that upon reaching an infection there would be button links to each of the clinical conditions. Upon clicking these buttons the Antibiotic and Secondary Antibiotic would be displayed with a further collapsible in which the comments would be stated.

As the aim of the application was to be as dynamic as possible, a JavaScript function was written that would utilise the multi-page template system in jQuery-Mobile that would dynamically add these buttons and separate pages upon reaching the infection. This was quite a difficult function to write as there were many variables involved in this. System performance became an issue due to the amount of content.
the function was generating. After careful tweaking performance was improved and the dynamic function was achieved. Below are screenshots of the function and the improved look of the Empirical Guidelines.
5.6 Dosing Calculator

The next major step taken in the implementation was the introduction of a Gentamicin and Vancomycin Dosing Calculator. This was to be a significant advantage over the paper format as previously prescribers had to do these computations by hand or use the computers provided on the ward which could compromise good practice.

The hospital group provided the current technology used to calculate these dosing algorithms. It took the form of an excel sheet and failed to provide any additional info bar the calculations. See Appendix D for the Gentamicin Dosing Algorithm as seen in the guidelines.

The start of the chapter consisted of Aminoglycoside and Glycopeptide dosing and monitoring guidelines presented under a series of headings. A collapsible accordion was implemented that had each of the headings as the collapsibles and the relevant information in each of the dropdowns. This information was external and dynamically added in from JSON. A button was added at the bottom to access the calculator.

To commence the calculator, the algorithm was broken down and all variables identified. The first step in the algorithm was the Creatinine Clearance formula which took a patient’s weight, age, gender and serum creatinine and calculated their creatinine clearance:
However, there was a stipulation that required consideration when developing the dosing process. The first was that the patients BMI was over 30 (Clinically Obese), then the weight used to the CrCl would have to be the Ideal Body Weight (IBW). This required further computations and made it necessary that the patient’s height be added as a further attribute. A further factor to consider was a patient’s anuric level. If this was <500 ml/day the CrCl had to be treated as <10 ml/min. This was highlighted by a box in the excel sheet that if ticked, would indicate this as correct. In the applications calculator it is indicated as a yes or no switch.

Once the CrCl had been calculated the dose could be realised. The dosing included that ml/min, duration of dose and further action to be taken. It was decided that the further information would be button accessed as the aim was to keep the calculator as minimalistic as possible. Further measures were taken to ensure this minimalistic approach such as reducing buttons and introducing a toggle switch for either Gentamicin or Vancomycin. Below are screenshots of the calculator:
5.7 Neutropenic Sepsis:
Another challenging aspect of implementation was the conversion of the Treatment of Neutropenic Patients with Fever. As seen in Appendix E, the guidelines for Neutropenic Patients with fever follows a decision based guide with questions at the end of every step with corresponding recommendations on the following page.

It was originally thought the decision tree would be put in in picture form but it became much too small to read so a decision based structure was created. The whole structure was coded in one HTML file and consisted of 8 different pages, again utilising the multi-page template in jQuery-Mobile. At each page the information was displayed and the question asked at each branch with two buttons which were linked to separate pages within the file. All pages would eventually lead to the main information page where a recommendation would be given and the
prescriber would pick their treatment depending on the answer they were given. Screenshots of this decision tree can be seen below:

![Decision Tree Image]

**Figure 17.0 Neutropenic Sepsis Decision System**

### 5.8 Page Templating:

As previously described, all chapters in the guidelines that had the potential for future adaptation were made in a dynamic fashion. This would suffice for updates within the Connolly Hospital guidelines but not for chapter additions to Connolly’s guidelines. It would also need to be considered if the app was to be adopted by another hospital. Therefore the idea of page templating was introduced.

Through the implementation of the guidelines there were several forms in which chapters could be created. While some were very specialised, some could be quite generic and therefore could be re-created as templates with instructions on what to
fill in to create a page. Therefore four templates were created with instructions on what to fill in.

1) Basic JQM HTML Page:

This page is an empty HTML page with JQM initialised in it. It will give any hospital who implements it a blank page with an indication of where to put the heading and the basic text.

1) Menu Template:

Through the creation of a menu template, any hospital can set up and establish a main menu by creating various pages using the other templates, naming them, and then providing an empty JSON file with names and URLs to feed into the HTML page.

2) Empirical Guidelines Template:

As all hospitals will have some form of empirical guidelines, an empirical guidelines template was created as a basis for hospitals to work off. It will generate a page that needs to link with a JSON file and will generate both a tiled menu outlining the different infections but also a button menu dividing them into conditions and final pages storing all other relevant information.

3) Malaria Template:

The Malaria page was chosen to template, not because of its content, but how the content is displayed. Through the template information can be viewed in a
collapsible organ with information and a further nested collapsible inside. This can be a very efficient way of storing a table on the application.

4) Neutropenic Sepsis Template:

As Neutropenic Sepsis follows a decision tree format it is thought that other guidelines will have similar sections. Therefore a Neutro template was created in which there are 7 pages within the file, one for general information, five that have sections for additional info and yes or no buttons leading to other pages and one final information page.

5.9 Adding Content:

A user will either utilise the page templates by following the instructions or be using currently existing HTML pages so all that needs to be changed to add content is the JSON files. Like the HTML pages, these will either be created or be modified. While it is expect the HSE ICT Team will conduct this, it will be possible for a pharmacist or microbiologist to achieve also.

Through the use of free, online JSON generators, users can easily create and modify content without worrying about syntax. Once these are created and the proper tags are applied it will be easy for a user to link these to the HTML pages. Thanks to the pre-generated JavaScript code these HTML pages will update dynamically.
6.0 Evaluation - presentation of feedback received and your analysis of that feedback

Evaluation took many forms in this project. In this section I will discuss sprint evaluation used for the ongoing evaluation of the project in development and the HSE stakeholders and junior doctor evaluation through the use of the System Usability Scale. I will also discuss the issue of future testing that will occur after this project’s lifecycle.

6.1 Sprint Evaluation

Ongoing evaluation was a key factor to this project’s success. When dealing with an external client it is often important to seek their ongoing evaluation to both ensure their involvement in the project and that the project delivers a product that is both relevant and acceptable. When coding commenced, fortnightly meetings were held with the client to discuss the user stories that had been completed but also to identify what user stories should be completed next.

PhoneGap and JQM assisted in this, as these development tools made it very easy to display prototypes to the clients. At each sprint meeting, the user stories were presented to the client, and feedback was provided on the look and functionality of each user story. The feedback was taken into account and changes were made to the existing prototype and reviewed at the subsequent meeting.
This process meant that the stakeholders received exactly what they required and that resulted in them being more invested in the application and its development. As a result they received an app that was customised to their needs. These in turn led to higher levels of satisfaction than would have been possible if the app was made from start to finish without their ongoing input.

6.2 Evaluation using The System Usability Scale:
Upon completion of the projects specifications, feedback was required prior to launch. Upon reviewing various different methods of evaluation it was decided that the System Usability Scale would be used. SUS is a questionnaire that consists of 10 questions that gauges perceived usability by asking users to rate ten statements about the usability of a product on a scale of 1 to 5, generating a combined score of 0–100 (Bangor et al, 2008). The full list of questions can be found in Appendix F. Once all scores have been provided all even numbers need to be subtracted by 5 and taken as a positive number and all odd numbers need to subtract 1. When this is done the score will be out of 40. The score must be then multiplied by 2.5 in order to get the full score out of 100.

Through the utilisation of SUS feedback was received from both the HSE stakeholders but also from medical students from both Trinity College Dublin and the Royal College of Surgeons Ireland who are currently working in St James’ Hospital and Beaumont Hospital respectively. I will discuss the feedback given and evaluate it in terms of the success of the application.

Stakeholder Evaluation and Feedback:
The stakeholders that were asked to participate in the feedback were in all three groups which were liaised with from the HSE. They included Dr. Carton, Ms Love and Dr. O’Neill of the Hospital Group and Mr Richard Mulholland of the HSE ICT Group. By asking all three groups to participate, there was a well-rounded and diversified group of stakeholders from which to gather feedback.

Medical Student Evaluation and Feedback:

The medical students which were enrolled to help with the application were; Ivan Welaratne and Kevin Millar. Both have years of experience on the wards of various hospitals and are in their final year in their respective universities. Mr Welaratne also has experience in antimicrobial reference applications as he used R2Ss application while on placement in Tallaght Hospital. Both were used as they come from different medical schools and could therefore provide a broader scope on feedback.

The following is a table of these results:

<table>
<thead>
<tr>
<th>Main Liaison</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Final Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Carton</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>92.5/100</td>
</tr>
<tr>
<td>Hospital Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ms. Love</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>97.5/100</td>
</tr>
<tr>
<td>Dr. O’Neill</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>95/100</td>
</tr>
<tr>
<td>App Development Team</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Mullholland</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>92.5/100</td>
</tr>
<tr>
<td>Medical Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ivan Welaratne</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>95/100</td>
</tr>
<tr>
<td>Kevin Millar</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>95/100</td>
</tr>
</tbody>
</table>

*Fig 18.1 Table of SUS Results*
Evaluation of Feedback:

After taking all 7 scores, the average comes in at 94.58/100. On average software will receive a score of 68 on the SUS so these results are exceptional. SUS scores should not be considered as a percentage but as the following graph shows, the score can be viewed as a percentile rank.

Fig 18.2 SUS Percentile Graph

6.3 Self Evaluation:

Achievements & Pitfalls:
I feel that the project as a whole has been a success. All original requirements were met and stakeholders expressed particular gratitude upon its completion. I believe that big decisions such as the switch to JQM paid off and knowing when to make decisions such as these paid dividends. I think client interaction was essential to the
success of this project. Without this I think the client would not be as invested in the app and therefore may have lost interest over the commercial options.

I believe there are a number of things I could have done differently. I believe coding should have been completed in more than 8 weeks and that coding really should have commenced before January. If this had occurred, additional content could have been added and the app could have been already launched. Also this hindered my opportunity to deploy the application on Android before the project’s completion. This was a poor form of judgement on my part as it is much simpler to display android applications on devices before an applications launch and this could have been beneficial for both me and the stakeholders.

While I am pleased with the final product there are a few aspects which could have been improved upon. Simple unadaptable chapters such as general info and IV to Oral Switch were hardcoded in as they were not going to change between updates. However, if the application is to be adapted for other hospitals they will need to change. Making them dynamic too would have been the best option.

I think contact with the ICT group could have been more frequent. The ICT team’s knowledge of PhoneGap and JQM was a valuable asset that was not drawn on enough and time was often wasted trying to fix menial errors. While there were various pitfalls throughout the project overall I would view the project as a major success.

Future Features:

There are a few features which I believe need to be added to the application in order to complete the application.
• Chapters: Final chapters need to be added to the application in order to contain the full guidelines

• Search Function: A search function should be added in order to search by both infection and antimicrobial

• Color-coded Antibiotics: Colour coding of antibiotics can quickly indicate to doctors to allergens within the antibiotics. For example, if an antibiotic is green it is clear of all allergens and if an antibiotic is red it contains penicillin.

• Server-Side: While this will be done mainly by the HSE ICT team it is a necessary requirement in order for the application to be considered fully adaptable.

• Windows Phone Platform: Although this will not prove to be extremely difficult to achieve, a windows platform should also be constructed in order to accommodate with the rise in windows phones.

• Added Metrics: Another possibility could be to add metrics to the application. Horizon’s MicroGuide offers metrics such as how many people use the application per day and what is the most searched antimicrobial in the application.

6.4 Future Testing:
As the application is currently is currently in Beta it has not been uploaded to the App Store or the Play Store as of yet. However, over the summer two final chapters will be added to the application and the app will be launched onto both stores. Before the application is submitted for approval, testing will occur in conjunction with the HSE ICT team. We will review the code rigorously and ensure all is working on from a functional perspective.

In order for the application to get accepted by both stores, (in particular the apple app store) it will have to meet a number of requirements. This in itself will be testing as both stores check for any errors or structural issues within the app.
Once the application is approved on both stores, it will have restricted access via simple password protection. It will undergo two phases of testing before being fully released.

**Phase 1:**

The first phase of testing will be Antimicrobial Pharmacist and Microbiologist testing. Dr. O’Neill and Ms Love will be granted access to the application where they will use the application for two weeks. This testing phase will focus on identifying any bugs in the application and will also search for simple grammatical errors and information that may have been entered incorrectly. After the two weeks are complete they will report all bugs and errors they have found and these will be remedied.

**Phase 2:**

The second phase will be to provide a group of 20 junior doctors within Connolly Hospital with access to the application. This phase will take a further two weeks. During this time the junior doctors will use the application during their everyday tasks. They will test the application in its prescribing abilities but also the other features such as the Neutropenic Sepsis and the Gentamicin and Vancomycin Calculators. At the end of the two weeks, similar to the previous phase, feedback will be provided on bugs and errors. After the fixing of any errors found the application would be formally launched.

**Additional Actions:**

While this is how I plan to test the application for bugs and grammatical errors I will recommend that the hospital takes further action in ensuring all the data is correct.
While I am confident all data will have been entered correctly it is of the upmost importance that no information is incorrect as this could potentially be catastrophic if doctors accidentally mis-prescribe an antibiotic. As a precaution, an agreement was signed between me and the Microbiologist that I cannot be held accountable for any data which is entered incorrectly. Before the application is fully launched I will look to the screening processes which occurred in both Tallaght and Galway in order to recommend the best course of action for Connolly. If successful the same action will be followed in each subsequent hospital.
7.0 Conclusions & Future Work:
In this section future work on the application will be discussed along with final conclusions and acknowledgements.

7.1 Further Work with the Application:
While a lot has been achieved in the timespan of this project, the application’s lifecycle has just begun. There will be three sub headings to this section: Future within Connolly Hospital, Future within Ireland and finally Global Future.

Future within Connolly Hospital:
Meetings will be ongoing with the HSE ICT Team and in mid-May the application will be accessible on both the Google Play store and the Apple App Store. This will entail adding all the JSON data sheets onto the HSE servers, and setting an update operator and pulling the data from the servers every time there is an update. As the only thing that may be subject change are the data sheets and not the actual HTML files themselves, updates will be instant and will not have to go through the various app stores.

Once this is accomplished, a series of testing phases will be carried out to fix all bugs and errors as described in the previous section. It is expected that all changes will be just with the datasheets which means the updates will be instantaneous but if a change in structure is needed this will also be possible. After the testing phases are complete, it is hoped that the application will be rolled out on a hospital wide basis.
The HSE ICT Team in collaboration with myself will work on updating Connolly’s guidelines which are due to be finalised in September of this year.

**Future within Ireland:**

If a full roll out of the application is successful in Connolly, the HSE may look to roll the application out to other hospitals in the region and then on a national scale. The next hospital planned is Cavan Monaghan Hospital Group (CMHG). CMHG is of similar size to Connolly and is also in the same HSE Region. This will assist in ensuring a smooth transition between these two hospitals. If CMHG also proves successful, it is then planned to move implementation to a larger site. Beaumont Hospital has been identified as a possible site as it whilst still in the same HSE Region would be significantly bigger both in terms of size and clinical speciality. Similar testing phases would be carried out in each hospital.

There is also a possibility for the commercialisation of the application, mainly to private hospitals within Ireland. According to the HSE ICT Team and the Connolly Hospital, the application more than meets the standards of the competition and if the app was to be priced competitively, the possibility of commercialisation would be relatively high. It is certainly an avenue that could be explored in the future which leads to the next heading, Global Future.

**Global Future:**

While national commercialisation is still an uncertainty, the possibility of a global future should also be explored. Antimicrobial reference guides are not just specific
to Ireland but are applicable to all hospitals worldwide around and for this reason, the potential for marketing the application should not be limited to just Ireland.

Through Dr. Carton, contact has been made with Mr Charlie Shutter, a software developer who has experience in health informatics. Shutter has developed lab testing software for hospitals around Ireland, which undercut the American competition with major reduction in prices. He then received interest from Africa and South-East Asia to which he followed up and has since adapted his software for these markets. This is a potential route this application could follow, and by meeting with Mr Shutter it is a route that will be explored. A recent report from African telecommunications market suggests that mobile phone penetration has hit 80% (TA Telecom, 2013) and the exploitation of this could have huge benefits.

7.2 Conclusions
This project successfully achieved the goals it set out at commencement:

- To design and implement a mobile application which could be used in hospitals to assist doctors to make appropriate choices when prescribing antimicrobials. The importance of such choices has been underlined by the emerging threat of multiresistant organisms such as MRSA.
- To present a hospital’s antimicrobial guidelines in a user friendly manner while ensuring the systems architecture is capable of managing the content as the guidelines are subject to periodic updating.
- To construct an application in a manner that would be adaptable to allow for updates and modifications which could run on both IOS and Android devices.
- To ensure that the application is capable of being accessed offline as not all hospitals have access to Wi-Fi.
• To increase the ease of access to prescribers of the antimicrobial prescribing guidelines by having them in a portable electronic format, meaning that they would not have to seek access to these away from the point of decision making (the patient’s bedside).

The process adopted in achieving these goals required the developer to draw on many skills learnt in the course of his studies e.g.

• Identifying business opportunities.
• Networking to identify potential business partners.
• Negotiating with diverse client groups to establish the project.
• Listening to clearly understand the needs of the clients.
• The need for professionalism when dealing with clients.
• Translating the needs of clients into a functional product that could be applied in a real world environment.
• Overcoming barriers encountered in the development phase by considering options not anticipated at the outset.
• Developing resilience and adopting a problem solving approach.
• Meeting sometimes challenging deadlines with the client whilst keeping within the project timeframes.
• Establishing and maintaining relationships through ongoing and active two-way communication with all client groups.
• Being future focused in order to see potential future application of the project.

Through completion of this project the developer has therefore not only realised and delivered the product to the client but as importantly has experienced a taste of a real work environment and the challenges that it can present.
References:


Appendices:

A) Scrum Process:
B) Original Requirement Document

Requirements and Specifications Documentation

Requirements Document: Darragh O'Connor

Overview:
The goal is to create an antibiotic reference guide application to be used and distributed to hospitals nationwide.

Project Specification:
Originally set up as a generic web-based application that can be incorporated by multiple hospitals around the country. A hospital can enter their own antibiotic guidelines that gives a brief description of each antibiotic and which disease they are most effective against.

Once the antibiotic guidelines are fully incorporated into the application any doctor in that hospital will have access to them. A doctor will be able to search for an antibiotic based on a number of criteria. The return of this should give the doctor a detailed description of the antibiotic and guide the doctor on how to administer the antibiotic.

Scope:
A web-based application for the collection of detailed data about each antibiotic that a hospital administers.

Upon the entry of a particular antibiotic in the database and range of other data must be entered accompanying it. This additional data will then build up an archive of all the information about a particular antibiotic. This will range from hospital to hospital, depending on what antibiotics they use and what they are used for.

A doctor can search for an antibiotic in one of two ways. All antibiotics will be easily searchable and will give a brief description of each antibiotic and the common diseases in which it combats. A doctor can also use a much more specific way of searching for an antibiotic in which he/she will cross reference all the additional data that was previously entered to get a more patient specific answer on which antibiotic would work best.

The “additional data” will comprise of numerous restrictions that will narrow the search down at each stage. They will be a set number and will not change from hospital to hospital. This is important for the generic nature of the application. Some examples of this data which will feature in the app include condition of patient, site in which disease occurs, common organisms within the disease, etc.

Functional Requirements:

- A generic program that can store data and the data is easily manipulable
- Ability to edit antibiotic details in accordance with new regulations
- A search bar that will find an antibiotic and give a brief description
- Ability to be able to add and delete accounts
- Ability to add different antibiotics to specific hospitals list
- Ability to add constraints to antibiotics to narrow search down and be more accurate
- Ability to search for antibiotic depending on said constraints

Non-Functional Requirements:
C) User Stories

User stories for Connolly Hospital Antimicrobial Guideline Application

1. Viewing Table of Contents: As a prescriber in Connolly Hospital I need to view the table of contents so that I can navigate quickly and easily through the guidelines on the ward.
2. Viewing Introduction & Accessing contact details: As a prescriber in Connolly Hospital I need to view the introduction and contact details of the pharmacist and microbiologist so that I can get an overview of the guidelines but also have the contact information ready for the pharmacist and microbiologist in case of an emergency or query.
3. Viewing General Principles: As prescriber in Connolly hospital I can refresh my knowledge/view the general principles of antibiotic prescribing specific to this hospital so that I can ensure I am following the correct procedures in prescribing antimicrobials that are specific to this hospital.
4. Accessing the Empirical rules: As a prescriber of antimicrobials in Connolly hospital I can access the empirical rules of the antimicrobial guidelines anywhere on the hospital campus so that I can determine what antimicrobial & dosage needs to be administered to a patient depending on the infection and clinical condition.
5. Viewing the IV to Oral guideline: As prescriber of antimicrobials in Connolly hospital I can view the Connolly hospital guideline for the Intravenous to Oral switch of antibiotic therapy so that I can make an informed decision on whether to take a patient off IV antimicrobials or not.
6. Guidance on MDRO note: As a prescriber in Connolly hospital I need guidance on MDRO (multidrug resistant organisms) that are of particular concern to Connolly hospital, so that potential outbreaks are detected early and therefore prevented.
7. Viewing Malaria algorithm: As a prescriber in Connolly hospital I need to view the modified algorithm for the treatment of malaria, so that appropriate treatment can be commenced as soon as possible.
8. View the guideline on Neutropenic Fever: As a prescriber of Connolly hospital I need to view the guideline on the management of neutropenic patients with fever so that patients are managed appropriately as microbiology results become available.
9. Viewing Creatinine Clearance Calculator: As a prescriber in Connolly hospital I need to view the single daily dosing algorithms for Gentamicin and Vancomycin so that I am familiar with the principles of Aminoglycoside & Glycopeptide dosing and monitoring prior to prescribing these classes of antibiotics.
10. Calculating Creatinine Clearance: As a prescriber in Connolly hospital I need to calculate the creatinine clearance for my patient at the bedside so that the correct dosages of Aminoglycoside & Glycopeptide antibiotics can be prescribed.
11. Calculating Gentamicin and Vancomycin: As a prescriber in Connolly hospital I need to calculate the dosing regulations for both Gentamicin and Vancomycin prior to prescribing these antibiotics.
12. View guideline on Absent or Dysfunctional Spleen: As a prescriber in Connolly hospital I need to view the guideline on prevention of infection in patients with absent or
D) Gentamicin Dosing Algorithm

Single Daily Dosing Algorithm for Gentamicin

(If patient has endocarditis/cystic fibrosis/pregnancy, please contact microbiology—not suitable for standard once daily regimen)

Is Creatinine Clearance (CrCl) >50ml/min?

\[
CrCl = \frac{(140 - \text{Age}) \times \text{Weight}^* \times (1.23 \text{ males})}{\text{Serum Creatinine}} \text{ or } 1.04 \text{ females}
\]

**If urine (<500ml/day), treat as CrCl <10ml/min

*Weight used should be actual body weight (ABW) or for obese patients (BMI>30), an obese dosing weight (ODW) must be calculated.

\[
ODW = \text{IBW} + 0.4(\text{ABW} - \text{IBW})
\]

Dose should never exceed 500mg.

BMI = Weight (kg)/Height (m)^2

IBW (males) = 50 + 2.3kg for each inch over 58

IBW (females) = 45.5 + 2.1kg for each inch over 58

Give first dose of IV Gentamicin 5mg/kg
(based on Actual Body Weight or ODW if obese*). Record actual time of dose (ideally 4-8pm)

Take blood for serum gentamicin level 16-18 hours after FIRST dose.
Record actual time of sampling. (4pm dosing = 8-10am level, 6pm dosing = 10am-12noon level)

Is trough level <1mg/L?

\[
\text{Dose Calculator} \text{ is available on desktop of Clinical PCs to aide initial dosing.}
\]

**Dosing Calculator** is available on desktop of Clinical PCs to aide initial dosing.

<table>
<thead>
<tr>
<th>CrCl(mll/min)</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-50</td>
<td>3mg/kg*</td>
</tr>
<tr>
<td>10-30</td>
<td>2mg/kg*</td>
</tr>
</tbody>
</table>
| <10          | 1-2mg/kg* re dose when level <1mg/L

Is trough level <1mg/L?

Continue current regimen.

Check time dose given and sample taken. Was level taken at 16-18 hours after dose?

Is trough level >1mg/L but <2mg/L and treatment still indicated?

Reduce once daily dose by 1mg/kg*
Management of Neutropenic Patients with Fever.

Fever in neutropenic patients, especially with severe neutropenia (<500 neutrophils/mm³), is a common occurrence. Patients must be thoroughly examined with particular attention to the chest, mucosa, IV lines, abdomen, peri-anal area and wounds. It is also very important to review any recent microbiology results as these may guide treatment.

Empiric Antibiotic Treatment: Below is a step-wise introduction of antibiotics in the febrile neutropenic patient. Antibiotic treatment may be subsequently altered on the basis of positive microbiology results or the clinical course.

1. P. lact. 4.5g iv qds
2. Add gentamicin 5mg/kg/day if any of the following apply:
   - Patient is haemodynamically unstable
   - Duration of neutropenia greater than 10 days
   - Patient deteriorates after initial assessment
3. Temperature settles
4. Review planned duration of antimicrobial treatment (see below [d])
5. Ongoing pyrexia after 48 hours, repeat blood cultures, add vancomycin 15mg/kg iv bd (if central line in situ and evidence of line infection or patient has severe mucositis addition of vancomycin may be indicated before 48 hours have elapsed)
6. Ongoing pyrexia after a further 48 hours, add caspofungin 70mg iv stat; then 50mg iv od if < 80 kg (70mg iv od if > 80 kg). Consider HRCT thorax and removal of any lines in situ
7. Temperature settles
8. Review planned duration of antimicrobial treatment (see below [d])
9. Ongoing pyrexia, consideration should be given to other infective causes (see below [c])
a. Penicillin allergy or history of ESBL: substitute with meropenem 1g iv ds. Patient must be closely observed, for evidence of drug reaction, during and after first and second doses.

b. Regular serum assays and dose adjustment in renal impairment are required for patients on aminoglycosides or vancomycin.

c. Persistent fever:
If fever persists despite antibacterial and antifungal therapy contact microbiologist for advice. Consider other infective causes such as:
- CMV infection - CMV can present as pneumonitis, gastrointestinal or CNS symptoms. These patients should have an EDTA blood sample collected together with BAL and biopsy (as appropriate clinically) sent for CMV PCR. Treatment is with ganciclovir 3mg/kg/12 hourly (dose adjustment in renal impairment).
- Herpes simplex virus (HSV) and varicella zoster (VZ) – can present as vesicular or ulcerative lesions. Add aciclovir 5mg/kg ivs iv for HSV, 10mg/kg ivs iv for VZ infection. For early lesions if not widespread or haemorrhagic consider oral aciclovir 400 mg five times a day for HSV, 800 mg five times a day for VZ.
- Respiratory viruses e.g. RSV, influenza, adenovirus etc. - nasopharyngeal aspirate should be sent for immunofluorescence and viral culture. Contact microbiologist if positive.
- Sinus tenderness or nasal ulcerative lesions – suspect fungal infection e.g. aspergillus or rhizopus such as muco. Contact microbiologist if suspected.
- Pneumocystis jiroveci (carinii) pneumonia (PCP) - these patients should have BAL sent for PCP staining and if indicated treatment with co-trimoxazole, 120 mg/kg daily in 2-4 divided doses (dose adjustment in renal impairment).

d. Discontinuing antibiotics:
- In those patients where cultures are negative and non-infective causes of pyrexia are considered more likely, antibiotics may be discontinued after 5 days, or sometimes earlier if: the fever has resolved for >48 hours, the patient is clinically well and especially, if the neutrophil count has risen to >0.5x10⁹/L.
- In those patients in whom an infective cause is likely but has not been identified, continue antibiotics for up to 10 days treatment in total, or until neutrophil count >0.5x10⁹/L.
- If no organisms have been isolated, and the patient is pyrexial, when the neutrophil count has recovered, oral antibiotics are not usually necessary.

F) System Usability Scale Questions

- I think that I would like to use this system frequently.
- I found the system unnecessarily complex.
• I thought the system was easy to use.

• I think that I would need the support of a technical person to be able to use this system.

• I found the various functions in this system were well integrated.

• I thought there was too much inconsistency in this system.

• I would imagine that most people would learn to use this system very quickly.

• I found the system very cumbersome to use.

• I felt very confident using the system.

• I needed to learn a lot of things before I could get going with this system.
**Electronic Resources:**

Find enclosed a CD with all relevant electronic resources.