Lock Smart: Lock Your Bike Safely
With This Hybrid App

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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
Acknowledgements

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Abstract

This report aims to outline the research, design and implementation of an application, which is capable of highlighting the areas in which bike thefts most often occur. This information is to be crowdsourced from the cyclists themselves and can be updated and viewed via hybrid smartphone app and website.
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Chapter 1 Introduction

Any reference to ‘bike safety’ in this report is a reference to the safety of a bike from thieves and not a reference to the safety of the cyclist. Similarly ‘theft’ is a reference to bike theft.

1.1 Motivation

Ireland is currently in the grips of a cycling revival. Between 2006 and 2011 the number of people cycling to work grew by 9.6% (2012, CSO). Many factors have been credited with the rise, the “Bike to work” scheme and increased awareness of personal health not least among them. The government plans to add €5 million of cycle paths in Dublin Bay this May (2015, Irish Times) adding to the existing 250km (2015, Dublin City Cycling) of cycle paths already in the city. This indicates a belief that this trend will continue.

Figure 1 - DublinCycling.com graph showing bike theft in Ireland (Dublin Cycling, 2015)

![Graph showing bike theft in Ireland]

This is widely considered a positive trend, as the increase in cycling has helped cyclists lower their carbon footprint and stay healthy. This has been shadowed by an unfortunate negative growth. The graph shown above demonstrates how between 2003
& 2013 recorded bike theft increased by 100%, exceeding the growth in cycling during that period.

The constant threat of theft has become an unfortunate reality for Irish cyclists, particularly those living in cities. While cyclists have been slow to react to the problem, there are signs that they are beginning to do so.

There has been a rise in the number of high quality locks in use, while combination locks and other low quality locks are slowly disappearing. Alternative methods of keeping bikes safe such as registration services, have also emerged, however these services focus more on stopping the resale and helping the retrieval of stolen bikes. Both of which occur after the theft.

- The four main aspects of bike safety are:
  1. What type of lock to use.
  2. Where you lock your bike.
  3. How you lock your bike.
  4. Bike-user registration.

Lock companies and registration services focus on the first and last points respectively. While a casual glance at a bike rack will indicate the lack of knowledge or worse apathy regarding proper bike locking procedure.

The third aspect of bike safety is the most variable, as even a well-educated cyclist with a good lock can lock their bike in a theft hotspot due to asymmetric information. While common sense plays a large part in judging where a bike should be locked, cyclists to a large extent, rely on their community to know where not to lock their bike. Cyclists are quick to share the location of any thefts with fellow cyclists and this information is trusted. This method is largely effective but also flawed, as it does not help cyclists in judging where to lock their bike when traveling to a location, which is little known to their community.
1.2 Background
As stated earlier, the previous attempts to use ICT for bike safety, which are examined in detail below, have focused on the fourth area of bike safety. Linking the bike to its owner can only help with bike retrieval and does little to avoid the theft itself. This is akin to the famous metaphor of a doctor treating the symptom and not the cause.
For the purpose of this project the developer examined the cycling community and how they communicate. The information needed to increase bike safety exists. It is held as a resource within each community, with each community having extensive knowledge of its area. There are many such well-informed communities, however these communities exist in isolation. While there is mingling between groups, this is of little consequence as there is no means of collecting and storing this information outside of the minds of the cyclists.
The Gardaí attempts to collect and make use of theft information but their attempts are hindered by the low percentage of thefts that are reported. In the US this figure is reportedly 80% (bikecalgary.org, 2015). As so few bikes are ever recovered there is a general feeling that there is little point filing a report, as it is time consuming and only 4% of stolen bikes are recovered (Irish Times, 2015).
Thus a means of using ICT to increase bike safety was deduced. If the information contained within the communities could be collected, stored and then presented to users from outside of their community then they would have a better chance of choosing a safe location for their bike when travelling outside of their community’s comfort area.

1.3 Existing Technologies
The developer’s first course of action was to examine the existing ICT bike safety services to see how they had approached the issue. Based on the findings of this research a series of requirements were identified.
1.3.1 BikeRegister.com

BikeRegister.com is a UK based, police endorsed registration website. The bikes appearance and frame number are stored in a database. This collection of data is unique to the bike and is a reliable means of identification. The police cross-reference this database upon recovering a stolen bike, to attempt to find the owner. While there are other services on offer this is the core concept, which permeates their various product offerings.

If a bicycle is stolen the owner inputs the address of the theft and flags the bike as stolen, the site then adds this information and the bike details to their stolen bike database. This information is then displayed on the site heatmap.

While this is a helpful site, its focus is on creating an association between a bike and its true owner. The heatmap is used to highlight general theft information and is not for use to highlight specific thefts on a local basis. This is a UK site, which is little used in the republic and is not endorsed by the Gardaí.

(Figure 2 - bikeregister.com’s heatmap function)
1.3.2 BikeRegister.ie
BikeRegister.ie is an Irish bike registration website, which is not affiliated with its UK namesake. Despite this it offers a similar if somewhat lesser service. The registration service is a mirror of the UK site and it is not tied to the Garda. However there is no visual display of theft information, it is merely a means of tying the bike to its owner. While it is recommended to partake in this free service it will not impact your ability to safely lock your bike.

(Figure 3 - BikeRegister.ie’s registration page)

1.3.3 Stolen Bikes-Ireland (Facebook)
Stolen Bikes-Ireland is a community driven Facebook page with over 2500 members. Stolen and recovered bicycles are posted on this page in the hopes that the community can assist in locating the bikes in the case of thefts and owners in the case of recoveries. While this page displays the community interaction, which the app will aim to harness, Facebook seems, an ill suited medium. Facebook’s’ linear “newsfeed” style does not make it easy to search for bikes which have not recently been stolen and further it is not immediately obvious which bikes are stolen and which are recovered.
1.3.4 IntegratedTrackers.com
Integrated trackers have taken a different approach; they offer a range of GPS enabled devices, which can be hidden in a bike in various ways. They work on the basic principle that once armed they contact the owner in the case of prolonged motion and communicate the location. While this is a creative solution it is not without its pitfalls and at over €100 the devices are not cheap. Despite their clever designs an equally clever bike thief may still recognise the device on sight and once again, they do not deter the theft itself.

1.3.5 Conclusion
There is relatively little focus on the third element of bike safety, as businesses have instead focused on lock technologies and to a lesser extent location systems where they perceive greater profits are to be made. The dominant service in Ireland (bikeregister.ie) is a registration service the failings of which have already been identified. BikeRegister.com, which is rarely used in the republic, is on the right path with its visual displays, but it stops short of the mark. By combining the strengths of these services a picture begins to emerge of an application, which could be of benefit to cyclists. It would combine:

- The community driven aspect of the social media sites.
- The ability to record user input.
- The graphic display of bikeregister.com.

The shortcomings of these sites also inspired potential characteristics:

- Easy to navigate and accessible on the move.
- It should be free in order to get the number of users required to build a basis of information.
1.4 Going Mobile
Smartphone penetration in Ireland has reached 59% (Irish Times, 2015). Increasingly we rely on our phones to complete our daily tasks. For younger generations in particular, the phone has become an extension of self. With 4G coverage increasing and price decreasing, it can be confidently stated that this proliferation will only increase.

(Figure 4 - Statistics from State of the Net issue 25, Summer 2012 - Digital advertising, smartphone growth, ecommerce)

This app is an opportunity for bike safety to be added to this growing list of tasks. Part of the allure of cycling is its accessibility, a cyclist simply grabs their bike, lock and hopefully visibility equipment and they are ready to go. This app will complement rather than oppose this simplicity. This app will allow the cyclist to quickly use their phone to check the area is safe before leaving the bike.

Smartphones use the internet in two main ways and the growth seen in mobile internet use has not been even between them. The growth has been staggered toward native apps. Mobile web apps, while more accessible are less used. With this is mind the decision was made to create a native app called ‘Lock Smart’.
1.4.1 Mobile research

Once it was decided to create a mobile app the developer began to examine various successful apps in order to extrapolate any design commonalities between them. Initially the developer looked at transport apps such as Hailo, Dublin Bus, Google Maps and Dublin Bikes, but later expanded the search to all manner of applications. The findings of the research aligned with the developer’s vision for the app. The most successful apps, tended to be the most simple. Several opened straight to their main function. WhatsApp and Snapchat are examples of this style. Other apps employed an alternative style where they initially opened to a homepage, which acted as a sitemap from which the user could easily navigate through the apps functions.
(Figure 6 - Screenshots of splash pages from various successful apps)
1.5 Requirements
The broad goals outlined above were then given further thought and a unified modelling language (UML) use case diagram was used to organise these goals and help define the system requirements. A set of functional and non-functional requirements was then decided upon.

(Figure 7 - UML Use Case Diagram)

1.5.1 Functional Requirements

- Heatmap
  - A heatmap will be the main way in which theft information is shown to the users. It must be capable of overlaying large amounts data on the map.
• Map Markers
  ○ These markers will be displayed on the exact location of the theft and when clicked will display the available theft information.

• Database Functionality
  ○ The database will be used to store the theft information. This database must be linked to the display functions and also be scalable.

• Information Page
  ○ This page will contain videos, which details how to properly lock a bike, what type of locks to use and other such useful information. There will also be information from individuals who are in a position to give helpful advice

1.5.2 Non-Functional Requirements

• Portability
  ○ The app should be compatible with as many handheld systems as possible. While the focus is on handheld devices the app should also be desktop compatible.

• Scalability
  ○ In order to create a map populated with enough information to be useful the app will have to be capable of handling large amounts of data.

• Extensibility
  ○ As the user base grows, more functionality may be required from the app. This should be taken into account in the design so that future extensions are possible and not unduly costly.

• Price
  ○ In order to gather the amount of user data required for the app to be useful the app will have to be free.
● Usability
  ○ The app should be very easy to use. With a clear and concise user interface (UI).

1.6 Technical Approach
In order to meet the portability requirement it was decided to build a hybrid app. This was achieved with Phonegap Build.

Phonegap is an open source framework, which allows for the creation of apps, which are platform independent. Under usual circumstances apps must be developed for specific platforms. However, Phonegap apps are built using HTML, CSS and JavaScript, which are all web development languages. This means that not only would the app only need to be developed once to fit all mobile technologies it could also be accessed by web browsers.

Icenium another Apache Cordova hybrid app developing framework was also considered. However it was decided against as it only supports iOS and Android platforms, while Phonegap supports iOS, Android, Windows Phone, Blackberry, Symbian and webOS.

While there are resources available to aid specifically in Phonegap Build development they are not substantial and the developer at times struggled to find information on the specific issue, which was being faced. However as the app was built using web languages there was a vast array of resources available to aid in development. Stackoverflow.com and W3schools.com were the main sources of guidance for this part of the development.

MAMP was used to store the database information. The AMP stack provides developers with three of the key elements of a Web server: a database, Web server and Web scripting software. In this stack Apache is the Web server, MySQL handles the database components, while PHP represents the dynamic scripting languages. While the “M” stands for Mac, which is the operating system of the laptop, used during development. Any PHP code in a requested file is executed by the PHP runtime. Due to this PHP is not supported by PhoneGap build. To avoid this issue AJAX was used to make calls asynchronously. MAMP is a widely used piece of software and extensive resources were available online, which were used to aid in installing and utilising MAMP.
Google Maps JavaScript API v3 allows users to customise Google maps and the information, which is displayed on them. It was used to input information programmatically and have it displayed on the map via overlays. The API is also platform independent. In order to implement the API resources were gathered from the official users guide and Stackoverflow.com. The web resources mentioned in this section were relied upon heavily as the developer had limited and in many cases no experience with the software and languages mentioned. There was a steep learning curve during the project with the initial stages spent gathering and skills and information and the latter stages implementing them.

1.7 Development Method
The incremental build model is an agile method of software development where the product is designed, implemented and tested, either one feature or one set of features at a time until the project is completed. It involves both development and maintenance. The product is finished when it satisfies all of its requirements. This model combines the elements of the waterfall model with the iterative philosophy of prototyping.

This method was a natural fit for the project. Due to the inexperienced developer difficulties would have arisen during debugging if complex features were added in in batches. The incremental nature of the changes made bugs easier to identify, as the build could be rolled back and the code returned to its original state, then the code added back in sections with echo commands until the section, which caused the issue, was identified.

There was a constant awareness of the time constraints, which were in place. In order to ensure that the final build was as close to a finished product as possible the features were added in descending order of importance. This development method allowed the developer to keep the project from straying from its requirements as after each build the project was reviewed.
1.8 Additional Information Gathering

A problem came to light during the initial stages of developing the app. In order for the app to attract users it would need to be populated with data. Conversely, in order to gather this information, the app would require users. The developer considered the possibility of incentivising the early users of the app to submit information and influencing their friends to also do so by offering a pro-version of the app. This idea was decided against as the app is built on a sense of community, where all are equal and this may compromise that. Monetary incentives were likewise ruled out, as the app will have no source of income until late in its development.

The solution to this problem was to create an online survey using SurveyMonkey.com. This survey would ask a number of pertinent questions directed at gathering bike theft information. In order for a survey such as this to be sent out by a Trinity student, the permission of the Ethics Committee is required. The inexperience of the developer was problematic here, forms were filled out incorrectly and mistakes were made in the documentation, which caused several setbacks. Once these problems had been amended the questionnaire was shared on social media. While this survey generated some usable information, the majority was not fit for purpose, due to the lack of detail given by users regarding the location of the theft. The usable
information has been stored in a table in the database for future use. This survey as well as the required documentation is contained in the appendix (Appendix 1). Additionally the safety information, which is displayed on the information page, was garnered during an interview with Trinity campus security (Appendix 2). The Ethics Committee approved this questionnaire at the same time as the survey. Campus security kindly agreed to an interview in the security office. Trinity campus security was chosen, as they are responsible for protecting trinities many bikes from Dublin’s thieves. And seen, as Trinity is the busiest spot in the city for bike thieves they are something of an authority on the subject. Particularly with their current ad campaign visible across campus.

(Figure 9– Trinity Campus Security Safety Campaign)
Chapter 2 System Design

2.1 Introduction
Once the core requirements of the project had been outlined the next step was to design the system architecture, which complimented these requirements. Once this had been achieved, designing a suitable user interface (UI) was the next port of call. This chapter will examine the outline, revisions and eventual implementation of these steps.

2.2 System Architecture
The figure below shows the system architecture for Lock Smart. This two-tier client server architecture was chosen, as the app does not require data manipulation, merely storage and display.

The client tier of the architecture is also known as the presentation tier. The core of this tier is the UI, which was created using HTML, CSS and JavaScript as explained below. As suggested by the name this tier defines what the user will see and how they will interact with the app.

The server tier, also known as the data tier, is responsible for the storage of information. In the case of this app the data tier is composed of MYSQL relational database management servers. The two tiers are connected via PHP. As PhoneGap is agnostic of back end technologies HTTP requests were used to facilitate this connection by making asynchronous calls to the PHP. These HTTP requests were made via AJAX, which produced XML, which could then be interpreted and presented by the JavaScript in the map-making classes.
2.3 User Interface
This section will outline the UI, which dictates how the end user interacts with and views the app.

2.3.1 UI Background
The usability requirement was central to the design. Users are acclimated to simple, intuitive interfaces. To the extent that if these prerequisites are not met it is difficult for an application to gain traction. Research indicated that many of today’s most popular apps allow for the operation of their main function directly from their splash screen with other functions accessed via widgets. This is, in the developer’s opinion an aesthetically pleasing option and looking at Snapchat, Hailo, Facebook messenger and Yahoo! Weather we see examples of this.

This was the initial design for the app. With the heatmap as the splash screen and other functions accessible by a collapsible menu. However it was later decided that this was not the best layout, having other functions linked via slide in menu did not offer the same clear structure as is offered by a menu splash screen, as seen in the Dublin Bus app and the AIB Mobile app. It was also decided not to let the user move between functions without returning to the homepage, as it was believed that this would stop the user from becoming confused and having difficulty finding specific functions.
This change of design indicates that while aesthetics are a component of the UI they are trumped by the usability requirement.

2.3.2 Mockups
Storyboards were used to move the envisioned designs from the developers mind to a physical form, this allowed for the developer to better understand the manner in which the pages would be linked. This method was chosen as while the online alternatives such as balsamiq.com are more polished, they require more time to create and thus are better suited when the developer is trying to communicate their ideas to a third party. Whereas this was an individual project and the developer only required rough and ready visual interpretation.

(Figure 11 - Early Storyboard map of app)
As each storyboard was completed the developer was able to see how the app would fit together. And begin to design the generic features, such as the deep blue colour scheme and return widget.

2.3.3 UI Design
There is sufficient variance in the design to necessitate that each window is outlined individually. There was one almost global feature, the return widget. This widget, which is represented as a green arrow in the top centre of the page, appears on every page bar the homepage.

2.3.3.1 Splash Screen
The heatmap was initially planned as the splash screen. The Heatmap appeared as it does currently does but with an additional menu widget in the top left corner. The menu was created when the page was loaded, but it was created minus the width of the menu to the left of the page so that it was off-screen. Once the menu widget was clicked, JQuery was used to move the menu its own width to the right, sliding it onto the screen and allowing the user access. As mentioned above this design was decided against. The developer felt that starting the user on the heatmap implied that this page was the focal point and that many users may simply avail of this map and not explore further in order to add their own information.

The splash screen design, which was decided upon is a minimalist menu displayed over a high quality picture of a curved city bike lane. This page allows the user to navigate to every feature offered by the app via clearly labelled widgets. There are also links to Facebook and twitter pages, which have not been implemented yet but will be a feature of the Beta release.
In order to create continuity between the desktop and mobile versions of the app the same background and menu were used for each. CSS was used to adjust the background to fit whichever screen size it is displayed on. Similarly, the menu is always displayed in the centre of the page. Initially issues arose as when loaded on a small screen such as that of a mobile device the homescreen appeared in the same dimensions as the desktop version. This caused the menu to be unacceptably small. The developer then considered creating two separate menus or using two different background pictures. The result presented itself when the developer discovered the viewport meta tag.

```html
<meta name="viewport" content="width=device-width, initial-scale=1"/>
```
This renders the page at the physical width of the device's screen and crops the edges of the display. The menu was redesigned to fit on the smallest possible screen so that while the menu is always displayed in its entirety the background image is cropped to fit.

2.3.3.2 Heatmap
The heatmap design was inspired by the simplicity of the map displayed on Hailo. This window allows the user to view all of the registered thefts as an overlay on an embedded Google map. The map is automatically opened with the users location as the centre point. This is achieved via the HTML5 geolocation function.

```
if(navigator.geolocation) {
    navigator.geolocation.getCurrentPosition(function(position) {
        var pos = new google.maps.LatLng(position.coords.latitude,position.coords.longitude);
        map.setCenter(pos);
    }, function() {});
} else {
    map.setCenter(altcenter)
}
```

(Figure 13 - initialises the map with the users location as the centre or if not possible and alternative point is used)

If the user is not using a HTML5 enabled browser or has declined to allow the app use their location the map is cantered on Dublin as it is envisioned that the majority of users will be based in this location. The map is identical to the standard Google Map, which most users are well acquainted with. They have access to the zoom and street view functions as well as the ability to change from map view to satellite view.

Through the SUS usability testing (which is examined in detail in a later section) the users found it hard to view the underlying map through the heatmap overlay. In answer to this a toggle heatmap widget was added that would allow the users to toggle the heatmap in order to view
the underlying image. The opacity of the heatmap was also lowered, and the colour scheme and gradient changed. Subsequent testing confirmed that this had amended the problem.

2.3.3.3 Detailed Marker View
This window is designed in a similar fashion to the heatmap in order to maintain cohesion as the user navigates the app. The underlying map has the same functions, default zoom and centre point as the heatmap map. It displays all of the registered thefts as markers on a Google Map. These markers are customised to show an image, which indicates that a theft has taken place. Once a marker is clicked an information window is opened, which contains the theft information that the user was willing to disclose.

Through this separate display the user is able to view not just the locations of the thefts but to get a feel for what style of bike was taken, under what circumstances and more importantly view the exact point where the theft took place.
2.3.3.4 Report Theft
The theft-reporting window was also built around Google Maps. It does not occupy the entire screen, but apart from this it has all of the same characteristics as the other iterations of Google maps. These features were once again enabled so that the user could pinpoint the exact location of the theft. Once they have done so they click the map on their chosen location, which creates a marker. If the user is not happy with this location they may click again to simultaneously delete this marker and place a new one.
Once this marker has been placed its location is passed into the form below.
Below the map are several input boxes, which the user may fill out if they wish to disclose further information regarding the theft. These boxes are contained with a div, which is used to uniformly style the form.
2.3.3.5 Safety Tips
The design for this window was based on the design for the menu page. The same image is used in the background with the information displayed in the centre of the page.
This page displays a video on Dublin bike safety sourced from dublincycling.com (available at https://www.youtube.com/watch?v=VVd9-0HhsfA). Beneath this video are the results of a question and answer session with trinity college campus security. Trinity college is the most active area in the city for bike thieves and campus security are in the midst of a bike safety campaign, so these individuals are well positioned to offer advice on the subject (Irish Times, 2015).
It was originally intended for this window to display information from several sources, but during testing users indicated that there was too much information and when questioned about their answers stated that sufficient information from one credible source would better suit their needs. They felt that the page looked cluttered and as the majority of experts offer the
same advice there was unnecessary repetition. They also stated that the video was particularly helpful as it shows real life examples of how to properly lock bicycles. This page can be very easily edited to reflect new information or extend to what is shown here. A monthly newsletter is one possible addition, which has been strongly considered by the developer.

(Figure 17 - Comparison of storyboard and final information page)
2.3.4 Summary of UI

As stated earlier usability was the requirement, which permeated every aspect of the UI design. The developer believes that the app has successfully embodied this requirement. The simple design where the user must return to the homepage to alternate function ensures that every function is immediately obvious on opening the app. While the commonality between each of the screens ensures that there is consistency in the user experience, which allows the user to quickly master the UI.

While the app changed during development it did not vary greatly from the original design. This can be credited to the developer’s research into existing app designs, efforts to emulate these and extensive use of storyboards early in the process.

The major issue encountered during development of the UI arose in ensuring that the app would retain a consistent feel on screens of various sizes. This was achieved through extensive use of CSS. Originally pixels numbers were used to locate the divs, which contained the elements, this had to be changed to percentages to ensure consistency between devices of different sizes. Early builds used floating positioning in order to position the composite elements of each page in relation to each other but this created difficulties with the return widget. This issue was eventually resolved by changing the div containing the widget to absolute positioning then assigning it ‘left:50%’ and setting the margin-left to minus half the width of the div. In this way the div would always be displayed in the centre of the page. This method was also used in the safety tips page.

Meta tags such as the viewport tag were also used to ensure that screen sizes were taken into account. W3schools and StackOverflow were used extensively in gathering the knowledge resources used to achieve the overall effect. The developer was often unable to get CSS to behave as expected, as it seemed that any change, which was made to one div’s position, would somehow affect another. This made it difficult to combine aspects from different resources, as was the case in this project, as each part of the formatting seemed to somehow affect another part. The result of this was that rather than having difficulty finding solutions to problems the problems arose in finding several solutions to several problems, which could operate in unison.
Chapter 3 Implementation

3.1 Introduction to implementation
This chapter will examine the main features of the app, which were developed using a combination of HTML, JavaScript, MYSQL, PHP, AJAX and XML. The software, which was used to facilitate this, will also be outlined. A similar style to the design chapter will be used where the implementation of each feature is examined separately. The features examined in detail will be the heatmap, map marker display and user marker insertion. The homepage and information page will also be discussed.

3.2 Software Used

3.2.1 Google Maps JavaScript API v3
Google Maps allows developers to embed maps on their pages, Google maps API’s allow them to customise these maps and the information displayed on them. The JavaScript API is the most customisable of these. It allows for the end user to input information programmatically and have it displayed on map via overlays. Also unlike the Android and SDK for iOS API’s the JavaScript API is platform independent. And as it is created using JavaScript it is compatible with PhoneGap. There is extensive documentation available to assist in the use of this API, both from Google and independent tutorials.

3.2.2 PhoneGap build
PhoneGap Build allows developers to create hybrid apps using HTML, CSS and JavaScript and deploy them to iOS, Android and Windows phones. This is achieved via its standards-based, open-source development framework. PhoneGap Build is an extension of Apache Cordova, which is a set of device APIs that allow a mobile app developer to access native device functionality. PhoneGap Build was chosen over PhoneGap, as it does not require any software installation until the app itself is installed on a device. The developer simply compresses the necessary files, including any images, into a folder which is then uploaded to the PhoneGap
Build website, where it is built. From there a QR code scanner is used to link the device to a site where the app is available for download. The use of PhoneGap created several issues, primarily due to its inability to execute back end languages.

3.2.3 Xcode
Xcode is an integrated development environment (IDE) containing a suite of software development tools developed by Apple for developing software for OS X and iOS. The IDE also supports web development languages. As Xcode is designed for OS X and iOS it does not offer a system for debugging the languages, which were used in this project. During implementation the echo command was used as a debugging tool. By strategically placing echo commands it could be seen to which point the code progressed before becoming stuck.

3.2.4 MAMP
The MAMP server stack provides developers with the four key elements of a Web server: an operating system, database, Web server and Web scripting software. In this stack Apache is the Web server, MySQL handles the database components, while PHP represents the dynamic scripting languages and the Mac operating system. This is a very popular server stack and many online tutorials were available to assist in its installation and use.

3.3 Software Technologies

3.3.1 HTML
Hypertext Markup Language, commonly referred to as HTML, is the standard markup language used to create web pages. The language allows for the creation of webpages and navigation between them.
3.3.2 CSS
Cascading Style Sheets (CSS) is a style sheet language used for describing the look and formatting of a document written in a markup language.

3.3.3 JavaScript
Once the pages had been created and formatted JavaScript was used to add the interactive features of the page.

3.3.4 MYSQL
MYSQL is a relational database management system. It was used to create and query the information database.

3.3.5 PHP
PHP is a general-purpose scripting language that is suited to server-side web development. Any PHP code in a requested file is executed by the PHP runtime. It was used to connect to the database.

3.3.6 AJAX
AJAX allows web pages to be updated asynchronously by exchanging small amounts of data with the server behind the scenes. This meant that it was possible to update parts of a web page, without reloading the whole page. AJAX was necessary to connect with the database as PHP is back-end agnostic.
3.4 Implementation

3.4.1 Creating the Database
In order to create the database the researcher compared several free to use servers such as serversfree.com. MAMP was chosen due to its excellent reputation and UI. While MAMP served well for the development of the app it only offers local connections to the server and a paid server will have to be used when the app is made available to the public during Beta testing. MAMP allowed the developer to create the database via the phpmyadmin UI. This UI can be implemented either by SQL commands or via the point and click UI. As time constraints were an issue, the developer opted for the point and click method. After viewing an online tutorial the developer was then able to create a basic table, which was updated regularly to reflect the needs of the maps.

This table contained columns, which would hold the information describing the thefts. These columns were tailored to hold the specific types of information. Each column was also given a size limit to stop users from entering data, which were too long and creating memory issues.

![Table design](image)

(Figure 18 - the table design)

These limits were somewhat arbitrary, apart from the columns, which held longitude and latitude values. These were originally truncated to four decimal places. This caused the marker to lose accuracy as can be seen in the graph below.
Decimal degrees distance places

<table>
<thead>
<tr>
<th>Number</th>
<th>Places</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1.0111 km</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.111 km</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.0111 km</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0.001111 m</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0.000111 m</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>0.0000111 m</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>0.00000111 m</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>0.000000111 cm</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>0.0000000111 mm</td>
</tr>
</tbody>
</table>

(Figure 19 - Accuracy of latitude and longitude values (Stackexchange, 2014))

Once this had been discovered the developer set the max value to 10,6, which is capable of holding decimal values to the order, which Google Maps produces.

The phpmyadmin UI was user friendly, which was of benefit to the developer, as during builds the information that was stored in the table as well as the table itself changed various times, which necessitated numerous edits to the table.

(Figure 20 - Screenshot of phpmyadmin)
3.4.2 Homepage
As this page would serve only to link the functions of the app, only HTML and CSS were required. An href link to each function is held in an unordered list. Each list item displays its function via html <p> tags. This allows the user to clearly perceive the destination of each link. Links to Facebook and Twitter were also added at the bottom of this list so that once the app is released it could be easily linked to its social media.

(Figure 21 - Shows how the list items are given a hyperlink destination and viewable title)

This design was beneficial as it allowed for simple edits to be made to the homescreen, as new pages were created, links to them were added to the list using the same template as the previous page.

The title and list were both contained within divs, which allowed for them to be easily edited with CSS. Both of these divs were also contained in another div, which allowed for uniform sizing and styling of the page. This CSS was linked to the page in the header using the link tag. This allowed for the page to be presented in a less cluttered fashion making it more human readable.
3.4.3 Creating the Data Overlay Maps
There were three major steps involved in the creation of each function. The initial two steps of connecting to the database and creating the underlying map, are common to both functions and are examined in detail below. The final stage of creating the overlays is where the difference lies. This will be examined separately for each function.

3.4.3.1 Creating the Map
The Google Maps JavaScript API allows for developers to create maps for their websites. The first step in doing so is to load the API. This was achieved by loading the “http://maps.googleapis.com/maps/api/js” script src tag in the header. The next step was to create a div, which would later contain the map. This div was then styled with CSS in order to ensure that the map was the correct size and appeared in the correct portion of the page. Once this had been completed the specifics of the map were dictated via JavaScript function, which in this case was called ‘initialise’. This function sets the zoom level and map type via variables native to the API. The centre of the map is then set to users location using the HTML Geolocation navigator.geolocation.getCurrentPosition function. As this is a HTML 5 method, which is only available on modern browsers an if else statement was used. This statement checks if the browser is capable of using the function, if it is not capable the centre of the map is set to Dublin, if it is capable the centre of the map is set to the location of the user.
The initialise function is then tied to an instance of the Google Maps map object so that once it is loaded it will be defined by these parameters and the map is placed inside the designated div using the `getElementById` function.

Outside of the initialising function a JavaScript event listener which waits for the page to load before calling the initialise function was added. This loading is done asynchronously as Google maps takes several seconds to load and the developer did not want to decrease the quality of the user experience by allowing the entire page an extended load time. The other information contained within the initialise function relates to the latter steps in creating the map and will be examined below.

W3Schools Google Maps Tutorial and the Google Developer suite provided the information necessary to create these maps.
3.4.3.2 Linking the Database
This was the area where the developer had the greatest difficulty. As stated earlier PhoneGap is backend agnostic, however in order to communicate with the database PHP was required. Where the earlier builds were able to read from the database and display the information, they would not function in the PhoneGap framework. After much research on StackOverflow and failed attempts to work around the problem the developer was able to find a similar method on the Google developers page which was modified to solve the problem. The database is read using PHP, which then translates the information to an XML document, which can be accessed with asynchronous JavaScript calls and passed into the overlays. The specifics of this process are outlined below.

The first steps were to connect to the server and database using PHP, query the table using SQL and then translate the response to XML.

The connections were created first, this was achieved through the mysql_connect and mysql_select_db commands. If statements were used to alert the user if there was difficulty connecting either.

Once the connections had been made an SQL query which selected all of the information from the database was assigned to a PHP variable. This query was then executed on the database through the mysql_query method. Once again an if statement was used to alert the user if there was a problem receiving the response.

There were several options available to the developer in order to make this file capable of handling the demands of both overlay making classes. The developer opted to execute a return all query on the database and have the information sorted by the JavaScript in their respective classes. In this way each class would handle its specific data requirements internally. This decision was in part made as it allowed for the developer to more easily understand exactly what each class was doing. This was helpful during debugging as once the PHP class was implemented and tested any errors experienced attempting to represent the data from the database on the maps was known to be internal to the class which was presenting the data. The developer now understands that this is bad practice and that the information should be sorted into two separate XML documents in the PHP file, this is covered in the future work section.
In order to use PHP’s DOM function to output XML, an XML document and parent node had to be created and then this node appended to it.

(Figure 24 - Creating the XML document and parent node then appending them)

Once this was complete the final step was to iterate through each tuple in the SQL returned from the earlier query, create a new child node for every tuple then assign the SQL values to XML nodes of an appropriate name, which were in turn children of this parent node. This is achieved inside a while statement, which looped through every value in the table. This XML is then accessed via XMLHttpRequest object from the file where the map is created. This AJAX object allows the code to retrieve a file from the same domain as the requested webpage. The method below assigns the XMLHttpRequest according to the browser, which is in use, the request variable then checks to see if the connection has been successfully made. If not, the function is halted and the user made aware. If successful the data is stored in the data variable by the callback function specified as an argument to the function.
function downloadUrl(url, callback) {
    var request = window.ActiveXObject ?
        new ActiveXObject('Microsoft.XMLHTTP') :
        new XMLHttpRequest;

    request.onreadystatechange = function() {
        if (request.readyState == 4) {
            request.onreadystatechange = doNothing;
            callback(request, request.status);
        }
    };

    request.open('GET', url, true);
    request.send(null);
}

(Figure 25 - AJAX call to get the XML file)

Once this function has been defined it can be called from within the map initialising function. The address of the PHP file is passed as an argument to the function, as is the response function, which stores the resulting XML in the local data variable. This variable can now be used to create the overlays.

Prior to the above method, the developer attempted to implement several methods with varying levels of success. One such method, was to read from the database using PHP then using a while, loop store the information in an array. Once the information was in an array the script of the file was changed to JavaScript. The following code was then used to assign a JavaScript variable the value of this array in the form of Json.
This allowed for the information to be read in the mapmaking classes. This method however was not accepted by PhoneGap and had to be retooled into the method shown above.

3.4.3.3 Creating the Heatmap

```javascript
for (var i = 0; i < markers.length; i++) {
    var point = new google.maps.LatLng(parseFloat(markers[i].getAttribute("lat")),
    parseFloat(markers[i].getAttribute("lng")));
    locations[i] = point;
}```
In order to create a heatmap an array of Google Maps locations is required. This was achieved by creating a for loop which iterates through every marker parent node contained in the XML. Once each node is selected the latitude and longitude node values associated with each marker parent node are used to create a point, which is then stored in an array. The final steps for creating the heatmap are contained in the initialise function so that they load simultaneously with the rest of the map. The heatmap overlay is created using the HeatmapLayer, which is contained, within the visualisation library. This library was loaded by appending ‘libraries=visualization’ to the end of address of the API when it is loaded in the header of the class. The array of points is given as an argument along with the other characteristics, which are specified when the heatmap is created. As mentioned in the design section the heatmap is not added to the map until the user clicks on the heatmap widget.

3.4.3.4 Additional Features
During testing it became apparent that the users were at times finding it difficult to view the map, which was displayed below the heatmap. In answer to this the opacity of the heatmap was lowered so that it became more transparent. A toggle heatmap widget was also created which allowed the user to switch the heatmap on and off.

```
function toggleHeatmap() {
  heatmap.setMap(heatmap.getMap() ? null : map);
}
```

(Figure 28- Toggle heatmap function)

This allowed the user to more accurately view the theft hotspots, where before it was at times difficult to decipher exactly which areas were being shown. The heatmap is in fact still created during the maps initialisation it is simply not assigned to the map until the toggleHeatmap() function is called.
3.4.3.5 Creating the markers
The creation of the markers was handled in a similar fashion. Once again the first step was to create a loop, which would cycle through every marker node in the XML and create a map location using the longitude and latitude values. However in this instance instead of creating an array, each node attribute of the parent marker was stored in a local variable, which was reassigned during each loop.

```javascript
var bicycle = markers[i].getAttribute("bicycle");
var address = markers[i].getAttribute("address");
var time = markers[i].getAttribute("time");
var day = markers[i].getAttribute("day");
var type = markers[i].getAttribute("type");
var frame = markers[i].getAttribute("frame");
```

(Figure 29 - Storing the XML node values in local JavaScript variables)

Once this was achieved another variable was given a string value, which was the concatenated value of each of the variables taken from the XML with an introductory string preceding each variable.

```javascript
var html = "<h4>Theft Details</h4>" +
"<b>Frame number: </b>" + frame + "<br/>" +
"<b>Style of Bicycle: </b>" + bicycle + "<br/>" +
"<b>It was Locked to: </b>" + address + "<br/>" +
"<b>Approximate Time: </b>" + time + "<br/>" +
"<b>Day of The Week: </b>" + day + "<br/>" +
"<b>Style of lock: </b>" + type;
```

(Figure 30 - Creating a string to describe the marker)
Once this was achieved the next step was to create a marker using the `google.maps.marker` method. In this way one marker was created for each point in the table.

The final step in this loop was to bind an info window to the point. This was done using the `bindInfoWindow` method. This method is passed the marker location, target map and string as arguments and creates an info window, which can then be accessed by the user by clicking the marker. This info window once opened, displays its string, which contains the theft details.

### 3.4.3.6 Conclusion

The developer struggled to create a connection between the database and front end, which PhoneGap would allow. However the heatmap and information window display were functional requirements for the app and so the developer persisted. The incremental build model of development allowed the user to slowly create this connection over the course of several builds. This allowed for a greater understanding of the underlying methodology, unfortunately the time consumed by added features one at a time and then finding out at a later date they were not compatible proved costly. This lack of compatibility would have been noticed earlier if the developer implemented all of the parts at once. This was not possible as the developer’s skill levels were too low and the problem would have been attributed to human error and time wasted searching for the error as a pose to finding a different set of methods.

### 3.4.4 Registering theft

This function can be split into three composite parts; creating the map, gathering the information from the user and storing the information in the database. This method involves creating a form below the map which then has the values pulled from it via JavaScript and then posted to a PHP file via AJAX. This file then connects to the database, takes the variables and stores them in the database via SQL statement. The creation of the map is done in the same manner as with the other map-based functions and is not covered below.
3.4.4.1 Gathering the information from the user
The manner in which the information is gathered depends largely on how the information is stored in the database. As the developer had difficulty storing the information and had to attempt to implement several methods, the manner in which the information was gathered had to change in keeping with this.
Throughout the methods the information was always input via HTML forms. This method was consistently applied in the tutorials and outlines viewed during the research.
Initially the user created a marker by clicking on the map. This marker had an info window bound to it similarly to before. Once clicked this info window opened and presented the user with a form in which they could input all of the information allowed by the database.
When the form was created inside an info window, the developer had trouble connecting to the form from inside the Google Maps API as the $("#submit").click(function() function, which loads the information from the form once the submit button is clicked, would not work. Once this problem was identified the developer was able to work around the issue by separating the form from the API. The div containing the map was shrunk and set to the top of the map with the form redesigned and set below the map. This presented a further issue as the API, which was now separated from the form, dictated the location of the marker.
In response to this the next iteration had the user click a point, which would create a marker and an info window. The info window would display the latitude and longitude of the point, which the user then had to manually type into the form below. This was not an acceptable input method. Finally the developer implemented the document.getElementById('ElementToHaveValueChanged').value('SetThisValue') method. This allows for the value of a HTML element to be set to the selected value. This was then combined with the event listener, which creates the marker. Now when the point is created the values of the inputs for latitude and longitude are set to that of the point using the above method. Once again this presented an issue as the user was capable of clicking into the input boxes and changing the values. Setting the inputs to readonly amended this. The rest of the inputs were given appropriate maxlength values to stop users from inputting values greater than the database could store as was previously occurring.
Another issue highlighted by the SUS Usability testing was that if the user clicked on the map several times they would create several points and although it was always the last point which had its location assigned to the inputs, the map look cluttered, which could lead to confusion. The developer discovered that even if these points were deleted the overlays remained on the map. Looking to the Google Maps developer’s page and the tutorial on marker deletion solved this. On creation the markers are now pushed into an array. When a new point is created all previous points in the array are set to null and then deleted. This solved the cluttering problem.

3.4.4.2 Storing the Information in the Database
The method used to store information in the database is to a certain extent the reverse of the method used to read from it. The crucial difference and the area where the difficulty arose were in using AJAX to pass the values to the PHP file. The developer spent a large amount of time attempting to implement solutions to this issue. Eventually the developer’s research provided a possible solution as an online tutorial explained how this could be achieved. The methods learned in this tutorial were repurposed in order to suit the needs of the app. JavaScript is used to first parse the values from the form once the user clicks the submit button below the input form. These values are then stored in a String separated by their title with an ampersand preceding it, a ‘1’ following it and ‘frame’ at the end of the string. This allows the PHP file to match values to variables and each pair from the next. This string is then passed to the PHP class via ‘POST’ AJAX call. Then in the opposite manner to the previous PHP file this String is broken back down into its composite parts and stored in PHP variables. These variables are then entered to the database via SQL query.
3.4.4.3 Conclusion
The developer spent an extended amount of time struggling with this issue. Initially attempting to reverse the methodology used to take information from the database and later attempting to read the HTML from inside the info windows. The final method is a combination of several tutorials and knowledge that was gathered while implementing unsuccessful methods.

3.4.5 Safety Tips Page
As this page’s only interactive functions were the return widget and video displays the primary issue in creating the information page was its layout. The developer had very little experience with CSS and due to this relied heavily on online tutorial with W3schools being particularly important.

There was initially trouble displaying the video as the developer was attempting to do so using the html video tags, it was later discovered that in order to display YouTube content it was necessary to include iframe tags.
Chapter 4 Evaluation
The purpose of this chapter is to examine the project as a whole. In order to achieve this requirements outlined earlier in the report are used as a barometer for success. First, the requirements, which were met are outlined, followed by an outline of the requirements, which require future work. Finally there is a discussion of the opportunities for future work, which would improve the project.

4.1 Successes
The current build of the app has successfully met all of its functional requirements. It is capable of collecting information from the user, storing this information in a database then graphically representing this information back to the user via two separate map overlays. It also has an additional general information page that clearly displays pertinent information. In this way this app is now capable of creating a public platform from which the second (Where you lock your bike) and third (How you lock your bike) aspects of bike safety can be improved.

A number of the non-functional requirements were also successfully met by the app. While the initial user testing highlighted a number of minor issues, these have all been addressed and subsequent testing has confirmed that the app now meets its usable requirement.

The app has been designed using common technologies and extensively commented so that another developer could with a minimal amount of effort grasp the underlying methods and begin to improve upon them. There are a number of viable improvements outlined below which could be implemented on the app. Also there is a wide array of functions available through the Google Maps API, which could be brought into the app and could improve the overall performance. These characteristics in aggregate satisfy the extensibility requirement.

This app has been created using only open source technologies and the developer is not seeking compensation for the time spent developing the app, so the app can be released free of charge. A small amount of advertising could be added to the app at a later stage in order to cover the price of hosting the app on a server and app store as well as the cost of using Google Maps (Which will not become a factor until the app reached 2,500 map loads per day)
In the developers research no previous project to create an app such as this has been attempted. The developer can happily state that the project has been a success overall. In spite of this not every non-functional requirement has been fully met. The details of this are discussed below.

4.2 Requirements, Which Require Future Work

4.2.1 Portability
While the app is capable of running on all of the devices, which were used during testing, and the documentation confirms that the app should operate on all major mobile devices and browsers. The developer did not have access to any windows devices meaning that it cannot be confirmed that the app will run on these devices. Also, as the developer did not possess an iOS developer’s licence, the app has not been tested on these devices either. This is covered in the future plans.

4.2.2 Scalability
While the architecture of this app is sufficient to support large amounts of traffic the methods, which are used to load from the database are inefficient. Every marker is loaded when the page is initialised, this is excess to the needs of the user and presents issued for larger data sets. This is also covered in future plans.

4.3 Future plans
As this app was created under duress from time constraints and the developers abilities a number of issues remained present in the current build. These issues are highlighted and resolutions proposed below.
4.3.1 Separate SQL Queries
In order to facilitate more efficient loading of the heatmap the PHP file will be amended to execute two SQL queries and create two XML documents. The second query will be `$query = "SELECT latitude, longitude FROM theft WHERE 1";` This will allow for a shorter XML document to be passed to the heatmap which will in turn shorten loading times. The AJAX calls which load the XML documents to the two display maps will also be slightly changed so that they load the correct document.

4.3.2 Map Bounded Loading
The greatest issue currently faced by the app is excessive loading of map markers. Currently all of the information is loaded onto the map regardless of what the user is viewing. This will lead to longer load times when creating the overlays as the database grows. There are several ways in which this can be amended. According to the developers research the best available method is to use Google Maps API’s Fusion Tables. However as the developer only became aware of this issue close to the deadline and this is an experimental technology, which does not have an extensive amount of documentation associated with it the developer was not able to implement the changes. Through this method the information would be loaded from the database and stored in a fusion table from there the user could add a method to the map initialising function which would gather the map bounds (the location on the map of the screen) and the zoom level in order to uncover what portion of the map which is being viewed and then only load points from within the viewpoint. The use of Fusion tables would also alter the way the map itself is created.

Alternatively map bounded loading could be implemented, without the use of fusion tables, this would be less efficient but still an improvement on the current system.
4.3.3 Picture Stored in Database
The developer would like to add another input to the form, which takes information from the user that, is capable of gathering pictures. This would be achieved by using the accept=image parameter. From here the picture would be treated in the same fashion as the other information and be available for viewing within the thefts marker on the view markers window. This would help cyclists to know exactly what type of bike thieves are targeting.

4.3.4 API Key
Once the app leads to over 2,500 map loads a day Google will demand payment. This will require an API, these are freely available on the Google developers page. This key is entered when the map API is loaded. The key will also allow for detailed metrics on map use to be made available to the developer.

4.3.5 Testing
While testing has been carried out, it has not been substantial. The developer would like to acquire an Apple Developer Licence and gain access to a windows device so that the app can be tested on these devices. Further the app has only been formally tested by a small sample of users. The sample size will have to be increased in order to fully test the app.

4.3.6 Login
Another issue, which is present in the current build, is the possibility that the thieves themselves could take advantage of the information. In answer to the developer would like to implement a login, using tables in the existing database. This login feature would then be the basis of several new features. Users could then be allowed to join groups, these groups could then choose to only share information with each other. For instance a college group could be created where only users with valid @tcd.ie emails were allowed to join could be created, this group would then allow Trinity student to privately pool their information.
4.3.7 Gardaí Involvement
Once the app has been completed the developer plans to contact the Garda in order to create a situation similar to that which bikeregister.com has created in the UK. The Gardaí could then benefit from this information as currently only a low percentage of thefts are reported. In exchange for this information they may be willing to allow the developer access to their theft information, which could be used to increase the accuracy of the app.

4.4 User testing
While the app was constantly tested by the developer this was not sufficient to ensure that the app satisfied the usability requirement. In order to gauge the usability of the app the developer used the SUS Usability Scale. This is a standard test for projects such as this. In order to allow this test to be fulfilled by individuals from outside the development team the permission of the Ethics Committee was once again required. The developer had learned from the previous difficulties and experienced significantly less difficulty in securing this permission the second time.

Once this had been achieved the developer engaged with individuals who had no previous experience with the app, which was installed on several different devices for the purpose of this test. The users were asked to register a theft and then select a safe location to lock their bike, without any help from the developer. They were then asked to fill out the SUS Usability scale shown below. Their answers were instrumental in designating this app’s usability. The original mean score was 63.9, which is below the average score of 68 (Usability.gov, 2015). This feedback led to a number of changes, which are outlined below, which resulted in the score moving to 79.3.
(Figure 32 - SUS Usability scores before and after initial user testing)
Chapter 5 Business Plan
This chapter will examine the potential for a business to be developed around the app. In order to achieve this the Business Model Canvas is used. This is a strategic management and lean startup template often used in developing business models. This chapter is completed under the assumption that all future work has been successfully completed.

5.1 Key Partners
While no partners are required early in the apps development, during its growth strategic alliances with organisations will be required.

The first group to be approached will be Trinity campus security. Their goodwill and access to campus wide advertising will be leveraged to give the app an initial boost in users. Campus security across the country will be used in the same manner.

The next group to be approached will be the Garda. The Garda have access to the countries largest database of bike theft. The developer will attempt to use this database to further increase the amount of information in the database.

The final group to be approached would be businesses such as Kryptonite and Abus who are known for their high quality locks and use of emerging technologies. They would be offered the opportunity to advertise on the page.

5.2 Key Activities
The key activities of the developer would be the maintenance of the app. The information, which is input by the users would also have to be reviewed to ensure that it is genuine. Once the integrity of the app is guaranteed the developer is responsible for engaging the parties outlined above.
5.3 Value Proposition
Bike safety is an area which cyclists are constantly aware of. The proliferation of locked bikes on our streets is testament to this. Cyclists grow attached to their bikes and in some cases have spent large sums of money acquiring them. This app offers cyclists another line of defence against bike theft. Both the maps and information offered contribute to this. Further this service is offered free of charge through a medium which is easily interacted with and commonly possessed.

5.4 Customer Relationship
This app will act as a trusted and crucially impartial advisor to its users. This will be achieved by constantly monitoring the information that is generated, the developer may do this initially, but in later stages a system will be put in place to do so automatically. By doing so the user can always be sure that what they are seeing is genuine information. This trust will need to be built over time.

5.5 Customer Segment
While this app is targeted at all cyclists, its main focus is on smartphone possessing, urban cyclists. This is the case as the majority of bike thefts take place in the urban setting and smartphones are necessary in order to access the app on the go.

The most important customers to the community will be those who have had a bike stolen and are willing to share this information. Contrary to what may be expected users who continue to lock the bikes in dangerous areas with improper technique and locks will be of the most benefit to the community as they will continue to generate new information

5.6 Key Resources
Information is the key resource of the app. The generation and representation of information forms the core idea on which the app is based.
5.7 Distribution Channel
Initially users will be reached through free advertising on campuses across the country. If this is successful the app will have been able to generate useful maps of large parts of the country. At this point the app could be taken to the government, who have already demonstrated their willingness to participate in safety schemes such as this through initiatives such as dublincycling.com. From this point the app could use the governments distribution channels to offer the app greater exposure to its target market.

5.8 Cost Structure
The costs involved with maintaining this app would be very low. As the developer would be willing to offer their time free of charge, the principle costs would be hosting the app on a server and AppStore as well as paying Google Maps. These costs would be paid by the developer in order to maintain the apps zero charge policy.

5.9 Revenue Stream
While customers may be willing to pay a small charge for this app once it has a sufficient amount of data at its disposal, this is contrary to the app’s aim of improving bike safety for all. Charging for the app may also dissuade not for profit groups such as colleges and government groups from offering their help.
Once the app has gathered a sufficiently large user base it may become an option to allow advertising from the businesses mentioned in the key partners section of this analysis. This would provide income to cover the costs of maintaining the app and reimbursing the developer for covering these costs during the earlier stages of development.
Chapter 6 Conclusion
This report has outlined the process of researching, designing and implementing an hybrid mobile and web app that uses ICT and crowdsourcing to assists cyclists in securely locking their bikes. The research conducted throughout the entirety of this project has confirmed that although isolated efforts have been made to implement aspects of the app they have not been packaged similarly and provided for the users in an app. The app as presented here is not the final build rather a high-fidelity software prototype. The app has undergone alpha testing and according to the findings of the SUS Usability Scale has enjoyed a mostly positive reception. A number of changes as outlined in the Future Work section will have to be implemented before the app is ready for Beta testing.

The development process that was undertaken has facilitated a large leap forward in terms of both the knowledge and the ability of the developer. As they had very little experience in this area and were somewhat hesitant to begin a project of this magnitude the project proved a catalyst for development.

The developer has enjoyed the challenge presented by a project and is proud to present their current build for the purposes of this report.

6.1 Difficulties faced
The above section may give the impression that that there were not times of difficulty, this is not the case. The developer struggled greatly at times and relied heavily on online resources to gather the information necessary to bring this project to its current state. Some of the major difficulties faced are examined below. These difficulties are segregated into high and low level difficulties.
6.1.1 High Level Difficulties
The greatest difficulties faced in developing this project were the developer’s abilities. A large amount of time particularly during the early stages of the project was spent on websites such as CodeAcademy.com and CodeSchool.com. While it would be untrue to say that this time was not of benefit, on reflection during the latter stages of the project it became apparent that the best way to learn to code, was to complete projects, not by follow online tutorials. These tutorials moved very slowly and were somewhat meticulous in their covering of the basics of each language, which while interesting and useful in a broader sense were not directly related to this project. This is a circumstance, which was unfortunately repeated throughout the project numerous times as the developer time and again found himself implementing a solution to a problem, piece by piece gathering each component from resources only to realise that they were moving in the wrong direction. This led to hours and sometimes days of work being spent building a solution which could not be implemented and in one unfortunate case an entire function.

This first problem leads directly into the next high-level difficulty, which was faced, time management. While the developer benefitted greatly from the use of the iterative build method, it was difficult to gauge at the outset of each build how long it would take to implement. Particularly while dealing with outside distractions. Regularly the projects deliverable dates had to be extended to allow extra time to finish a section where the developer was having difficulty. Compounding this was the often-overlooked difficulties, which occurred in attempting to combine separate functions.

6.1.2 Low Level Difficulties
The issues outlined above manifested in issues such as that, prior to the discovery of the heatmap overlay the developer envisioned using polygons to separate Dublin into its area codes with each area being coloured according to the number of markers contained within it. As the research conducted had not uncovered the points of information required for creating these polygons, they were in the process of being created manually by collecting the latitude and longitude values of the border of each area code using Google Maps and then creating
polygons based on these. Fortunately the research uncovered the implemented overlay before too much time had been spent.

The developer made the mistake of first implementing the functions and then later attempting to use PhoneGap Build. This proved problematic as the database functionality had been implemented using PHP, which is not supported by PhoneGap. This caused great distress for the developer, as initially they could not find the source of the error and then once the error had been found they were forced to roll back several steps of all database related functions in order to attempt to create an accepted function. More problems arose due to this, as when a solution was finally designed the developer could only implement it to read from the database. In order to store information into the database yet another solution had to be designed and implemented, this solution used AJAX similarly to the reading solution but not require the use of XML which was the source of the confusion.

Another issue, which caused the developer difficulty, resulted directly from lack of experience. As MAMP is a local server the database can only be accessed using a PHP file and the root localhost if MAMP is running on the same device as the call is being made from. During the majority of development this was the case and the developer did so. However once the developer began to use other devices to test the code the PHP files could not be accessed. After some research the developer realised the mistake. The files were being accessed using their local file names, this needed to be changed so that other devices could access the files. This was achieved by adding the IP and file location to the filename.

http://10.6.28.4:8888/untitled%20folder/Please/createxml.php

This created further problems as the developer noticed that the code would only sporadically work. Sometimes for days after being fixed. Eventually it was noticed that the IP was prone to changing from day to day, while using the college network. This would not have been a problem if the developer was more experienced.
Appendix

Appendix - 1 online survey

Has your bicycle ever been stolen in Dublin City?

Welcome to My Survey

TRINITY COLLEGE DUBLIN

INFORMATION SHEET FOR PROSPECTIVE PARTICIPANTS

I am a final year Business and Computing student in Trinity College. For my final year project I am building an app which will identify hot spots for bike theft in Dublin city. I am asking you to fill out this form, so that I can begin to populate my app, with accurate information regarding previous bike thefts.

I am familiar with the Data Protection Act and the College Good Research Practice guidelines.

You will be asked to complete a short unobtrusive survey. None of the questions are mandatory and you can exit the survey at any time without penalty. This should take no longer than 5 minutes.

Please do not be tempted to provide false information as a favour. False information could lead to an unreliable heatmap.

If enough participants are willing to provide reliable information we can begin to identify the worst spots in our city for bike theft.

Once the survey has been completed you are free to review you information and change any answer you are unhappy with.

If I discover any illegal activities, these will be reported to appropriate authorities.

You were selected as you live in Dublin city and can be relied upon to provide well founded information.

It is acknowledged that this study represent a possible conflict of interest because you may be a friend of mine or a relative. In respect of this I ask that you act with integrity if you take part, and I undertake to do the same as a researcher.

Copy this link to your browser in order to download a copy of the consent form:
dlewis.ie/consentform.docx
Has your bicycle ever been stolen in Dublin City?

INFORMED CONSENT FORM

TRINITY COLLEGE DUBLIN
INFORMED CONSENT FORM

LEAD RESEARCHERS: Aaron Martin

BACKGROUND OF RESEARCH: For my final year project I am building an app which will identify hot spots for bike theft in Dublin city. I am asking you to fill out this form, so that I can begin to populate my app, with accurate information regarding previous bike thefts.

PROCEDURES OF THIS STUDY: You will be asked to complete a short unobtrusive survey. None of the questions are mandatory and you can exit the survey at any time. This should take no longer than 5 minutes.

PUBLICATION: Your information will be displayed anonymously on the app.

Individual results may be aggregated anonymously and research reported on aggregate results.

DECLARATION:
I am 18 years or older and am competent to provide consent. I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me. I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity. I understand that if I make illicit activities known, these will be reported to appropriate authorities. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I understand that I may refuse to answer any question and that I may withdraw at any time without penalty. I understand that my participation is fully anonymous and that no personal details about me will be recorded. I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk. This form is available for download by emailing the lead researcher at the address given below. I have received a copy of this agreement.

Statement of investigator's responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

RESEARCHERS CONTACT DETAILS:
Email Address: aamartin@tcd.ie

1. Do you agree with these conditions?

- [ ] I agree
Has your bicycle ever been stolen in Dublin City?

None of the following questions are mandatory.

2. Have you ever had a bicycle stolen in Dublin City?

3. What style of lock was used?
   - U-Lock
   - Chain
   - Cable Lock
   - Other
   - I had No Lock

Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised.

4. Please enter the address where the theft took place. Format (Street name, postal code. e.g 123 fakestreet, Dublin 23)

5. On which day of the week did the theft take place?

6. What style of bicycle was it?

7. What time of day did the theft take place?
   - 5am - 10am
   - 10am - 3pm
   - 3pm - 8pm
   - 8pm - 5am
   - Not sure
Has your bicycle ever been stolen in Dublin City?

Thank you for completing this survey

While your input is greatly appreciated if you would like to discard your answers simply close this window now.

If you are happy to submit your answers please follow the prompt below, otherwise click the 'exit this survey' button on the top right of the window to exit without submitting.

Prev  Done

Powered by SurveyMonkey
Check out our sample surveys and create your own now!
Appendix - 2 Questionnaire for Campus Security

Questions

Each question is optional. Feel free to omit any question; however the researcher would be grateful if all questions are responded to.

● Is there a particular style of bicycle lock, which you would recommend?

● Is there a particular style of bicycle, which is more likely to be stolen?

● Could you outline how to properly lock a bicycle?

● Are there any areas of the city/campus, which are particularly active for bicycle thieves?

● Would you like to offer any general advice on bicycle security?
Appendix 3 - Application for Ethical Approval - Informed Consent form

TRINITY COLLEGE DUBLIN

INFORMED CONSENT FORM

**LEAD RESEARCHERS:** Aaron Martin

**BACKGROUND OF RESEARCH:** I am a final year Business and Computing student in Trinity College. For my final year project I am building an app, which will identify hot spots for bike theft in Dublin city. I am asking you to fill out this form, so that I can begin to populate my app, with accurate information regarding previous bike thefts.

**PROCEDURES OF THIS STUDY:** You will be asked to complete a short unobtrusive survey. None of the questions are mandatory and you can exit the survey at any time. This should take no longer than 5 minutes.

**PUBLICATION:** Your information will be displayed anonymously on the app.

Individual results may be aggregated anonymously and research reported on aggregate results.

**DECLARATION:**
- I am 18 years or older and am competent to provide consent.
- I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
- I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
- I understand that if I make illicit activities known, these will be reported to appropriate authorities.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded.
  - I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.
- This form is available for download by emailing the lead researcher at the address given below.
- I have received a copy of this agreement.

**Statement of investigator’s responsibility:** I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

**RESEARCHERS CONTACT DETAILS:**
  Email Address: aamartin@tcd.ie
INFORMATION SHEET FOR PROSPECTIVE PARTICIPANTS

● I am a final year Business and Computing student in Trinity College. For my final year project I am building an app, which will identify hot spots for bike theft in Dublin city. I am asking you to fill out this form, so that I can begin to populate my app, with accurate information regarding previous bike thefts.

● I am familiar with the Data Protection Act and the College Good Research Practice guidelines

● You will be asked to complete a short unobtrusive survey. None of the questions are mandatory and you can exit the survey at any time without penalty. This should take no longer than 5 minutes.

● Please do not be tempted to provide false information as a favour. False information could lead to an unreliable heatmap.

● If enough participants are willing to provide reliable information we can begin to identify the worst spots in our city for bike theft.

● Once the survey has been completed you are free to review your information and change any answer you are unhappy with.

● If I discover any illegal activities, these will be reported to appropriate authorities.

● You were selected as you live in Dublin city and can be relied upon to provide well-founded information.

● It is acknowledged that this study represents a possible conflict of interest because you may be a friend of a relative or mine. In respect of this I ask that you act with integrity if you take part, and I undertake to do the same as a researcher.
Appendix 5 - Application for Ethical Approval - Details of project

Title

Bicycle Theft Hotspot Identifier.

Purpose of the project

I am building this app for my final year project. Once completed it will help the cyclists of Dublin avoid the areas of the city in which bicycle thieves are most active.

Brief description of the methods and measurements to be used

I will be gathering my information via an online survey, using surveymonkey.

Participants

I will be posting the survey on my Facebook page, distributing it to my college course and also asking for my friends who have had their bicycles stolen in Dublin to complete the survey. I will also be approaching trinity security and the Gardai to ask for any information, which they are willing to disclose.

Information storage

Any information will be stored in a secure database for a period of 1 year.

Debriefing arrangements

Once the survey has been completed I will allow the user a chance to review their information and change any answer they are unhappy with.

Ethical considerations

It is acknowledged that this study represents a possible conflict of interest because you may be a friend of a relative or mine. In respect of this I ask that you act with integrity if you take part, and I undertake to do the same as a researcher.

Relevant legislation

The Data Protection Acts of 1988 and 2003 and College Good Research Practice guidelines are relevant. I will gather and store any information in a manner, which is compliant with this legislation.
TRINITY COLLEGE DUBLIN

INFORMATION SHEET FOR CAMPUS SECURITY

● I am a final year Business and Computing student in Trinity College. For my final year project I am building an app, which will identify hot spots for bike theft in Dublin city. I would like to ask you a few questions regarding bicycle safety. Your answers will be used to better inform cyclists of the safest way to secure their bicycles.

● None of the questions are mandatory and you can end the questioning at any time without penalty. This should take no longer than 5 minutes.

● Once you have answered all of the questions you are free to review you information and change any answer you are unhappy with.

● If I discover any illegal activities, these will be reported to appropriate authorities.

● You were selected as you are dealing with this issue on a day-to-day basis and are in the best position to offer sound advice.

● I do not believe that there are any conflicts of interest as it is in best interest of both An Garda Síochána and Campus security to encourage proper bicycle security.
LEAD RESEARCHERS: Aaron Martin

BACKGROUND OF RESEARCH: I am a final year Business and Computing student in Trinity College. For my final year project I am building an app, which will identify hot spots for bike theft in Dublin city. I would like to ask you a few questions about bicycle safety. Your answers will be used to better inform cyclists of the safest way to secure their bicycles.

PROCEDURES OF THIS STUDY: You will be asked to complete a short unobtrusive survey. None of the questions are mandatory and you can exit the survey at any time. This should take no longer than 5 minutes.

PUBLICATION: Your information will be credited to my organisation and displayed in the advice section of the app.

DECLARATION:
● I am 18 years or older and am competent to provide consent.
● I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
● I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications and credited to my organisation.
● I understand that if I make illicit activities known, these will be reported to appropriate authorities.
● I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
● I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
● I understand that my participation is fully anonymous and that no personal details about me will be recorded.
● I have received a copy of this agreement.

Statement of investigator’s responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

PARTICIPANT’S NAME:
PARTICIPANT’S SIGNATURE:
Date:

Statement of investigator’s responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

RESEARCHERS CONTACT DETAILS:  
Name: Aaron Martin  
Email: aamartin@tcd.ie  
Number: 0861020045

INVESTIGATOR’S SIGNATURE:
Date:
Title

Bicycle Theft Hotspot Identifier.

Purpose of the project

I am building this app for my final year project. Once completed it will help the cyclists of Dublin avoid the areas of the city in which bicycle thieves are most active.

Brief description of the methods and measurements to be used

I will be gathering my information via questionnaire.

Participants

I will be asking the members of my course to use my app as they have an understanding of the technology and spend significant time in the area in which my app is focused.

Information storage

Any information will be stored in a secure database for a period of 1 year.

Debriefing arrangements

Once the questionnaire has been completed I will allow the user a chance to review their information and change any answer they are unhappy with.

Ethical considerations

It is acknowledged that this study represents a possible conflict of interest because you may be a friend of a relative or mine. In respect of this I ask that you act with integrity if you take part, and I undertake to do the same as a researcher.

Relevant legislation

The Data Protection Acts of 1988 and 2003 and College Good Research Practice guidelines are relevant. I will gather and store any information in a manner, which is compliant with this legislation.

Appendix 10 - Results of SUS Usability survey - before changes
### Appendix 11 - Results of SUS Usability survey - after changes

<table>
<thead>
<tr>
<th>Question</th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
<th>Participant 4</th>
<th>Participant 5</th>
<th>Participant 6</th>
<th>Participant 7</th>
<th>Participant 8</th>
<th>Participant 9</th>
<th>Participant 10</th>
<th>Participant 11</th>
<th>Total beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I think that I would like to use this system frequently</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2. I found the system unnecessarily complex</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3. I thought the system was easy to use</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>4. I think that I would need the support of a technical person to be able to use the system</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5. I found the various functions in the system were well integrated</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. I thought there was too much inconsistency in the system</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. I would imagine that most people would learn to use this system very quickly</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>8. I found the system very confusing to use</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9. I felt very confident using the system</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10. I needed to learn a lot of things before I could get going with the system</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>2</td>
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<td>1</td>
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**SUS Score**

<table>
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<tr>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
<th>Participant 4</th>
<th>Participant 5</th>
<th>Participant 6</th>
<th>Participant 7</th>
<th>Participant 8</th>
<th>Participant 9</th>
<th>Participant 10</th>
<th>Participant 11</th>
<th>Total beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>28</td>
<td>27</td>
<td>28</td>
<td>33</td>
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<td>34</td>
<td>32</td>
<td>32</td>
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</tr>
</tbody>
</table>

SUS Score: 70.31/100

Total beams: 34
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