

Tax-E - Android App for Local Taxi Bookings

CS39440 Major Project Report

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(G400)

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Declaration of originality

I confirm that:

- This submission is my own work, except where clearly indicated.
- I understand that there are severe penalties for Unacceptable Academic Practice, which can lead to loss of marks or even the withholding of a degree.
- I have read the regulations on Unacceptable Academic Practice from the University's Academic Registry (AR) and the relevant sections of the current Student Handbook of the Department of Computer Science.
- In submitting this work I understand and agree to abide by the University's regulations governing these issues.

Name: Rhys Evans

Date: 23rd April 2019

Consent to share this work

By including my name below, I hereby agree to this project's report and technical work being made available to other students and academic staff of the Aberystwyth Computer Science Department.

Name: Rhys Evans

Date: 23rd April 2019

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Abstract

Web and Mobile Technologies have become increasingly ubiquitous in the travel and tourism industry. These technologies, together with a company's ability to successfully adopt them is often pivotal to the company's success within the industry.

This project's aim was to provide a platform for local taxi companies to interact with and provide a service for their customers. The key aspect of the platform is the creation, viewing, and management of bookings. By handling bookings this way, customers and taxi companies can reliably keep track of their past and present bookings in real time.

This project has produced a fit for purpose, fully functional platform. It is split into 3 key systems: a REST API to interact with the backend database and be consumed by other systems within the platform; a web app to be used by controllers within a company to claim, delegate, and manage bookings; and an Android App to be used by customers and drivers to view, create, and manage bookings. The developed product is flexible, allowing taxi companies to choose the level of adaptation that would best fit their business.

Predictably, however, there is room for improvement and future development within the project. Given the scope and time restrictions provided, the produced platform is only intended as a starting point and proof of concept.

This document will provide an insight into the motivation behind platform's development, address weaknesses and key areas for improvement, and discuss the engineering and project management challenges encountered and how they were overcome.

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Chapter 1

Background & Objectives

1.1 Background

The aim of this project was to create a platform that serves as an intermediary between local taxi companies and their customers. The platform supports three types of users: Company Admin, Driver and Customer. It consists of two user-facing applications: An android app - intended to be usable by Drivers and Customers, and a mobile-friendly web application - intended to be usable by Company Admins. Both applications are served by a single REST API.

Currently, it is intended that a single instance of the platform is used by many taxi companies, each with their own Company Admins and Drivers. The companies would then use the platform as a service in order to support their internal booking mechanisms. However, it can be adapted to be used by a single Company as their sole booking management mechanism. This makes the platform very flexible, allowing for varying use cases.

The primary motivation for this project was to streamline the process of making taxi bookings in small, local areas. With the hope that a fully mobile, digital solution would lead to a better experience for both the companies and their customers. For example, being able to view a history of all bookings could be extremely helpful for cases of lost property, criminal damage, etc. In addition to this, by viewing the live status of their booking, and communicating with their driver via notes, customers can make sure they are present for their booking at the correct time, hopefully resulting in fewer wasted Taxis.

1.1.1 Background Research

In order to successfully execute the project, research had to be done into various aspects of the app's development. This includes methodology, technologies, and deployment options.

1.1.1.1 Methodology

Software Development Methodology is a key part of any large project. The effect of the methodology on the product, along with a project's ability to adapt to the methodology should always be considered when making a selection. With this in mind, several options were researched for the project.

The first methodology researched was the Waterfall Model, or 'SDLC' [1]. Having already worked on a project using the Waterfall Model, there was less of a focus on researching the methodology but rather to consider its applicability in this project. As the Waterfall Model is a plan-driven approach it would require a lot of upfront documentation and decision making with regards to requirements, thus potentially making it rather inflexible. Given that this project also involved a significant learning curve with regards to the technologies used, it would perhaps be tricky to accurately gauge the ability to implement various functionalities early on.

The next methodology researched was Feature Driven Development, or 'FDD' [2]. FDD is an agile methodology created by Jeff Luca, it is an iterative approach with an emphasis on the timely and successful delivery of features. It is broken down into 5 key processes: developing an overall model, building the feature list, planning by feature, designing by feature, and building by feature. It is clear from these processes that the project's development would be done on a 'per-feature' basis, comparable to stories in other agile methodologies. At first impressions, this methodology seemed much more appropriate for the project than a plan based approach.

Extreme Programming or 'XP' [3,4], was the final methodology to be researched. It was one of the recommended methodologies provided for the project. XP is described as being ideal in projects with dynamically changing requirements, risks from fixed time projects using new technology, and when using technologies that allow for automated tests [4]. The methodology is often identified by its values, which give a great indication to the mission of XP. Reading literature written by one of XP's creators provided a great insight into the application of XP and its key advantages over other approaches.

1.1.1.2 Technologies

Having only experienced Android app development with a local, offline backend; it was essential to the project's success that research was done to explore the tools and technologies available to support a networked mobile app. This research was required for each aspect of the project, including its deployment.

The first and arguably most significant area to research was the API that would support the app(s). It was clear from very early on that there would likely be at least two apps within the platform to consume the API (web app and mobile app). Therefore, an API would need to be developed and a language/framework had to be selected to develop such an API. The researched options were: ASP.NET [5], Rails 5 [6], Node.js & Express.js [7, 8] and Flask (Flask-RESTful) [9]. All of the researched options had fairly similar learning curves (due to the technology they are built on and past experiences), each option was also perfectly fit for purpose to create a REST API to serve a mobile

application.

The next technology to research was the database management system (DBMS) that would be used by the REST API for data persistence. The selected DBMS would ideally be able to interface easily with the framework used to create the API itself. The options researched were: PostgreSQL [10], MySQL [11], and MongoDB [12]. The first two options were both traditional relational database management systems, whereas the final option is a NoSQL document-oriented system.

In order to successfully consume the REST API within the Android application, a HTTP Client library had to be chosen. During this selection, two complementary technologies were researched, Retrofit [13] and rxJava [14]. Retrofit is a HTTP Client library for Java and Android that is primarily used to consume REST APIs, rxJava is an asynchronous programming library with observable streams. This allows requests to be made to the REST API from the mobile application and the responses can be stored in a life-cycle aware Observable object, thus fully supporting asynchronous programming.

It became apparent that a relatively small web app would need to be created as part of the platform to support the Company Administrator's role. Therefore, a front-end web framework to consume the API had to be chosen. The frameworks that were looked into were: Angular [15] and React [16]. Although Vue.js [17] was initially considered, it became apparent that React and Angular were the two most prominent options and would be the most beneficial technologies to learn.

Due to previous experience, it was already decided that Android Studio would be the chosen IDE used to develop the Android application. However, there was still a decision to be made about developing the API and Web Application. The standard code editor 'Atom' had been used for previous web projects. However, upon further research JetBrains's 'WebStorm' IDE was discovered. Therefore research was done into both solutions in order to select the most appropriate.

Lastly, project management, deployment, and development tools had to be researched. In terms of project management, it was already decided that an online Trello board would be used to keep track of the needed tasks. It was also decided early on that GitHub would be the primary version control tool used in the project, due to its familiarity and potential integration with continuous integration tools. In order to fully explore the potential of using an agile development methodology, various continuous integration tools were researched. These included: JetBrains's TeamCity [18], TravisCI [19], and Jenkins [20]. Each CI tool has its strengths, with TravisCI standing out as the most lightweight and easily integrated. TeamCity is developed by JetBrains, several of their products were also considered/used for the project so familiarity would be an advantage. Lastly, Jenkins appeared to be the most widely used tool and therefore would have plenty of documentary and online tutorials. Finally, in order to potentially support any CI tools, the containerization tool 'Docker' [21] was researched for use in the API's development.

1.1.1.3 Deployment Options

Deployment of the Android app itself is made fairly straightforward by Android Studio's build options. Allowing for APK signing and Google Play Store support. However,

with regards to the REST API and the Web Application, some research was required to decide on the most appropriate deployment solution. The following solutions were researched and considered as options: Heroku [29], Amazon Web Services (AWS) [30], and self-hosting using Nginx [31]. Each of these solutions had its advantages, deploying via Heroku would be made simple due to its in-built Docker support. Using AWS would allow for very fine grain control over server size, resources, and traffic management; it would also make supporting SSL encryption trivial. Lastly, a custom hosting solution using Nginx would be the simplest and easiest to manage, due to pre-existing server setups. However, this solution could have some security implications.

1.1.2 Functionality Research

1.1.2.1 Related Products

A major part of the functionality research required for this project was to investigate applications already on the market that are targetted towards Taxi booking creation and management. This research would go on to help identify the key functionalities required within the platform and the most effective way to implement them. Having already decided on a name, rough purpose, and short description. Researching similar products on the market is regarded as the next key step in developing an app idea.

The first and perhaps the most prominent product to be investigated was 'Uber' [22]. Uber's mobile app is designed to manage and delegate bookings for registered Uber drivers and not self-contained Taxi companies. However, the interaction and flow of the booking process between the driver and the customer served as a major influence when coming up with the concept for this project. Together with in-app messaging to allow easy communication between customers and drivers, Uber's use of GPS is the ultimate goal for booking creation and tracking. However, it was clear from early on that these well-polished features fell outside of the scope of this project.

Having investigated a commercial solution that did not target Taxi companies directly, the research required a more applicable product. 'My Taxi' [23] is a cross-platform, mobile application that allows customers to book, track and pay for their taxi. The app is incredibly well polished and maintained with an intuitive sign-up flow and booking creation process. The app is supported in many major European cities, including Brighton, Edinburgh, London, Manchester, Nottingham, Oxford, Reading, Derby, and Leicester. In addition to their mobile app, they also have a web client to support taxi business administrators.

Lastly, a primarily web-based service, 'minicabit' [24] was investigated. Minicabit is a UK based service, that allows users to retrieve taxi booking quotes, it is also possible to book a taxi based on the quotes received. The website's user interface was very friendly and intuitive. The look and feel of the quoting system were very similar to other websites within the travel industry. Although this service provides support for booking taxis, it appeared to have minimal support for any booking management or tracking.

1.2 Analysis

Taking into account the problem and what you learned from the background work, what was your analysis of the problem? How did your analysis help to decompose the problem into the main tasks that you would undertake? Were there alternative approaches? Why did you choose one approach compared to the alternatives?

There should be a clear statement of the objectives of the work, which you will evaluate at the end of the work.

In most cases, the agreed objectives or requirements will be the result of a compromise between what would ideally have been produced and what was determined to be possible in the time available. A discussion of the process of arriving at the final list is usually appropriate.

As mentioned in the lectures, think about possible security issues for the project topic. Whilst these might not be relevant for all projects, do consider if there are relevant for your project. Where there are relevant security issues, discuss how they will affect the work that you are doing. Carry forward this discussion into relevant areas for design, implementation and testing.

1.3 Process

You need to describe briefly the life cycle model or research method that you used. You do not need to write about all of the different process models that you are aware of. Focus on the process model that you have used. It is possible that you needed to adapt an existing process model to suit your project; clearly identify what you used and how you adapted it for your needs.

Chapter 2

Design

You should concentrate on the more important aspects of the design. It is essential that an overview is presented before going into detail. As well as describing the design adopted it must also explain what other designs were considered and why they were rejected.

The design should describe what you expected to do, and might also explain areas that you had to revise after some investigation.

Typically, for an object-oriented design, the discussion will focus on the choice of objects and classes and the allocation of methods to classes. The use made of reusable components should be described and their source referenced. Particularly important decisions concerning data structures usually affect the architecture of a system and so should be described here.

How much material you include on detailed design and implementation will depend very much on the nature of the project. It should not be padded out. Think about the significant aspects of your system. For example, describe the design of the user interface if it is a critical aspect of your system, or provide detail about methods and data structures that are not trivial. Do not spend time on long lists of trivial items and repetitive descriptions. If in doubt about what is appropriate, speak to your supervisor.

You should also identify any support tools that you used. You should discuss your choice of implementation tools - programming language, compilers, database management system, program development environment, etc.

Some example sub-sections may be as follows, but the specific sections are for you to define.

2.1 Overall Architecture

2.2 Some detailed design

2.2.1 Even more detail

2.3 User Interface

2.4 Other relevant sections

Chapter 3

Implementation

The implementation should discuss any issues you encountered as you tried to implement your design. During the work, you might have found that elements of your design were unnecessary or overly complex; perhaps third-party libraries were available that simplified some of the functions that you intended to implement. If things were easier in some areas, then how did you adapt your project to take account of your findings?

It is more likely that things were more complex than you first thought. In particular, were there any problems or difficulties that you found during implementation that you had to address? Did such problems simply delay you or were they more significant?

You can conclude this section by reviewing the end of the implementation stage against the planned requirements.

Chapter 4

Testing

Detailed descriptions of every test case are definitely not what is required here. What is important is to show that you adopted a sensible strategy that was, in principle, capable of testing the system adequately even if you did not have the time to test the system fully.

Provide information in the body of your report and the appendix to explain the testing that has been performed. How does this testing address the requirements and design for the project?

How comprehensive is the testing within the constraints of the project? Are you testing the normal working behaviour? Are you testing the exceptional behaviour, e.g. error conditions? Are you testing security issues if they are relevant for your project?

Have you tested your system on “real users”? For example, if your system is supposed to solve a problem for a business, then it would be appropriate to present your approach to involve the users in the testing process and to record the results that you obtained. Depending on the level of detail, it is likely that you would put any detailed results in an appendix.

Whilst testing with “real users” can be useful, don’t see it as a way to shortcut detailed testing of your own. Think about issues discussed in the lectures about unit testing, integration testing, etc. User testing without sensible testing of your own is not a useful activity.

The following sections indicate some areas you might include. Other sections may be more appropriate to your project.

4.1 Overall Approach to Testing

4.2 Automated Testing

4.2.1 Unit Tests

4.2.2 User Interface Testing

4.2.3 Stress Testing

4.2.4 Other types of testing

4.3 Integration Testing

4.4 User Testing

Chapter 5

Evaluation

Examiners expect to find a section addressing questions such as:

- Were the requirements correctly identified?
- Were the design decisions correct?
- Could a more suitable set of tools have been chosen?
- How well did the software meet the needs of those who were expecting to use it?
- How well were any other project aims achieved?
- If you were starting again, what would you do differently?

Other questions can be addressed as appropriate for a project.

The questions are an indication of issues you should consider. They are not intended as a specification of a list of sections.

The evaluation is regarded as an important part of the project report; it should demonstrate that you are capable not only of carrying out a piece of work but also of thinking critically about how you did it and how you might have done it better. This is seen as an important part of an honours degree.

There will be good things in the work and aspects of the work that could be improved. As you write this section, identify and discuss the parts of the work that went well and also consider ways in which the work could be improved.

In the latter stages of the module, we will discuss the evaluation. That will probably be around week 9, although that differs each year.

Annotated Bibliography

- [1] Tutorialspoint, "SDLC - Waterfall Model," https://www.tutorialspoint.com/sdlc/sdlc_waterfall_model.htm, 2019, accessed April 2019.

This web page is a simple breakdown of the SDLC software development methodology.

- [2] S. Palmer and J. Felsing, *A practical guide to feature-driven development*. Upper Saddle River, NJ: Prentice Hall PTR, 2002, 0130676152.

This book attempts to provide an in-depth guide to apply Feature Driven Development to a project by explaining the importance of roles, overall models and feature lists.

- [3] K. Beck and C. Andres, *Extreme Programming Explained: Embrace Change*, 2nd ed. Boston: Addison-Wesley, 2005, 0321278658.

This book provides an explanation of the practices and principles of Extreme Programming and gives an insight into the philosophy and motivations behind its creation. The book is authored by one of the original creators of the Extreme Programming methodology.

- [4] A. Alliance, "What is Extreme Programming?" <https://nodejs.org/en/>, 2019, accessed April 2019.

This is an entry in Agile Alliance's methodology glossary. It provides an easy to understand overview of Extreme Programming, adapted from literary pieces by Kent Beck and Don Wells

- [5] K. e. a. Burke, "Flask-restful," <https://flask-restful.readthedocs.io/en/latest/>, 2019, accessed April 2019.

Flask-RESTful is an extension to the Flask micro framework. It is written in python and can be used to quickly and easily build REST API's.

- [6] D. Hansson, "Ruby on rails," <https://rubyonrails.org/>, Feb. 2019, accessed February 2019.

Ruby on Rails is a web application framework for server-side use, it is written in Ruby. It will be considered as an alternative to Node.js to create the REST API and backend services needed for the App.

- [7] Various, "Node.js Foundation," <https://nodejs.org/en/>, Feb. 2019, accessed February 2019.

Node.js is an open source JavaScript runtime that can be used server-side. It will be considered as an option to build the REST API needed for the mobile app.

- [8] Node.js Foundation, "Express.js," <https://expressjs.com/>, Feb. 2019, accessed February 2019.

This is a web framework for Node.js, it will be considered as an option to build a REST API together with Node.js

- [9] Microsoft, "Asp.net," <https://dotnet.microsoft.com/apps/aspnet>, 2019, accessed April 2019.

ASP.NET is a cross-platform, open source framework designed to support the creation of web apps, services and APIs using .NET and C#. It is developed and maintained by Microsoft and is very prominent technology in industry.

- [10] PostgreSQL Global Development Group, "Postgresql," <https://www.postgresql.org/>, accessed April 2019.

PostgreSQL is a very well established, open source database management system for relational databases.

- [11] Oracle Corporation, "Mysql," <https://www.mysql.com/>, accessed April 2019.

MySQL is a database management system for relational databases widely used in industry.

- [12] MongoDB Inc, "mongodb," <https://www.mongodb.com/>, accessed April 2019.

MongoDB is a free and open source NoSQL database solution. It is document-oriented and uses JSON-like documents.

- [13] Square, "Retrofit," <https://square.github.io/retrofit/>, 2019, accessed April 2019.

Retrofit is a HTTP Client for Java (and by extension, Android). It is commonly used to consume REST APIs and serialize/de-serialize JSON objects into Java Objects.

- [14] ReactiveX, "rxjava," <https://github.com/ReactiveX/RxJava>, 2019, accessed April 2019.

rxJava is an implementation of the ReactiveX asynchronous programming API for Java. It implements the Observer pattern to allow asynchronous programming with observable streams.

- [15] Google, "Angular," <https://angular.io/>, 2019, accessed April 2019.

Angular is a frontend web framework developed by Google. It is TypeScript based and open source, it has an in-built HTTP client and various supports for Material Design.

- [16] Facebook, "React," <https://reactjs.org/>, 2019, accessed April 2019.

React is a Javascript based frontend web framework, it is developed and maintained by Facebook and similarly to Angular it is component based.

- [17] E. You, "Vue.js," <https://vuejs.org/>, 2019, accessed April 2019.

Vue.js is a frontend web framework that is based in Javascript, it is very versatile and is designed to be used in conjunction with other libraries.

- [18] JetBrains, "Teamcity," <https://www.jetbrains.com/teamcity/>, accessed February 2019.

Team City is another CI/CD tool for consideration, it is created by JetBrains; the same company who develops IntelliJ Idea, the platform on which Android Studio is built.

- [19] Travis CI, "Travis ci," <https://travis-ci.org/>, accessed February 2019.

Travis CI is a continuous integration tool that can be synced with github projects to create a build flow.

- [20] Jenkins, "Jenkins," <https://jenkins.io/>, Feb. 2019, accessed February 2019.

Jenkins is an open source continuous integration and continuous delivery tool in the form of an easily configurable server.

- [21] Docker Inc, "Docker," <https://www.docker.com/>, accessed February 2019.

Docker allows for containerization of software. Containers are isolated and can be used to bundle tools, libraries and configuration files for simple and easy deployment. Docker works very well with CI/CD tools.

- [22] U. T. Inc., "Uber," <https://www.uber.com/gb/en/>, 2019, accessed April 2019.

Uber provides a platform that allows registered drivers to receive 'ride' bookings from customers. The platform also allows communication between the customer and the driver regarding the booking (either via in-app messaging or GPS).

- [23] M. N. Ltd., "mytaxi," <https://mytaxi.com/uk/>, 2019, accessed April 2019.

mytaxi is described as a 'taxi e-hailing' app. They operate in many major cities across Europe and allow customers to electronically book taxis with participating companies.

- [24] minicabit Ltd., "minicabit," <https://www.minicabit.com/>, 2019, accessed April 2019.

minicabit is an online service that allows customers to compare quotes for taxi journeys across the UK. It also provides support for making taxi bookings.

- [25] K. Auer and R. Miller, *Extreme Programming Applied: Playing to Win*. Boston;London: Addison-Wesley, 2002, 0201616408.

This book is part of the XP Series, it is described as a pragmatic guide to getting started with Extreme Programming. This book will provide guidance on how to apply the important principles and practices of XP in this Project.

- [26] K. Duuna, *Secure Your Node.js Web Application*. Dallas: The Pragmatic Bookshelf, 2016, 1680500856.

This book provides guides and best practices to improve the security of Node.js web applications. It provides tips for creating robust database calls, user authentication, and session management.

- [27] Mills, C. et al, "Express web framework (node.js/javascript)," https://developer.mozilla.org/en-US/docs/Learn/Server-side/Express_Nodejs, Dec. 2018, accessed February 2019.

This is a user-created guide to using Node.js and Express.js, it is a resource that would be very useful if Express.js/Node.js were used to build the REST API.

- [28] C. Sevilleja, "Express web framework (node.js/javascript)," <https://scotch.io/tutorials/build-a-restful-api-using-node-and-express-4>, Apr. 2014, accessed February 2019.

This is a tutorial for building REST APIs using Express.js, it provides an introduction to routing using Express.js 4 and the use of middleware.

- [29] Salesforce, "Heroku," <https://www.heroku.com/>, accessed April 2019.

Heroku is a cloud platform that has support for deploying many web applications, including those written in Javascript, Python, and Ruby.

- [30] Amazon, "Aws," <https://aws.amazon.com/>, accessed April 2019.

AWS is owned by Amazon and provides on-demand cloud computing platforms on a pay-as-you-go basis. Allowing servers to be spun-up and deployed very easily, also allowing fine grain control over resources.

- [31] Nginx Inc, "Nginx," <https://www.nginx.com/>, accessed April 2019.

Nginx is a web server ideal for deploying REST APIs, as it can double up as a reverse proxy.

- [32] Adobe, "Adobe xd cc," <https://www.adobe.com/uk/products/xd.html>, accessed February 2019.

This is an user interface design and prototyping tool made by Adobe, there are material design expansions available. These can be used to quickly create extremely accurate Android Application prototypes.

- [33] Fluid UI, "Fluid ui," <https://www.fluidui.com/>, Feb. 2019, accessed February 2019.

Fluid UI is a web-based user interface design tool. Similarly to Adobe XD, it too has material design UI packages.

- [34] "Data protection act 2018," <http://www.legislation.gov.uk/ukpga/2018/12/contents/enacted>, May 2018, accessed February 2019.

This act controls how personal information is used by organisations, businesses or the government. It is the UK's implementation of the General Data Protection Regulation (GDPR)

Appendices

The appendices are for additional content that is useful to support the discussion in the report. It is material that is not necessarily needed in the body of the report, but its inclusion in the appendices makes it easy to access.

For example, if you have developed a Design Specification document as part of a plan-driven approach for the project, then it would be appropriate to include that document as an appendix. In the body of your report you would highlight the most interesting aspects of the design, referring your reader to the full specification for further detail.

If you have taken an agile approach to developing the project, then you may be less likely to have developed a full requirements specification. Perhaps you use stories to keep track of the functionality and the 'future conversations'. It might not be relevant to include all of those in the body of your report. Instead, you might include those in an appendix.

There is a balance to be struck between what is relevant to include in the body of your report and whether additional supporting evidence is appropriate in the appendices. Speak to your supervisor or the module coordinator if you have questions about this.

Appendix A

Third-Party Code and Libraries

If you have made use of any third party code or software libraries, i.e. any code that you have not designed and written yourself, then you must include this appendix.

As has been said in lectures, it is acceptable and likely that you will make use of third-party code and software libraries. If third party code or libraries are used, your work will build on that to produce notable new work. The key requirement is that we understand what your original work is and what work is based on that of other people.

Therefore, you need to clearly state what you have used and where the original material can be found. Also, if you have made any changes to the original versions, you must explain what you have changed.

The following is an example of what you might say.

Apache POI library - The project has been used to read and write Microsoft Excel files (XLS) as part of the interaction with the client's existing system for processing data. Version 3.10-FINAL was used. The library is open source and it is available from the Apache Software Foundation [?]. The library is released using the Apache License [?]. This library was used without modification.

Include as many declarations as appropriate for your work. The specific wording is less important than the fact that you are declaring the relevant work.

Appendix B

Ethics Submission

This appendix includes a copy of the ethics submission for the project. After you have completed your Ethics submission, you will receive a PDF with a summary of the comments. That document should be embedded in this report, either as images, an embedded PDF or as copied text. The content should also include the Ethics Application Number that you receive.

Appendix C

Code Examples

For some projects, it might be relevant to include some code extracts in an appendix. You are not expected to put all of your code here - the correct place for all of your code is in the technical submission that is made in addition to the Project Report. However, if there are some notable aspects of the code that you discuss, including that in an appendix might be useful to make it easier for your readers to access.

As a general guide, if you are discussing short extracts of code then you are advised to include such code in the body of the report. If there is a longer extract that is relevant, then you might include it as shown in the following section.

Only include code in the appendix if that code is discussed and referred to in the body of the report.

3.1 Random Number Generator

The Bayes Durham Shuffle ensures that the psuedo random numbers used in the simulation are further shuffled, ensuring minimal correlation between subsequent random outputs [?].

```
#define IM1 2147483563
#define IM2 2147483399
#define AM (1.0/IM1)
#define IMM1 (IM1-1)
#define IA1 40014
#define IA2 40692
#define IQ1 53668
#define IQ2 52774
#define IR1 12211
#define IR2 3791
#define NTAB 32
#define NDIV (1+IMM1/NTAB)
#define EPS 1.2e-7
```

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#define RNMX (1.0 - EPS)

double ran2(long *idum)
{
    /*-----*/
    /* Minimum Standard Random Number Generator      */
    /* Taken from Numerical recipies in C             */
    /* Based on Park and Miller with Bays Durham Shuffle */
    /* Coupled Schrage methods for extra periodicity   */
    /* Always call with negative number to initialise  */
    /*-----*/

    int j;
    long k;
    static long idum2=123456789;
    static long iy=0;
    static long iv[NTAB];
    double temp;

    if (*idum <=0)
    {
        if (-(*idum) < 1)
        {
            *idum = 1;
        }else
        {
            *idum = -(*idum);
        }
        idum2=(*idum);
        for (j=NTAB+7; j>=0; j--)
        {
            k = (*idum)/IQ1;
            *idum = IA1 *(*idum-k*IQ1) - IR1*k;
            if (*idum < 0)
            {
                *idum += IM1;
            }
            if (j < NTAB)
            {
                iv[j] = *idum;
            }
        }
        iy = iv[0];
    }
    k = (*idum)/IQ1;
    *idum = IA1*(*idum-k*IQ1) - IR1*k;
    if (*idum < 0)
    {

```

```
    *idum += IM1;
}
k = (idum2)/IQ2;
idum2 = IA2*(idum2-k*IQ2) - IR2*k;
if (idum2 < 0)
{
    idum2 += IM2;
}
j = iy/NDIV;
iy=iv[j] - idum2;
iv[j] = *idum;
if (iy < 1)
{
    iy += IMM1;
}
if ((temp=AM*iy) > RNMX)
{
    return RNMX;
}else
{
    return temp;
}
}
```