

NAMIBIA UNIVERSITY OF SCIENCE & TECHNOLOGY



**FACULTY OF COMPUTING AND INFORMATICS
DEPARTMENT OF COMPUTER SCIENCE**

**Designing a mobile application to increase open data
awareness and consumption in Namibia: A best practice
example of public transportation in Windhoek**

THESIS PRESENTED FOR THE RESEARCH PROJECT IN FULFILMENT
OF THE DEGREE OF MASTER OF COMPUTER SCIENCE AT THE
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Project Thesis Submitted: 16th September 2016

DECLARATION

I, Lameck Mbangula Amugongo, born on the 9th of July 1992 at Ehenye, Oshana region, Namibia, hereby declare that the work contained in the Thesis for my Master in Computer Science, titled: “Designing a mobile application to increase open data awareness and consumption in Namibia: A best practice example of public transportation in Windhoek”, is my own original work and that I have not previously in its entirety or in part submitted it at any university or other higher education institution for the award of a degree.

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Abstract

Over the past few years, there has been a paradigm shift in the way public data has been administered. The need to effectively manage public data has led to an increased adoption of open data initiatives by many governments. Open data is an initiative that advocates for data to be freely available for all to use and redistribute without restrictions. However, lack of awareness about opportunities and the benefits of open data among citizens, as well as the steadfastness of governments to control certain public data are some of the challenges facing open data initiatives. Nevertheless, high mobile internet penetration and the effectiveness of persuasive computing present an opportunity to alleviate these challenges and unleash open data potential. Furthermore, the power of persuasive technologies such as mobile applications to influence and change user behaviours present even greater opportunities to create awareness on a larger scale. Open data is not a new phenomenon, however to date only few studies on open data exist that emphasise on awareness and the usage of open data.

This study proposes a mobile application as a best practice example to increase awareness and persuade the government and citizens to change their attitudes towards open data and therefore increase the use of public data in Namibia. The developed mobile application is aimed at improving access to public transportation services within the City of Windhoek using official bus stops, schedule and routes data. Developed using the Android mobile development platform, the application was designed using the incremental software methodology, thus allowing space for useful feedback from potential users.

The obtained results show that the application was able to extract bus stops, routes, and schedule information from the database in real-time as well as display them to the user. However, the application could not track buses in real time.

Keywords: Mobile application, Open data, Awareness, Consumption, Public transportation, Persuasive computing

Acknowledgements

While pursuing my honours studies in Software development, investigating 'Computer aided detection and classification of prostate cancer from magnetic resonance images (MRI)', I had a challenge acquiring quality images needed to train the classifying algorithm. The frustration of not being able to acquire these images and domain knowledge from doctors did not only annoy me but also made me to start thinking of open data and how this will not only be helpful in sharing of data among personnel in the medical field but also generally enhance service delivery across many sectors. So I started thinking of ways on how we can realise this level openness, ease access to data and the information it provides. However, as I started engaging and talking about using open data to improve services and access to information, I realised that many people did not know what open data entails, thus I decided to focus my master's research in creating awareness and increasing open data consumption.

The journey was long and tough, with so many learning curves and sleepless nights. Now that it has come to this point of presenting my work, I would firstly like to thank the Almighty God for the courage and strength He provided to undertake this study. Secondly I would like to thank the Faculty of Computing and Informatics for the support and opportunity to carry out a study in this amazing field of open and big data. Specifically, I would like to thank my supervisor Prof Dr Jürgen Sieck for accepting to supervise my work, for the guidance, patience and for an opportunity to work as a student researcher at the University of Applied Science Berlin (HTW). During my time at HTW I was exposed to the Berlin public transportation system, which helped improve the solution we propose in this study. I would also like to thank Prof. Dr Hippolyte Muyingi, Prof Jose Quenum and Dr Norbert Jere for the great support and encouragement when my morale was low. Last but not the least, I would like to thank my research cluster members and colleagues, and the Namibia open data community for the fun, stimulating information sharing discussions and sleepless nights and weekends spent in the mobile lab during the open data innovation hackathons we hosted in the context of this study.

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List of Acronyms

ADB – African Development Bank

ADT – Android designer tool

API – Application programming interface

CSV – Comma separated variables

ER-D – Entity relationship diagram

GPS – Global positioning system

GUI – Graphical user interface

IDE – Integrated development environment

IoT – Internet of everything

JSON – JavaScript object notation

NSDI - National spatial data infrastructure

NSO – National statistics office

NFC – Near field communication

ODI – Open data infrastructure

OGD – Open government data

OSM – Open street map

RDBMS – Relational database management system

SDK – Software development kit

UML – Unified modelling language

UN – United Nations

XML – Extensible mark-up language

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1. Introduction and background

1.1. Introduction

Open data or open government as it is alternatively known is not a new concept, but it has gained a lot of momentum over the last few years, attracting interest from major governments and public institutions across the world. The idea of open data advocates and encourages for public data to be freely available for use, reuse and distribution by citizens without any imposed restrictions (Open Knowledge Foundation, 2012). Evidence suggests that open data has the potential to unleash innovation and transform every sector of the economy. The government can play a critical role in ensuring that stakeholders capture the full value of this information (Chui, Farrell, & Jackson, 2013). In 2009 after the election of President Obama, the US government, followed by the World Bank became the first institutions to release various open datasets which became accessible to all (Open Knowledge Foundation, 2012).

After initiatives by the US, more governments started launching initiatives to open up public datasets. Open data popularity has not only been confined to governments, but organisations such the United Nations (UN), World Bank and African Development Bank, which are increasingly becoming involved, investing millions of dollars to encourage governments to open up public data (Mutuku & Colaco, 2012). The rapid growth, interest and success of open data has been greatly accredited to the following reasons (Cabinet Office, 2012):

- 1) Access to data enables citizens to make informed decisions, enhance transparency, and hold government and public institutions to account.
- 2) Open data can be used to develop applications (apps) and services that transform the efficiency and improve the delivery of public services.

3) Open data keeps the citizens informed, which encourages vigilance among citizens and improves data collection via constant citizen participation in public discussions.

4) Creation of new economic, environmental and social opportunities that are of high value to the citizens.

Growing evidence (Cabinet Office, 2012; Cowan, Alencar, & McGarry, 2014; Reichman, Jones, & Schildhauer, 2011) strongly suggests that reasons why public data should be open outweigh those against open data, in that open data creates massive values for both government and citizens through unleashing of new entrepreneurial, social opportunities and saving money.

Despite the growing interest, some governments are still sceptical and reluctant to release public datasets. According to Open Data Research Network (2013) only 77 out of 196 countries published government or public data. Only 22 of the listed countries are from Africa; however more African countries are increasingly releasing their datasets. Despite this fact, open data faces numerous challenges; including lack of awareness on where and how to access and handily consume the data. Another issue facing open data is the question as to which data should be published without compromising national security and the privacy of citizens (Cowan *et al.*, 2014).

Over the past decade, we have seen major investments to facelift and enhance communication infrastructures in Africa (Aker & Mbiti, 2010). Fibre-optic submarine cables, Eastern Africa Submarine Cable System (EASSY) and West Africa Cable System (WACS) completed in 2010 and 2012 respectively connected several African countries to major international routes in Europe and Asia (M&C Saatchi Mobile, 2013). These developments have led to an African mobile 'renaissance' which has increased access to mobile networks, broadband services and skyrocketed mobile subscription.

With a growing number of mobile phones, Africa has one of the highest mobile penetration rates in the world, second to the Asia-pacific region, and the continent leads in mobile broadband growth (ITU, 2014). Mobile phones present a great opportunity to revolutionise how people interact, gain easy access to information, improve information dissemination mechanisms and enhance service delivery. Technology is fast growing and rapidly changing such that presently interconnected computing devices with powerful capabilities to influence a change in behaviour or attitude can be found everywhere and anywhere.

The new capabilities and the power of mobile devices enable developers to develop persuasive applications that transform data into useful information and incentives to change what users think and do. Although open data is proving to be an important phenomenon that is gaining significant attention; awareness and consumption of public data has been neglected. Yet, it is very important for citizens to be aware of the availability of public data in order to consume it by developing innovative solutions, or using products of open data. This study thus posits that a mobile application can be a best practice approach to create and increase awareness, change citizens' attitudes towards open data, and increase the consumption of open data through the development of service applications that keep citizens informed, promote accountability, transparency and innovation across all sectors.

This will be demonstrated by designing a mobile application that will serve as a practical example of how citizens can utilise open data to develop innovative solutions that solve societal challenges. The mobile application intends to serve as the bus service application for the city of Windhoek, providing the following functionalities:

- Bus and bus stops information
- Routes information
- Bus schedules and timings

- Alarm notification when user arrives at destination
- View places nearby the bus stop

The scope of this application will later be extended to enable bus users to buy bus tickets using their mobile devices. The following sections of this chapter aim to put the problem into context and what we achieved during this study.

1.2. Problem statement

Traditionally, public data has not always been available to the wider public online and in machine-readable formats; it has been limited to a few leaflets, books in many developing countries like Namibia and also available as static, unusable content on government websites in some developed nations (Fang & Sheng, 2005; Geiger & Lucke, 2012). However, as the desire for more transparency, participation and eagerness among citizens to be informed matured, a public outcry for more openness in governance emerged (Tydd, 2014). Today governments have also realized that opening up public data is best for both the government and citizens. Responding to this general call, the open data movement continues to encourage and persuade governments to release their public datasets in open, reusable formats which citizens can use, reuse and share as they wish.

Despite the great enthusiasm, the data revolution as it has come to be known, the open data phenomenon is still in its early days especially in developing countries such as Namibia where no open data policies exist; thus its true potential is yet to be achieved. Furthermore, access to data and the information it provides remains a huge challenge for many. Furthermore, vast variations exist in how the data is used in different parts of the world, where in some countries it is well utilized while in others it is not utilized, perhaps because it is non-existent or people do not know how to interact with it.

Up to date, the uptake of open data has been slow in developing countries, and Namibia is no exception (Open Data Research Network, 2013; Schwegmann, 2013). Moreover, Namibia does not have any open data policies or initiative of its own. This study intends on changing this by proposing a practical approach using a mobile app as a best way to increase open data awareness and consumption. This would help to realise value in open data. This is the aim, but this study and the app cannot prove that this has been realised, but rather a successful app was developed.

1.3. Research questions

Main question: To what extent will a mobile application be used to increase open data awareness and consumption?

Sub questions:

- 1) What are the incentives of open data?
- 2) What are the challenges facing the open data initiative?
- 3) How can challenges facing open data initiative be overcome in Namibia by using persuasive technologies such as mobile applications?
- 4) What are the best technologies, infrastructure and architectures for the mobile application?
- 5) How will the best practice example mobile application be designed?

1.4. Research objectives

The main objective of this study is to design a mobile application as best practice approach to increase open data awareness and consumption. The objectives of this study will be achieved by accomplishing the following sub-objectives:

- 1) Review the benefits and opportunities of open data.

- 2) Review challenges encountered by the open data initiative.
- 3) Explore and understand how persuasive technologies for example a mobile app can be used to create open data awareness and consumption.
- 4) Explore various technologies to design the best system infrastructure for the mobile application.
- 5) Design a prototype mobile application to ease access to public transportation in Windhoek, which will serve as best practice example of how open data can be innovatively used.

1.5. Research limitations

This study focused on open data awareness and consumption; hence policy drafting and privacy issues are not within the scope of this study but they were briefly touched on. Moreover, though open data is good and should be adopted as the norm, that can only be deviated from when dealing with citizens' privacy or when dealing with national security issues. Awareness is still lacking, increasing awareness and consumption faces the following constraints:

- 1) Lack of policies to govern the consumption of open data
- 2) Lack of legislature and frameworks to protect data privacy
- 3) Lack of technical enablers to make data open for all
- 4) Responsibility of citizens to make their own data available as soon as possible

These constraints create barriers for open data success; however, making data available and accessible to all creates a level ground for innovation and values for both citizens and government.

1.6. Research outcomes

The expected outcome or results of this study was to design a mobile application that uses public geolocation data. The application aims at increasing open data awareness and consumption in Namibia where many citizens and government officials are not aware of the value of open data. The mobile application intends on doing this by serving as a best practices example to show to citizens how they can transform mere data into something useful and of great value to society or in their communities. Moreover, the aim is to persuade government to release more public datasets, adopt open data policies that will ease access to public datasets, promote transparency, increase civic participation and spark innovation.

1.7. Research benefits

Open data is a massive phenomenon with the potential to unlock so many opportunities for both governments and citizens. However, this will not be possible if governments together with the citizens are not aware of these benefits, as well as how they can access and visualise the data into useful solutions. This study is of primary importance as it is aimed at increasing open data awareness and usage, which will promote the innovative use of open data to unleash new opportunities. This research work:

- 1). Eases access to public data and information
- 2). Encourages active citizen participation in civic affairs
- 3). Enhances the efficiency and effectiveness of government services through the creation of innovative applications
- 4). Empowers citizens with rich and valuable data and/or information
- 5). Establishment of an open data research cluster at the Namibia Business Innovation Institute's mobile lab in Namibia
- 6). Finally, the development of an open data portal for Namibia <http://demo.namopendata.com/>, which has been long overdue.

1.8. Thesis outline

Chapter 1 is the introduction and background of this study, which discusses the problem under study, highlights the research objectives, benefits and the impact that the study has towards the realisation of Open data infrastructure (ODI) in Namibia. The rest of this study is organised as follows. Chapter 2 is about the literature review; which provides an extensive critical review of different published materials and discusses the problem under study in detail. The literature review also explains what open data is; why we need it; and why opening up public data is good for society and economic transformation?

Chapter 3 discuss the methodology, methods and techniques followed to carry out the study; which include the design approach and data collection techniques used. Chapter 4 describes the requirements of the mobile application developed in the context of this study. Chapter 5 explains the design of the prototype application. In chapter six, we discuss how the application was developed. Thereafter, the performance of the developed prototype application was tested and evaluated in Chapter 7. The last chapter (Chapter 8) provides a brief summary and conclusion of the study. The chapter concludes by suggesting possible areas for future research.

2. Literature Review

In this chapter, the literature review begins by describing and explaining what open data entails. Thereafter the opportunities, benefits and challenges of open data are put into context. The chapter also reviews the fundamentals of persuasive technology, and how it may be applied to increase open data awareness and consumption. The chapter ends by reviewing existing open data frameworks, tools and other related work.

2.1 Overview

There are two common definitions of open data: “Data or content is open if anyone is free to use, reuse, and redistribute it, without any restrictions except conditions explicitly stated in the license” (Open Knowledge Foundation, 2012, p. 6). According to the Open Data Institute (2012), open data is any data that anyone can freely access, use, modify and share for any purpose, only subject at most to requirements that preserve provenance and openness. These two definitions of open data have some similarities in that they all refer to data as “open” when its use, reuse and redistribution (sharing) are at no cost. The first definition also talks about content; in other words, it is not only data that can be open but content as well can be open. The second definition also brings in the issue of free access, which is every important because for one to use, reuse and share the data, one first needs to have access to this data. Both definitions talk about licensing, which is very important to having the data open. They however do not give enough clarity as to what this license really implies.

Nevertheless, both definitions underline that the sharing of data should not distort the data, neither should it remove the openness nature of the data. So we can therefore combine these definitions to define data as data or content that is freely available for everyone to access, use, modify, and share without any constraints or limitations, excluding those mentioned in the license agreement. Open data is often mistaken for a transparent government and society; simply putting data on the portal or wherever to make it accessible to everyone does not change how the government

works, neither does it imply that someone is using the data to change lives and solve problems.

Although Namibia is lagging behind in terms of practical examples that make use of open data, in countries such as Kenya, we are seeing the transformation of open data into innovative solutions. Innovators and entrepreneurs in Kenya are using open data to develop numerous applications, ranging from apps that ease access to health related information and services to platforms that enable citizens to air their views, concerns and amplify their demand for better services (Mutuku & Mahihu, 2014).

These solutions are helping both rural and urban communities overcome some of the challenges they are facing. These solutions are not only making a difference in the lives of many Kenyans but also in the lives of citizens in the neighbouring countries and across the continent (Mutuku & Mahihu, 2014; Ncube & Ondiege, 2012). Many of these solutions can be replicated and contextualised to serve the Namibian nation. Namibia's first open data innovation hackathon intended to create awareness and increase the use of open data by encouraging citizens to develop useful applications and or solutions (Amugongo, Muyingi, & Sieck, 2015).

As a new technological trend, open data has attracted interest from major governments and public institutions across the world because of the great benefits and opportunities it presents to both governments and citizens. These opportunities and benefits are believed to have a great impact on the socio-economic values of countries, in the creation of new jobs, businesses and revenue (Cowan *et al.*, 2014). The next section of this literature review gives a detailed overview of how the concept of open data started and where we are in terms of open data worldwide.

2.2 Open data worldwide

The concept that public data should be made available for everyone to access, and thus use, reuse and distribute as they wish is not new in many developed nations. It has been around for quite some time, but it only

started gaining momentum and prominence in 2009 when President Barack Obama announced that the US government was going to open up most of its public datasets, to enable transparency and accountability in his government (New York State, 2013). This led to the renewal of the open data movement. Soon after President Obama's announcement, many governments, local authorities and public agencies began to make some of their datasets available.

Today, even institutions such as the World Bank, United Nations (UN) and the African Development Bank (ADB) are increasingly becoming more involved, supporting open data initiatives (African Development Bank, 2013; Kiringi *et al.*, 2010). More importantly, when the Millennium Development Goals came to an end in 2015, the United Nations Secretary General Mr Ba Ki-Moon appointed an independent advisory group to propose solid and tangible recommendations on bringing about tangible recommendations on how the data revolution can be utilised to bring about sustainable development (UN Data Revolution Group, 2014). Sustainable development is the focus of the post 2015 development agenda, which are future development goals that succeeded the Millennium Development Goals (MDGs), globally accepted targets to fight against poverty, hunger and disease, to protect the environment, enhance and expand education, as well as health, and to empower women.

Despite the enormous support and importance the open data movement is gaining, a noticeable difference exists between continents in terms of open data awareness and consumption (Open Data Research Network, 2013). The open data barometer findings further highlight that open data initiatives are strong in countries with strong political freedoms, and thus they tend to rapidly reach maturity. Yet, greater commitments and more action still need to be taken in order to increase advocacy, awareness and unleash the maximum potential of open data.

In Africa for example, only 12 countries of the 54 states had open data platforms launched by 2013 (Mutuku & Mahihu, 2014). However, this number may have increased over the years, especially with the

establishment of the National Statistics Agency in Namibia and South Africa alike. Nevertheless, a lot still needs to be done to address the fundamental challenges surrounding building blocks of national statistics agencies and public datasets, how data is produced, analysed and made accessible.

Although shattered by slow progress, Africa has been making strides, with governments releasing more public datasets for their citizens to consume (African Development Bank, 2013). Namibia, like her fellow neighbour South Africa, has created a powerful national statistics agency, with the mandate to collect, analyse and release official statistics (Government of the Republic of Namibia, 2011). The barometer findings credit this achievement, partly to the support by international donors and powerful civil society engagements. However, awareness about public data availability remains a challenge for many people in Namibia and across the world.

Nevertheless, open data success stories in developed countries, such as the United Kingdom and others show that key to these successes were the experiments of public-private models as new institutional models. Public-private partnerships were used to generate demand and increase access to open data (Center for Global Development, 2014). Developing countries therefore do not need to reinvent the wheel, thus they can use some of these lessons learned and open data best practices in order to leap frog in this domain.

Moreover, the fact that Kenya and Thailand ranked 22nd and 31st on the open data barometer (Open Data Research Network, 2013) is a clear sign that developing nations are catching up. Kenya's open government data (OGD) initiative was launched in 2011 by former President Mwai Kibaki. The initiative faced a lot of challenges in its early days such as securing the datasets from various government departments and creating awareness (Mutuku & Mahihu, 2014). Today, Kenya is one of the best practices example of how open data based solutions can change the lives of the citizens.

In order to use open data to inform and empower marginalised communities, we need to ensure that public data is reachable through a range of technical and non-technical intermediaries, for example radio, community centres and national data portals. Hence in this study we proposed a practical approach, illustrating how open data can be used to thus obtain value from the data. The next section of this literature review provides insight on new opportunities and benefits in this fast-growing field.

2.3 Opportunities

The Open data initiative embraces the promise of enhanced transparency, accountability, citizen participation and an endless window of opportunities across all sectors of the economy (Tim, Fernando, & José, 2013). In this section, these benefits and prospects are put in two categories: economic values and social values. The economic value sub-section elaborates on the economic incentives that open data has for both citizens and the government in terms of businesses and jobs. The second sub-section explains how open data can be used not only for planning but to solve societal challenges and issues; and thus improve the quality of life for the citizens.

2.3.1. Economic values

Often referred to as the untapped “Gold mine”, open data is envisaged to be economically rewarding for both the government and citizens, with an annual estimate of about US\$ 3 trillion worldwide, according to McKinsey and Company (2013). Although raw data is not valuable in its self, it is believed that by making public data accessible; it opens up a new window of opportunities for entrepreneurs and innovators who will create businesses that will reuse the data by transforming it into new solutions and products that solve problems facing society as well as to enhance services delivery. These businesses will contribute to the economic growth of countries in the form of new jobs and taxes to government.

Open data is also valuable for the government because intermediaries can use the data made available by governments to deliver services on behalf of the government. This reduces the workload for the government and facilitates to deliver services faster and cheaply; thus it helps to reduce costs usually incurred in the delivery of such services. For example, governments in Africa are often faced with the challenge of getting government services to widely spread out citizens, mostly in remote areas. However, making public data accessible presents opportunities for intermediaries to visualise the data into applications that deliver services for both the government and private sectors to citizens in remote areas.

SberBank, the oldest and largest bank in Russia began practising crowd sourcing, engaging the public and its staff in developing innovation (Sberbank, 2014). In 2011, the bank saved about 30 billion RUB, approximately US\$ 1 billion, from open innovation. There is a growing trend of innovators who are not only using public data to develop apps but to establish companies and enterprises that are creating jobs and wealth (Deloitte LLP, 2012; McKinsey & Company, 2013).

The Dutch ministry of Education published most of its education data online. Since this undertaking, the number of queries the ministry receives drastically dropped, thus this reduced the workload and the costs of the ministry (Open Knowledge Foundation, 2012, p. 9). Since the launch of Huduma, a platform where citizens can conveniently access all government services in Kenya, the concept of Huduma centres has not only transformed the delivery of services in Kenya, but the concept has become a best practices example to revolutionise how governments and public entities can best deliver services to the public. For the transformative and innovative way, Huduma Kenya received the United Nations Public Service Award (Mokaya, 2015). These are some examples on how public data is making things happen.

While there are many different ways in which open data is already delivering huge economic outputs, technology is becoming very disruptive and exponential; we do not know yet what amazing things will come with

this fast growth. However, we hope more exciting economic opportunities will become possible. In the next sub-section, we uncover the social values that can be realised with open data and thrilling social values that we will see in the near future.

2.3.2. Social values

In today's world, cities are faced with challenges of rapid urbanisation and stressed infrastructure, and data is placing new demands and creating new prospects for cities. Multi-national corporations such as IBM and CISCO have identified these enormous opportunities presented by data and openness. Therefore they partnered up with cities across the world to use advanced technologies, such as analytics, to help identify ways to tackle urbanisation challenges, improve sustainability and deliver better services to citizens (Harrison & Donnelly, 2011; IBM, 2011). Barcelona is one of the many cities that have signed an agreement with IBM to use IBM technology to effectively manage beaches, public transportation and parks within the city.

Although most of these great initiatives are happening in Europe, African cities are also catching up. In 2012, the city of Johannesburg signed a deal with IBM to outline a road map to improve public safety within the city and to overcome other challenges facing the city such as the shortage of resources and change the crime perceptions (IBM, 2012). Open data opportunities are endless, reiterating on the words of the founder of the Internet, Sir Tim Berners-Lee who said that "if people put data onto the web -- government data, scientific data, community data, whatever it is -- it will be used by other people to do wonderful things, in ways that they never could have imagined." (Berners-Lee, 2010). The majority of people in Africa live in rural areas, therefore to make data drive every aspect of their lives also, why not conceptualise smart villages. This is so because phones make more sense here in Africa, where more than 50% of the population live in rural areas and villages so to say (United Nations, 2014).

We do not need to set up any expensive new technology for this; the village council can for example make all monthly spending information

available for community members to view, scrutinise and comment. This is very helpful as community members become informed of how money in their constituency, village and or region is spent and they can direct how it should be spent through their feedback and comments. In India, the MKs is running a similar project, where they take the spending data of the state and paste it on village walls, and then invite villagers to come and comment. This data will for example say who is on the government pay roll, who has actually died, what are the bridges that have been built to know and many other things. But what is really important is to work together through civic engagement in order to save real money, participate and have access to that budget.

Open data is not only about policing in government, but it is also about co-creating governance. Spacehive in the UK for example is exploiting the power of crowdsourcing to raise money in order to revive and build public spaces. The platform allows anyone with great ideas: from parks, playground, bringing life to old buildings or creating new things to helping communities to get noticed by crowds of people, companies, agencies and most of all attract funding to realise these projects (Steinberg & DeMaria, 2012). We live in an open, interconnected world, therefore we are beginning to see more apps that make use of public data to improve the living conditions of people. Twitter for example is so successful because it has opened up its APIs for external developers to build software on top of twitter APIs (Makice, 2009).

2.4 Challenges

Despite the great success of open data, the initiative is not without challenges. Lack of open data policies, government reluctance to adopt open data guidelines and governance are regarded as some of the global challenges facing open data (Open Data Research Network, 2013b). In their work, Cowan *et al.* (2014) highlighted numerous issues facing open data; 1) Sustaining storage 2) Delivering and maintenance costs 3) Redundancy of the data to enhance performance. Some of the challenges or shortcomings discussed in this study are relative to certain countries,

regions or continents, while others are generic. In the following subsections, we discuss these challenges in detail.

2.4.1. Political-economic

Strong evidence Open Data Research Network (2013), and the Center for Global Development (2014) suggests that open data initiatives are strong in democratic countries where citizens are free to express their views and concerns. This is due to the fact that open data calls upon those who control the data, in most cases governments, to give up control on how the data is utilised, with the intention of holding the governments accountable for their actions. In countries plagued by corruption, politicians are often reluctant to make public data open because they do not want the citizens to be aware of the corrupt practices, as this will mean the end of their terms in office.

In most countries, national statistics offices are often departments in ministries, thus they do not operate independently. Lack of autonomy often lead to National statistics offices (NSOs) not carrying out their mandate as they ought to because they are subjected to political influences and power (Center for Global Development, 2014). Thus, it is very important for NSOs to function independently in order for them to carry out their mandate of ensuring that there is accurate and reliable data. Literature also points out that instability in many institutions the world over, especially in Africa is a major challenge because it undermines the legitimacy of institutions and often weakens institutional governance.

In the next section, we discuss funding as a challenge for open data initiatives.

2.4.2. Funding

Open data initiatives in many developing countries, especially in Africa are often insufficiently funded, making it almost impossible for institutions responsible for the collection and dissemination of data to carry out their mandate effectively (Center for Global Development, 2014). Although open data is regarded as free, its production is not free. Additionally,

publishing open data is not just a once off process; data needs to be kept up to date. For example, capturing transportation data requires occasional updates to capture new roads, stops and of course money. This money needs to come from somewhere; someone has to pay for the release, publishing and maintenance of open data. Two opposing camps exist; the first camp believes that the government should pay for open data, while the second camp believes that end users should bear the costs of open data.

In an attempt to answer the question of funding and sustainability, Pollock (2008) suggests three charging policy options from which governments can choose from: profit maximisation, cost recovery and marginal cost. Ferro and Osella (2013) suggest different models to enable profit oriented value creation from public data. They claim that open data is a public necessity which will produce diverse consumer values and generate more innovative products. Therefore, funding of open data initiatives is the responsibility of government. Open data is worth the investment of public spending because it will open up a new window of opportunities in terms of innovative products which will create new markets and increase government revenue through tax (Pollock, 2008).

The National Spatial Data Infrastructure (NSDI) policy document of the republic of Namibia, was passed in the National Assembly in March 2015, aimed at enhancing accessibility and affordability of spatial data, and thus promote its use. Moreover, the NSDI outlines that all current and historical spatial metadata and datasets should be made available to the public at no cost (Namibia Statistics Agency, 2015). The bill further emphasises that the custodian of the data can charge a fee which will be determined by the NSDI committee for the services rendered to develop spatial data for clients. Despite the need for open data to be funded and sustained, we strongly disagree that citizens should pay for requesting data - either spatial, environmental or any type of data. This is due to the fact that citizens as taxpayers already indirectly pay for this, so the government should ensure that enough money is allocated to ensure that good and

quality public datasets are available for citizens to consume and aid government plans.

The next section is about privacy issues and it highlights issues related to the infringement of user privacy. The section also further outlines possible solutions on how these issues can be overcome.

2.4.3. Privacy issues

In this digital era, protecting citizens' privacy is essential for maintaining an open society. Although the concept of open data is breath-taking, presenting enormous opportunities to keep citizens informed, deliver better services, creating new companies and jobs, questions pertaining to the extent we should open up data and how we protect the privacy of citizens amidst this data revolution are always raised. This section aims to critically review and underscore some of the important take away regarding data and privacy. In order to ensure that the privacy of citizens, families and communities are protected, it is essential for the government to devise policies, laws and legal frameworks that define how it protects private information.

Despite the genuine call for transparency, accountability in governance and all other positive benefits that open data intends to unleash, it is worth noting that not all public collected data should be accessible by everyone. In order to clearly put this into perspective, when dealing with open data, data is often categorised into three (3) broad categories (Open Data Research Network, 2013; Parker & Jain, 2015): 1) Infrastructural data – data about the state of the world and state of infrastructure - this includes transportation networks, weather data, environment data, national spatial data and alike; 2) Public service data – data regarding public activities of government or public institutions, such as budgets, location of public services, schools' performances statistics, public clinics/hospitals and other public facilities; 3) Personal data – this is the most controversial type, as it regards an individual so the nature of this type of data is personal such as medical records, sexuality and any other data that pertains to an individual.

Advocates of open data often claim that the benefits of open data outweigh the disadvantages. Furthermore, they also claim that privacy issues are just delay tactics and mere excuses from the government for it not to publish the data, especially the data that will scrutinise governance. However, as much as these claims are true, it is important to explicitly make it clear that as open data activists we are not calling for governments to open up their defence data, conversations between heads of states and governments or any other data that can compromise the security of the citizens.

Nevertheless, privacy concerns are legitimate, but they are holistic in nature. Despite the strong connection to technology, these issues are both policy and legal (Parker & Jain, 2015); thus they will not be solved by technology but through good enabling policies and legal frameworks. When constructing such policies, it is important to first classify the data that will be publicly accessed and used to avoid future controversies. The following section thus highlights some of the technical challenges facing open data.

2.4.4. Technical issues

Often treated as two separate topics, open and big data are closely related and they have so much in common (Gurin, 2014; Cukier & Mayer-Schönberger, 2013). As more public data is gathered, data volumes will gradually increase, resulting into lack of storage and presenting a new challenge of big data. Big data has over the years emerged as a huge challenge for many organisations and governments.

Another major technical challenge facing open data, often experienced by developers is the unavailability of open data in non-proprietary, reusable formats such as csv (comma separated variables) or xml (eXtensible markup language) as initially imagined by Bizer, Heath and Berners-Lee, (2009). In addition, inadequate infrastructure such as access to telecommunication in some areas, especially in rural areas is another pending challenge (Aker & Mbiti, 2010; ITU, 2014; M&C Saatchi Mobile, 2013). In addition, Cowan *et al.* (2014) highlighted numerous issues that

should be considered around open data such as sustaining storage, delivery and maintenance cost, and redundancy of the data to improve performance when data is being used.

Traditionally, relational database management systems (RDBMS) have been perceived as the single real alternative to storing large data and making it easily accessible to multiple users. Hence, relational databases such as MySQL, SQL Server and oracle are widely used to store structured data in many web and business applications today (Strauch, 2009). Over the years, other techniques such as XML store have emerged but it has not been widely adopted as RDBMSs.

In the last few years, NoSQL databases referring to non-relational databases have emerged as real alternatives to relational databases. First we can start off with a database such as Cassandra which is used by Facebook, CouchDB and MongoDB (Obasanjo, 2009). NoSQL databases are increasingly gaining prominence among developers because of their ability to rapidly reduce development time. Today, Firebase, a powerful backend service is fast becoming a convenient choice for data storage as it handles application hosting, user authentication and other backend services, thereby enabling developers to only focus on the application functionalities and building extraordinary experiences for the users.

Not all data custodians have the capacity nor the technical know-how or resources to manage their own open data portal (repository). Today we are increasingly seeing more publicly supported repositories by governments, municipalities and NGOs. Nevertheless, managing the diverse data on these portals still proves to be cumbersome and difficult with the conventional database management systems. In recent years we have seen the increasing adoption of NoSQL databases such as Cassandra, CouchDB and the like to complement traditional relational database management systems. Designed for massive data processing and storage, the use of NoSQL databases proliferated with the expansion of major internet companies such as Google and Facebook. These databases are helping these companies better deal with their diverse and

huge quantities of data, which conventional relational database could not manage (Moniruzzaman & Hossain, 2013).

Furthermore, critics of open data often claim that open data violates intellectual properties because it promotes the reuse and sharing of data without restrictions (Cowan *et al.*, 2014). They further claim that some users of open data do not give credit to authors and publishers for their work. As a counter argument to the above claim, the open data institute emphasises that open data is governed by a license that implies that the data is open, how the data should be used, and without this licence the data cannot be reused, neither can it be distributed (Open Data Institute, 2012). Today, companies are collecting a lot of data through daily transactions. For example, Google is building more data centres to store its huge pile of data and our smart phones are endlessly collecting data everywhere. There is thus a growing need to effectively and efficiently manage this data.

In this study, Firebase, which is a real time, scalable NoSQL cloud based database for storing data and building mobile and web applications was used. In Firebase, data is stored as JSON objects and synchronised in real time to every connected client (Firebase, 2015). Although the prototype described in this study is developed in android, in future, a cross platform application will be developed to cater for the other platforms such as IOS, windows phone, and all will share one database, enabling all users to receive the same information.

These are not the only challenges facing open data but many other challenges exist, which also need to be addressed. The following section explains the big data phenomenon and the opportunities it presents.

2.5 Big data

We live in a digital world, where volume, velocity and variety of the data never cease to grow. Although often treated as two separate topics, open and big data are closely related as governments, citizens and institutions continue to collect and publish more data on platforms such as portals for

everyone to access. The size of the data on portals increases and in the long run this will result into a huge silo of data. This unprecedented amount of data is referred to as “Big Data” because it is way beyond the ability of usual database systems to store, examine and administer (McKinsey & Company, 2011). Big data as a challenge is not only facing data portals or open data initiatives, but it is also facing many organisations as their daily transactional data increases and as they engage with customers they generate tremendous amounts of data. Big data has also become a huge research interest for big corporations, for example Google, IBM and Oracle just to mention a few, in their pursuit to seek solutions to their ever increasing data centres and leverage value from the data.

However, due to technological advancement, many no longer see storage as a huge problem because the prices of servers, storage and computing capacities have become very cheap over the years. According to SAS (2012), the price of one gigabyte of storage and computing power significantly slumped from US\$16 in 2012 to less than US\$0.27 today. Furthermore, many believe that computing technologies today are designed to store and process large volumes of data, therefore big data is no challenge. However, acquiring new storage might be cheap but building new data centres is a very expensive process due to the fact that these data warehouses need to be powered and air-conditioned. Nevertheless, a flood of data is flowing in from social networks and other interconnected systems into every sector of the economy, increasing the volume, velocity and variety of existing data. Thus it is important to mine the data before storing it, ensuring that only relevant data is stored.

Despite the challenges, big data has so much value; if well utilised a lot of products can come out of it, and companies such as Google for example gains billions of dollars from data by transforming data into information and or services that make it easier to access information (Milić, Veljković, & Stoimenov, 2012). By releasing public data, governments will enable citizens to similarly harness the power of data to develop applications and

or solutions that enhance the delivery of public services, uplift the living conditions of citizens and combat crime. In this regard, data mining is critical to make it possible to extract value and uncover patterns or associations in large sources of data.

A lot of literature on data mining exists, however only few studies describe data mining with regards to open data or e-government. In their work Milić *et al.* (2012) proposed a framework for open data mining to analyse the efficiency and extract useful information from a large amount of data. Defining a framework for open data mining is just one thing in the analysis of big public data. Although they mention data cleaning, a process where useless and meaningless data is removed, they did not describe or explain how this will be done. Data cleaning is a very important step in data mining because it avoids storing useless data; thus it reduces the amount of data that needs to be stored.

As more and more public data becomes available, data mining will increasingly continue to gain significant attention. Concurrently, advancement in technology further presents better ways to improve data mining in this digital age, overcomes big data challenges and unleashes unlimited opportunities. The next section of this literature review underlines how the persuasive nature of mobile computing can be explored to realise the true potential of open data. The following sections discuss fundamentals of persuasion, technologies and techniques applied.

2.6 Mobile computing and persuasion

2.6.1. Fundamentals of persuasive technology

The history of persuasion can be traced back to as far as the days of Aristotle, a great Greek philosopher and scientist. During this time in classical Greece, rhetoric was used during public speaking to persuade listeners (Aristotle, 2004). Affluent Greeks, usually males mastered the art of rhetoric and often exercised this skill to influence the opinions of citizens, encourage them to pursue a certain action and or change how they feel. During this time, the Greeks saw rhetoric and public speaking as

a way of maintaining Greek democracy. Today, rhetoric is still used often by politicians, and the best most recent example is during the Obama presidential campaign of 2008, candidate Obama used rhetoric such as “Yes, We can” to persuade voters. Throughout the 20th century, the art of persuasion advanced, primarily due to social psychology research on behavioural aspects aimed at understanding what motivates people to change how they think, do and feel.

In 2012, the Obama campaign team used data to persuade citizens to vote for President Obama although, the technique used was previously used by the George W Bush’s campaign in 2004. What the Obama campaign team did differently to what the Republicans used in 2004 was that they involved brilliant behaviour and political scientists to mine consumer data and they used these insights to direct campaigns to potential voters on a mass scale often through using the internet. President Obama used this information to understand voters’ needs and thoughts; especially the Latino community who were decisive in the 2012 elections (Cirugeda & Ruiz, 2013). President Obama incorporated this information in his speeches, which made him appealing to voters.

In recent years, new trends have emerged leveraging on the power of technology, with the intentions of influencing people and encouraging them to adopt certain behaviours. The study of persuasion technology is not new; it has emerged in the late 1990s (Fogg, 1998). Today, numerous scientific works exist, the prominent being the works of B.J. Fogg who is often referred to as the father of persuasion computing. There are two common definitions of persuasion technology. The authors Fogg (2003), and Oinas-Kukkonen, H., Harjumaa (2009) in their respective works define persuasion technology as interactive systems intended to change attitude and/ or behaviour. In one of his earlier works, Fogg extended this definition to provide more detail by defining the concept of persuasion as an “attempt to shape, reinforce, or change behaviours, feelings, or thoughts about an issue, object, or action” (Fogg, 1998).

Over the years numerous persuasive concepts have emerged, but not all of them are widely adopted like these two concepts: longer established persuasive technology and gamification. Generally, persuasive systems are built on assumptions that through technology human behaviours and attitudes may be influenced (Hamari, Koivisto, & Tuomas, 2014). However, humans are complex beings; therefore it is difficult to design a system that will change everyone's attitude because every person is different in their own way. So, for a system to be persuasive, it needs to incentivise the user. In other words, offer value to the user, either by improving the user's life style or providing any other benefits.

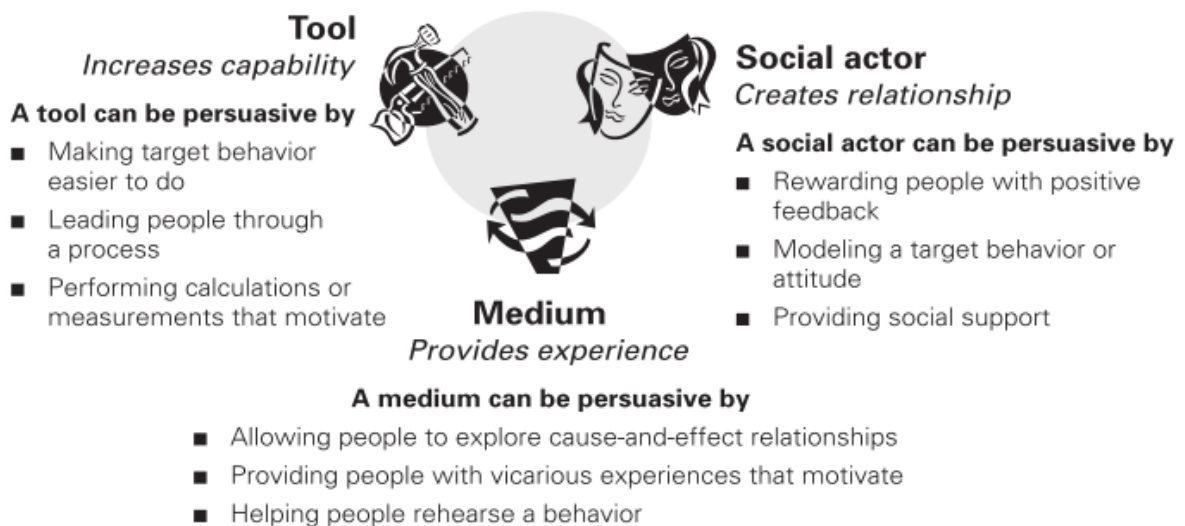


Figure 2-1 : Persuasive Technology model.

[Fogg B.G.]. (2003). Retrieved 30 October 2015, from: URL
 (<http://flylib.com/books/2/438/1/html/2/images/0201.jpg>)

Figure 2-1 above illustrates and explains the roles that computers play in our daily lives. According to Fogg (2003), computers can be used in three basic ways; as a tool, actor and medium. If one reviews the different computing products and or solutions available today, it is evident that most of them combine these three roles.

Although not initially created for persuasion, computers have over the years evolved from large mainframes to desktops, and they have become essential components in our daily lives, changing people's attitudes and

behaviours (Fogg, 2003). The ability of computers to change what people do, how they think and influence behaviour has made computers ubiquitous. Until a few years ago, the power of persuasion was only limited to laptops, main frame computers and or desktops. However, the emergence of powerful mobile devices such as mobile phones and tablets has made pervasive technology ubiquitous (Schmidt, 2015). Embedded with sensors, these devices gather data within the user environment, providing clues, services and information to help mobile users make informed decisions (Kimura & Nakajima, 2009).

Furthermore, these devices do not only have the power to persuade but they are smart, with abilities to gather data. Thus they present an opportunity for citizens not only to be consumers of data but to become data collectors as well. The following sub-section reviews some of the sensors and technologies embedded in mobile devices.

2.6.2. Embedded sensors in mobile devices

The widespread penetration of mobile broadband, high mobile subscriptions and advancement of social networks present opportunities that enable individuals to influence attitude and behaviour change on a large scale (Fogg, 2008). With its ability to influence behaviour change on a large group of people within a short period of time, mass persuasion has emerged as the new form of persuasion. In this study, mass persuasion was used to create awareness on the importance of open data, and the opportunities and benefits it promises to offer. The availability of smart technologies will enable the creation of smart and innovative citizens-led services, delivered in the most effective and efficient way (Mareels, 2009).

Macias, Suarez and Lloret (2013) affirm that ubiquitous computing has and will continue to drastically change how we apply computing and communication devices in our daily lives.

Ubiquitous computing has become a huge success, making it possible for smart objects to be everywhere. The abilities of these smart devices to gather data present an opportunity for citizens, not only to rely on

government data but to collect their own data which can be uploaded as open data on the portal, in order to be visualised and transformed into solutions. Up to date, numerous applications exist that capitalise on the power of persuasion to incentivise weight loss, assist users manage addiction and other health related problems (Larson, 2014).

Nevertheless, the ubiquitous nature of technology, together with the connectedness of these devices has enabled these “things” as they are often referred to to be remotely accessed from anywhere and everywhere, which poses a security concern. This therefore raises a need for better security mechanisms to protect data stored on these devices against undesirable access by hackers and other malicious people. Furthermore, these devices also inflict the users’ privacy as they will be everywhere even in places where the users do not need them such as the bathroom and bedroom.

In the next section, we describe some of the popular sensors in mobile devices in more detail.

2.6.3. Sensors

Our mobile devices today are programmable and come with powerful embedded sensors, for example: GPS, accelerometer, near field communication (NFC), digital compass, gyroscope, microphone, camera and many others. These allow for the possibilities of applications that make use of personal and community based information to enhance decision-making and improve the quality of life. These applications can be applied across multiple domains, such as health, safety, social networks, transportation and environmental monitoring (Lane *et al.*, 2010).

A GPS is a worldwide satellite, space based radio-navigation system operated and managed by the US air force. The GPS provides time and location information from anywhere, wherever you find yourself in the world (Trimble Navigation Limited, 2007). Although initially developed to improve the US military force, today watches, mobile devices and many

other gadgets are equipped with GPS sensors. It enables users and owners of these devices to easily locate places.

Another popular sensor in mobile phones is the accelerometer, initially developed to improve the user interface and the accurate use of a camera. This sensor is being used in many mobile devices to automatically determine the orientation of the screen between landscape and portrait. Thus it helps the phone to distinguish up from down. Unlike the accelerometer, the digital compass based on the magnetometer sensor feeds the device with the orientation angle based on the Earth's magnetic field. The gyroscope sensor aids the accelerator sensor by keeping track of the rotation of the device.

Although more than just a sensor, NFC (near field communication) is another technology found in mobile devices. This short-range radio communication based technology, establishes communication between two devices by bringing them into proximity or touching them together. Like Bluetooth, NFC enables two devices to exchange data such as contacts, images and even wirelessly pay bills. However, payments can only be made at places where NFC support is available.

Today, many mobile phones can be programmed, making it possible for developers to exploit and make use of these sensors and technologies. Widely spread platforms such as Android and iOS provide APIs, enabling developers, researchers and enthusiasts to explore the functionalities provided through these sensors. Some of these sensors explained in this section were used in the development of our best practice example mobile application.

However, as more technology comes of age, new ways of persuasion will emerge. We do not exactly know how this will look like at this point but we anticipate powerful interactive systems and self-tracking devices that will utilise data to personalise individuals by mashing up data into apps intended to influence the people's lifestyles and help them meet their goals on a daily basis.

In the next section, we review some of the common data mining techniques and algorithms.

2.6.4. Data mining and algorithms

The number of interconnected devices, including sensors, interconnected systems and mobile devices collecting and transferring data is posed to rapidly increase over the coming years. This volume of data that will be generated and transmitted through the Internet of everything (IoE) requires new techniques to manage, process and warehouse the data. Seeking for solutions to handle the anticipated unprecedented amount of data, studies in the field of big data mining and analytics has increased over the years.

Data mining refers to techniques and approaches used to extract useful information from large amounts of data (Daciuk & Jou, 2011). The extracted useful information or knowledge is then used to provide future insights and better information that is easily understood by the intended users. In order to discover patterns within the data, an algorithm based on neural network, support vector machine, decision tree or k-nearest neighbour may be used. Today we are increasingly seeing how companies like Facebook and Twitter are extracting useful information from the large data they hold not only to improve their services but also to offer the best experiences to their growing user base.

It is not only Facebook and Twitter that are mining the data of their users; today chain stores such as Walmart collect terabytes of data about what customers buy through their point of sales data mining terminals. Using this data, Walmart is able to discover patterns from the data, enabling them to give recommendations to customers based on products that were bought before a particular product (Dezyre, 2015). Moreover, Walmart also opens up these data to its suppliers, who use the data to uncover buying patterns of Walmart customers in order to identify new market opportunities (Zhang, 2010).

Even long before the term big data even became popular, the British Broadcasting Corporation (BBC), supported by SPSS launched the

Clementine tool, which enabled BBC to forecast their audiences' views that a given program will achieve its objectives if it is broadcasted at a particular time (SPSS, 1999). Clementine, a tool based on a neural network model was able to predict the audience shares with the accuracy of about $\pm 4\%$; although the achieved results were very good for the time, as the algorithm could in seconds match their expert program planners who have been trained for about 2 years. The complex nature of the TV programs made it difficult to use large data, thus only one year viewing data was used. Additionally, there were also occasions where the algorithm predicted wrongly by 4%. This could be because of the multi aspect nature of the TV programming data.

Data has multi aspects; thus data mining algorithms need to exploit all different aspects of the data in order to enhance the understanding of the fundamental network. However, this is lacking in many algorithms today as they only focus on one aspect of the data. In an academic research thesis, Papalexakis (2015) proposed a Tensor Analysis based, scalable, multi aspect unsupervised algorithm with the ability to mine diverse large data. The algorithm is able to extract multi aspect data from social media network, web and mine useful information from the data. Despite the great result obtained thus far, the algorithm still experiences efficiency and scalability challenges.

At present, Multi-nationals such as Google, IBM and Microsoft are increasingly investing huge amounts of money in machine learning research in the field of machine learning and data mining, using the learned classifiers to develop most of their products.

The application of big data mining is increasingly becoming the order of the day in many spheres of livelihood in health, transportation, climate change management and now in the creation of efficient cities. We anticipate big data analytics to even play a major role in every industry because of the insightful information companies can obtain from the data, which gives them a competitive edge over competitors. In the next section of this literature review, we assess how citizens across the world

innovatively combine computer science and open data to deliver better services, increase transparency, accountability and unleash economic values for themselves and their communities.

2.7 Open data consumption

There is nowhere in the world where there is a high need of quality data than in Africa (Center for Global Development, 2014). There is a huge need for good-quality data to improve governance, thus accurately plan, budget, and evaluate development activities. How this data is used is also equally important because data is meaningless if it is not visualised or transformed to make it meaningful and comprehensible. A trend of publishing data on the portal, with the hope of making it easily accessible and reusable is becoming a norm for many governments and agencies.

However, as much as open data portals provide essential support to ease access to public data, portals are just technical interventions and do not in any means imply that all citizens have access to the data or the information it provides. This is primarily because data on portals is only available on web based and mobile portals (Mutuku & Colaco, 2012). Therefore the citizens who may need the data the most might not have the means to access them or might be illiterate to read them, especially in countries with low literacy rates. Hence there is a need to raise awareness among citizens on what data can be acquired from portals, their usefulness and visualisation of the data into applications that will transform it into a format that is understandable to all.

Awareness can be created or increased in many ways, as Mutuku & Mahihu (2014) suggest that data will be more meaningful if it is analysed and visualized as applications that solve real needs. Davies (2012) supports this notion by saying that directly or indirectly, the end products of open data are applications. The high mobile penetration in the world has eased access to information and it has made mobile applications effective information dissemination tools (ITU, 2014). In Kenya, also known as Silicon Savanna, numerous mobile applications using open data have been developed over the past year and they have been making a huge

impact in the lives of rural and urban Kenya and beyond (Kiringi *et al.*, 2010; Ncube & Ondiege, 2012).

These solutions are making a major difference in the lives of ordinary Kenyans and citizens of other countries across the continent. The growing usage of open data has created valuable solutions. However, lack of awareness and the unavailability of open data in digital formats remains a major obstacle for open data innovation and products. As a step to alleviate this problem, Namibia's first open data innovation hackathon was held to engage policy makers to develop applications that advocate and promote open data. The hackathon brought together participants from both the private and public sector to persuade the government to publish more public datasets and promote the innovative use of open data (Amugongo *et al.*, 2015).

It is not only about consumption; the emergence of crowdsourcing tools such as Open Street Map (OSM) and the like are empowering citizens, enabling them to contribute by capturing and mapping useful information about roads, bars and many other amenities in their communities (Haklay & Weber, 2008). These data are used to power maps on apps, websites and hardware devices, for example GPS devices in cars and many others. Not so long ago, the mapping of earth was reserved to the highly skilled quantity surveyors. This has left large parts of the earth unmapped because there are inadequate resources to do so. In Windhoek for example, there are still many streets that are not available on Google maps or the information on Google maps is out dated. Inaccurate and out dated information about places makes it hard for people not familiar with the place especially tourists to get around.

As a way of practically illustrating how citizens can contribute with providing useful data, in this study OSM was used as an example. The researcher captured and updated the Namibia University of Science and Technology (NUST) (formerly Polytechnic of Namibia) map on OSM, mapping new buildings and updating missing information, even though the mapped area is not wide enough, compared to if this was done in the

whole of Windhoek. Nonetheless, now people can have access to accurate information of the Namibia University of Science and Technology map on their phones and other devices. Below are screenshots, illustrating the mapped campus map of the NUST on OSM.

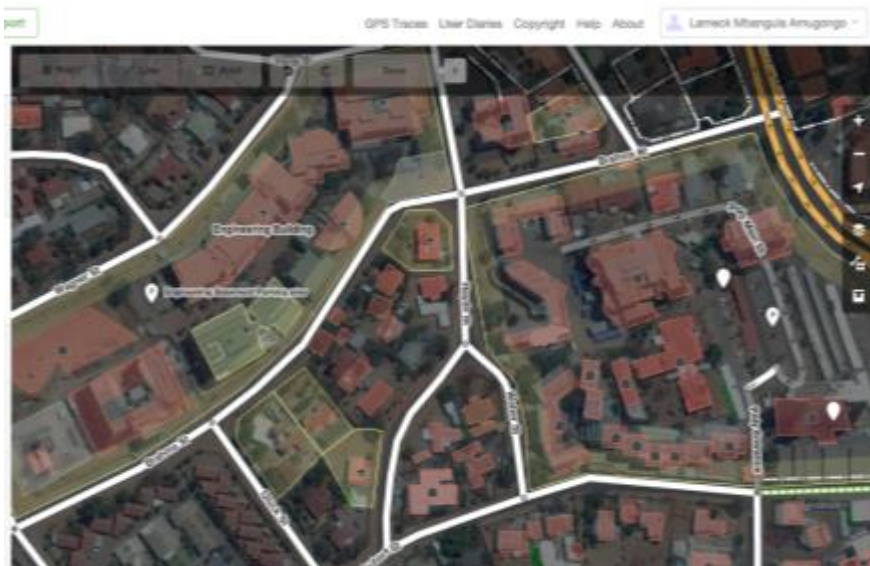


Figure 2-2 Updating building information

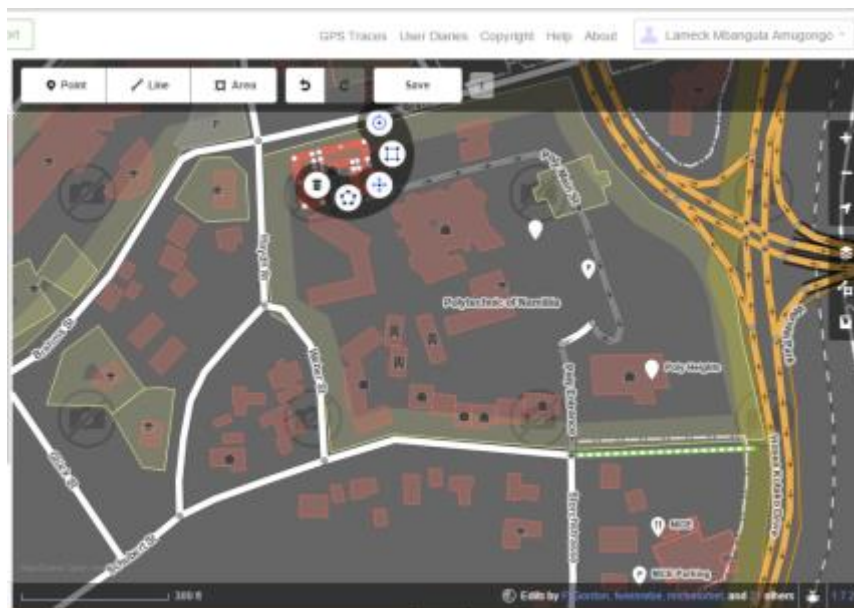


Figure 2-3 Capturing and mapping a new building

The last section of this literature review critically analyses existing frameworks and tools aimed at increasing open data awareness and consumption.

2.8 Open data frameworks and tools

2.8.1. Frameworks

Data and information have become the most valuable and strategic assets for governments, public institutions and citizens (Burwell, Vanroekel, Park, & Chieftchnolo, 2013). Open data is still in its infant stages, especially in developing countries (Schwegmann, 2013). However, we are increasingly beginning to see a lot of benefits being revealed as more institutions transform data into value. This has led to increased research in the field of open and big data, and the impact it has on communities, governance and economies. In their work, González, Garcia, Cortés and Carpy (2014) proposed a theoretical framework to analyse open government data, transforming the data to make it easier for ordinary citizens without the technical know-how to understand and as tool for policy makers.

Although practical, the framework proposed by González *et al.*, (2014) is only viable in countries where citizens are already aware of open data because the framework is demand driven. It is our view that citizens can only aggressively demand for the release of more data when they are aware of the importance of the data and incentives or benefits they can obtain from the data. Therefore, awareness is very important for the utilisation of open data and ultimately its success. Other than the resources, we presume that awareness is another reason for the differences of open data initiatives between developing and developed countries. We can thus deduce that by increasing awareness, open data initiatives in developing countries will eventually mature and leap frog to catch up with their counterparts in developed nations.

In the UK, the government responded rapidly to requests to make government data public by coming up with an open data strategy which defines guidelines for open data in the UK (Cabinet Office, 2012). Today, this strategy is revered and highly viewed by many enthusiasts as one of the best and progressive open data strategies, not only in Europe but in the whole world (Open Data Research Network, 2013). However, this strategy is specific to the conditions in the UK, thus this strategy will be

incompatible in other countries due to infrastructural differences, culture, laws and spending budget in the UK compared to other countries. Nonetheless, countries with similar conditions can adopt and customise this strategy to fit their respective countries.

Although the principles of open data are the same from country to country, there is no one size fit all strategy for open data. Therefore, it is important for countries to devise their own strategies, which take into consideration the socio-economic conditions in that country. Furthermore, regional blocks such as SADC and others can develop open data strategies that should be adopted by member states to encourage collaborations, innovation and for open data to have a wider impact.

In Columbia, an open data model was implemented to realise open data's social and economic benefits by enabling businesses and citizens to access public data (Prieto, Rodríguez, & Pimiento, 2012). The implementation of the model was not successful due to the public perception regarding privacy in open data. Like other open data frameworks, the model focused more on the government and not the citizens. Although open data mainly focuses in releasing government data and making it accessible to all, it is very important that open data frameworks take into consideration the needs and concerns of the citizens, who are integral in the realisation of open data potential.

2.8.2. Tools

As governments and public institutions seek approaches to ease access to data and obtain value from the data and thus unleash the real potential of open data; tools are being developed to aid in this regard. In response to making public data available, custodians of the data across the world are increasingly launching open data portals as enablers. Although releasing public data on data portals is a significant step towards improving access for citizens, data portals alone do not ensure that all citizens have access to this data. Due to the fact that data on portals is still in a raw form, it may only be meaningful to those with the relevant education, hence the need for data representation that considers its form and language to ensure that

citizens can easily understand and interpret it. Moreover, it is important for citizens to be vigilant and aware of the type of data available on the portals, which they can innovatively use to develop solutions that are relevant and useful. The raising of citizen awareness of data portals can be done in numerous ways; through direct interpretation by the citizens themselves or through easily digestible information produced by intermediaries through the analysis and visualisation of open data (Mutuku & Colaco, 2012).

In order to make data accessible, CKAN, an open source, powerful data management platform is often used to develop data portals, providing tools that streamline publishing, sharing, finding and using data. CKAN is developed for data publishers such as national and local governments, companies and institutions wanting to make their data open and available (Winn, 2013). DKAN is another powerful data management tool that is aimed at making data more open and accessible. Unlike CKAN, DKAN combines features of open data catalogues into already existing Content management system (CMS). Despite DKAN being a complementary effort to CKAN, it provides a single code base, allowing the team managing the content to be trained in one system instead of two.

Despite the success of open data portals, other tools exist and new tools are being developed to help governments, citizens and institutions obtain more value from the data. Hartung *et al.* (2010) proposed an Open Data Kit (ODK), an open source tool aimed at providing organisations in developed nations with tools designed to create information services. The ODK is made up of four tools: Build, Collect, Aggregate and Voice. Using the Build tool, users can flexibly design services to fit their needs. However, the build tool is not easy to use as the XML-based structure is very complex. The Collect is an Android mobile-based client that uses XLSform logic and displays prompts to the user. The third tool is the Aggregate, which acts as a server repository to manage the collected data. Furthermore, the Aggregate tool provides standard point of access to extract the data and integrate with other systems through HTTP requests.

The last tool is the Voice platform, which renders XForms via telephone calls. Users interact by calling with their phones.

The ODK suite is well supported by a large community of developers and community users. However, the ODK tools are too general, thus they will not be able to support specialised information based services. The application of open data is not only limited to the improvement of services and economic impact but it can be extended to policing in the government. Granickas (2014) recommends open data as a tool to combat corruption, based on the notion that if citizens have access to the public information, they become more aware and they are therefore in a better position to hold those who are in government accountable for their commitments.

The section of this chapter, critically reviews related works aimed at increasing open data awareness and or consumption.

2.9 Related works

Open data has become a huge phenomenon, attracting interest from major governments, institutions and researchers. Up to date, a lot of studies have been done on open data but only a handful of them have been aimed at increasing awareness and consumption. Mutuku and Colaco (2012) propose a design thinking approach to increase open data consumption through scalable mass appeal deployment and civic engagement tools and applications. However, this study only emphasised on one aspect, consumption, but in order for open data to be utilised as it ought to, awareness needs to be created first.

With the intention of bridging the gap between awareness and consumption, our earlier study pointed out the need to bring together diverse stakeholders through a hackathon to co-create and use ideas to transform datasets into meaningful and useful applications/solutions (Amugongo *et al.*, 2015). Furthermore, the idea was to use these solutions to create awareness among citizens on the incentives they can obtain from the public data. Additionally, the aim was to persuade the government to

realise the importance and relevance of open data in solving societal and governance challenges.

This is not the first study to propose a context-aware mobile bus application. Hansen (2010) proposed a context-aware application that makes route information available and enables users to request this route information by providing the destination they would like to travel to. Although the application is very easy to use, it requires GPS to be switched on the user's mobile phone. This however easily exhausted the phone's battery. Alternatively, the system could allow the user to input source and destination.

Tackling the bus transportation service problem from a different angle, in Addor (2011) proposes an Ant Colony Based Meta-heuristic approach to optimise the transportation costs by reducing the distance covered by four buses at Woodbridge school complex. Using a mathematical model that takes into account the actual distances between various pick up points (bus stops), they were able to improve route distances by approximately 33%. Despite the good results obtained in their study, the research was only limited to one school and it could be interesting to see the performance of the model if given more routes information.

Proprietary transportation applications also exist. Citymapper is such a solution, using the power of mobile and open transportation data to allow commuters to access real-time routing information in eight cities around the world (Aoun, 2013). What makes Citymapper different from transportation is its ability to incorporate data from multiple sources, such as Google, OpenStreetMaps, FourSquare, Apple, Uber and many other sources. Google transit is another popular solution, combining the power of Google maps with transportation data from multiple transportation agencies around the world. Google currently covers about 18 000 cities the world over to date (Catala, Downing, & Hayward, 2011; Google, n.d.-a). However, Windhoek is not one of them.

Although many transportation applications and solutions exist, none of them have access transportation data pertaining to Windhoek or any other town in Namibia. This study proposes a city bus mobile application based on the culture of openness and design thinking as an example to illustrate the creative visualisation of open data into useful solutions.

2.10 Summary

This chapter started off by providing a review of open data and opportunities of open data. Special attention was also given to challenges that open data initiatives are facing, and how persuasive computing can be harnessed to increase awareness and the consumption of open data. Furthermore, the existing open data frameworks were reviewed to highlight their shortcomings. Frameworks, policies and guidelines alone will not solve all open data challenges; neither will they create enough awareness and increase consumption of open data in itself. Hence, a multi helix and practical approach is needed. In this study, we propose a mobile application as a best practice example, based on three persuasion principles; passive observation, incentive to influence or change behaviour and ambient intelligence as conceived by (Kimura & Nakajima, 2009) to increase open data awareness and consumption; thus promote civic participation, transparency and inspire innovation by encouraging citizens to consume open data and use the data to solve social challenges.

Most importantly, the developed mobile app intends to bring about a cultural change, where open data is utilised to bring about efficiency, transparency and innovation into the public sector, and furthermore, to strengthen citizens' rights to data. Chapter 3, the research methodology explains and describes the methods, tools and techniques applied to undertake this study.

3. Research Methodology

This chapter describes and explains the methodology, techniques and methods adopted to conduct this study. The chapter also explains the data collection procedures used and how participants were involved in this study. The chapter concludes by outlining the software development methodology used to develop the city bus mobile application.

3.1. Introduction

Research has become a primary activity used by scientists, researchers and even unknowingly by citizens to uncover the unknown and solve daily problems. Traditionally, when one refers to the term research, one may immediately think of lab experiments, surveys and interviews. Different types of researches have been conducted for different reasons, which consequently lead to divergent definitions of the term research. Sekaran (2006) generally defines research as a throughout study and analysis of situational factors with the aim of finding solutions to problems. This definition is more related to researches in the field of business. According to Singh (2006), research is a process that searches for a solution to a problem, and the problem contains questions that have not been answered yet and also the researchers' view has an effect on the research.

In order to provide answers to these research questions, specific methodologies and methods were selected, and applied to acquire and analyse the data. Saunders, Lewis and Thornhill (2009), define the term methodology as a theory of how research should be carried out. They further emphasise that research methodology is different from research methods, as methods refer to techniques and processes used to acquire and analyse data. According to Singh (2006), a methodology refers to a strategy or plan followed in order to achieve the objectives of a study. Singh (2006) further distinguish a methodology from methods by defining a method as ways or sequences of activities applied to achieve the methodology, which are specific to the nature of the problem or field.

Rajasekar, Philominathan and Chinnathambi (2006), expand this discussion further by clearly distinguishing research methodology and methods. They describe research methodology as a systematic, sometimes theoretical analysis applied to a study, in order to solve a problem. A methodology is not the same thing as a method, neither is it aimed at providing solutions. Instead, a research methodology provides a solid theoretical foundation for understanding the method, collection of methods or best practices applied to a specific scenario to attain the envisaged results or accomplishments.

Although expressed in different ways, all above definitions refer to research methodology as an overall blueprint of a study, which outlines the actions aimed at solving the problem being researched. Unlike the methods which focus on procedures and techniques, a research methodology is scientific in nature and shows how a research will be conducted (Rajasekar *et al.*, 2006). Methodologies are discipline specific, and just like in social sciences, researchers in computer science use various methodologies to uncover and solve problems (Dodig-crnkovic, 2002).

In this study an inquiry was undertaken to help increase open data awareness and consumption in Namibia.

3.2. Research design

Research design can be defined as “a plan for conducting a study with maximum control over factors that may interfere with the validity of the findings” (Sekaran, 2006). In simple terms, research design refers to a blueprint or strategy utilised to achieve set study objectives. This study aims to measure the impact of persuasive technology such as mobile applications in increasing open data awareness and consumption in Namibia. The research approach adopted in this study is experimental methodology, supplemented by co-creation and qualitative methods. As a scientific approach in its nature, experimental methodology enabled the researcher to manipulate and control one or more variables to measure their influence on the dependent variable (Blakstad, 2013; Saunders *et al.*,

2009). Additionally, co-creation made it possible for potential users to be involved in the solution design and development process. Thus, this helped to ensure that the developed solution takes the real needs of the users into consideration.

The experimental methodology has been around for many years, and it has been in use ever-since the early days of sciences to facilitate and evaluate solutions to problems through the development and testing of prototype solutions (Dodig-crnkovic, 2002). In this study, brainstorming sessions were held with undergraduate students to discuss the challenge facing public transportation within the City of Windhoek and features to be incorporated in an app that will make public transport accessible and efficient. After identifying the possible functionalities to be provided in our envisaged bus app, using the incremental software development method, the application was then designed and developed.

After the successful implementation, each system feature was then tested. The testing methods used were unit and integration testing. However, these were just internal testing measures to ensure that each application feature operates as ought to. However, additional experiments were also carried out with the users to validate if the functionalities are working as defined in the brainstorming and co-creation sessions. The technologies and tools used to design and develop the bus app solution are explained chapter 5 and 6.

3.2.1. Data collection

Data collection is a critical phase for any study, given that inaccurate data can lead to misconceptions and inevitably inaccurate results (Sekaran, 2006). In today's world filled with interconnected mobile devices that are nowhere yet everywhere, this phenomenon presents so many opportunities. Often embedded with a variety of sensors, these devices enable citizens to become data gatherers, leveraging on powerful sensors to collect data any time and everywhere. So in this study, geolocation information of bus stops and routes were acquired from MoveWindhoek (<http://www.movewindhoek.com.na/>), a campaign part of the strategic plan

to improve public transportation in the City of Windhoek. In order to validate the acquired public data, the researcher went from one bus stop to another throughout Windhoek to validate the geo-location information of bus stops. The researcher did this in order to ensure that the acquired bus stops information was accurate.

Using a smartphone with a GPS sensor, 100 bus stops' geo-location information in Windhoek were validated. The acquired data was then used to power the mobile application, ensuring that bus stop coordinates are placed accurately on the map within the city bus application. Furthermore, conforming to the open data principle, these data were made available in open formats such as csv, xml and json to make it easier for citizens to reuse them to power other applications or solutions.

3.2.2. Population sampling

The study's target population was members of the Namibia Business Innovation Institute's (NBII) Developers Circle, consisting of software application developers and technology enthusiasts to discuss trends and technologies to solve local challenges. Additionally, students, primarily those enrolled for bachelor degrees at NUST were also involved. Other stakeholders from the private and public sector, including 3 parliamentarians also participated in the stakeholders meeting which aimed at shaping how Namibia's open data policies should look like. Moreover, members of the open data research cluster, made up of developers, designers and citizens were involved in crowd-sourcing geo-location data and testing system features. Using these individuals, we were able to collect bus stop geo-locations faster and timely.

Participants were selected based on their availability and interest in the advancement and realisation of open data in Namibia. A total of 120 people were involved in this study through the 2 hackathon events and open data stakeholders' meetings held in the context of this study.

3.2.3. Data analysis

Data analysis, by definition refers to the process of examining, cleaning, transforming and representing data with the aim of uncovering useful information that can enhance decision-making (Sekaran, 2006). In this study, qualitative data was acquired, and then used to develop the mobile application described in this study. Before data analysis, the data was first prepared and verified to ensure that it is in an open, reusable format. We also had to ensure that all coordinates are correct and accurate.

Leveraging on Google Maps' powerful API, provided through the Android Software Development Kit (SDK), a java-based algorithm was developed to gain insight from the acquire bus stop, schedule and route information. Moreover, the Google Maps API was also used to determine the distance between bus stops and to plot the location of bus stops on the map. This could be helpful information for officials to optimise the bus routes and as well as create new bus stops, especially in areas where only a few bus stops exist.

3.2.4. Application development procedures

In this section, the process followed in order to develop the city bus application are highlighted and explained. As stated in section 3.2, the application was designed and developed as a set of increments. This approach was adopted over other software development methods due to its ability to accommodate new changes at a relatively low cost; it also allows the initial system design to be delivered early to the users. The incremental method ensures correctness and the validation of the system design due to the fact that only small changes are made during each system increment. The ability to deliver an early increment of the system provides an opportunity for user involvement in the software design and development cycle through user feedback, which is very helpful and vital in the improvement of the system through the next increment (Sommerville, 2010). The involvement of potential users increases the likelihood that the actual users will accept the system.

Figure 3-1 depicts the incremental development method used in this study. This process was iterated numerous times to develop the application from the first version to the current version, version 0.8.

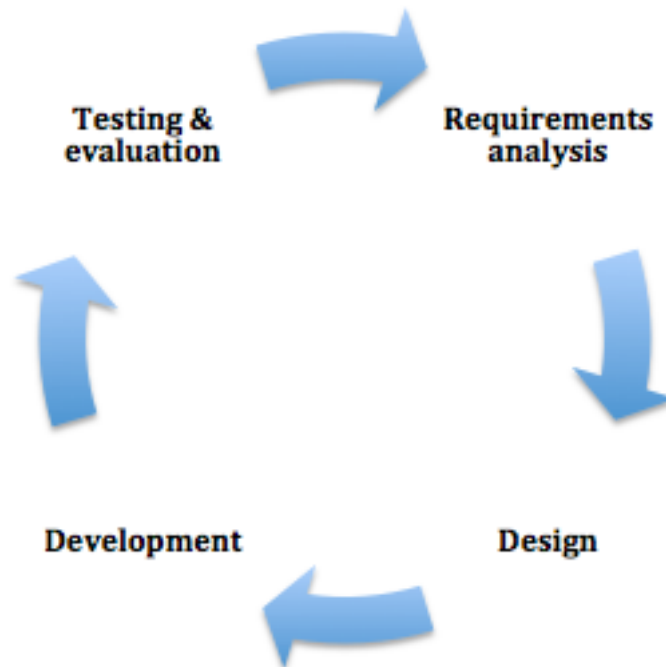


Figure 3-1: Incremental development

Requirements analysis – During the requirements phase, a session was held with study participants to discuss and brainstorm about the various system features. The user input during this phase was very helpful as it enabled the application to be designed according to the needs of potential users.

Design – During the design phase, tools were identified and used to mock up how the application should look like and to transform the ideas uncovered during the requirements elicitation phase into prototype design that helped clarify how the application should look like. Two main tools were used in this phase; Dia, an open source diagramming software used to model Unified Modelling Language (UML) diagrams, and flowcharts. In this study, Dia was used to design the Entity relationship diagram (ER-D). Another tool, Wireframe sketcher was also used to mock up the different app screens.

Development – The system designs were then transformed into an android mobile application using Android Studio, an integrated development environment (IDE) for android applications. Android offers a powerful code editor, developer tool and more features that improve apps' development productivity. During this phase, a Firebase database was created to store the acquired geo-location data. Moreover, the acquired bus stop data were plotted on map using the Google maps API available in android studio.

Testing and evaluation – In this phase, demonstrations and experiments were carried out to demonstrate how the application works and evaluate whether the application conforms to the requirements. The testing and experiments were carried with potential users, using real life scenarios.

The next chapter outlines and describes the system specifications of the best practices example mobile application developed in the context of this study.

4. Requirements Analysis

In the previous chapter, methods and techniques applied to carry out this study were outlined and explained. This chapter discusses the requirements of the system, which are a set of characteristics, behaviours and functionalities that the system must provide. These requirements are divided into functional and non-functional requirements. Non-functional requirements stipulate the overall behaviour of the system, taking into consideration matters pertaining to availability, security and performance. Functional requirements on the other hand look into what the system is supposed to achieve, thus taking into consideration the functionalities the system provides to the user.

User cases are widely used to capture functional requirements, as they clearly illustrate the interaction between users, also known as actors and the system. Figure 4-1 describes the functionalities provided by the mobile application developed in the context of this study

4.1 Overview

A location based service was developed to improve public transportation in Windhoek. The system is comprised of three main components: mobile application (frontend), logic layer and database (backend). The mobile application is the interface between users and the system, presenting enchanting and easy to use services to users. The backend is where all data, information about routes and bus stops are stored. Data stored in the database is converted into information that is presented to the user through the frontend component. The logic or middle layer is the interface between the presentation layer and database. It also performs complex operations such as translating bus stop addresses into coordinates and calculating the distance between two bus stops.

The next section explains how the system is supposed to work and the functionalities it aims to provide to the users.

4.2 Functional requirements

Functional requirements are specifications that describe the behaviour of a system and its components (Sommerville, 2010). In other words, functional requirements describe what the system does.

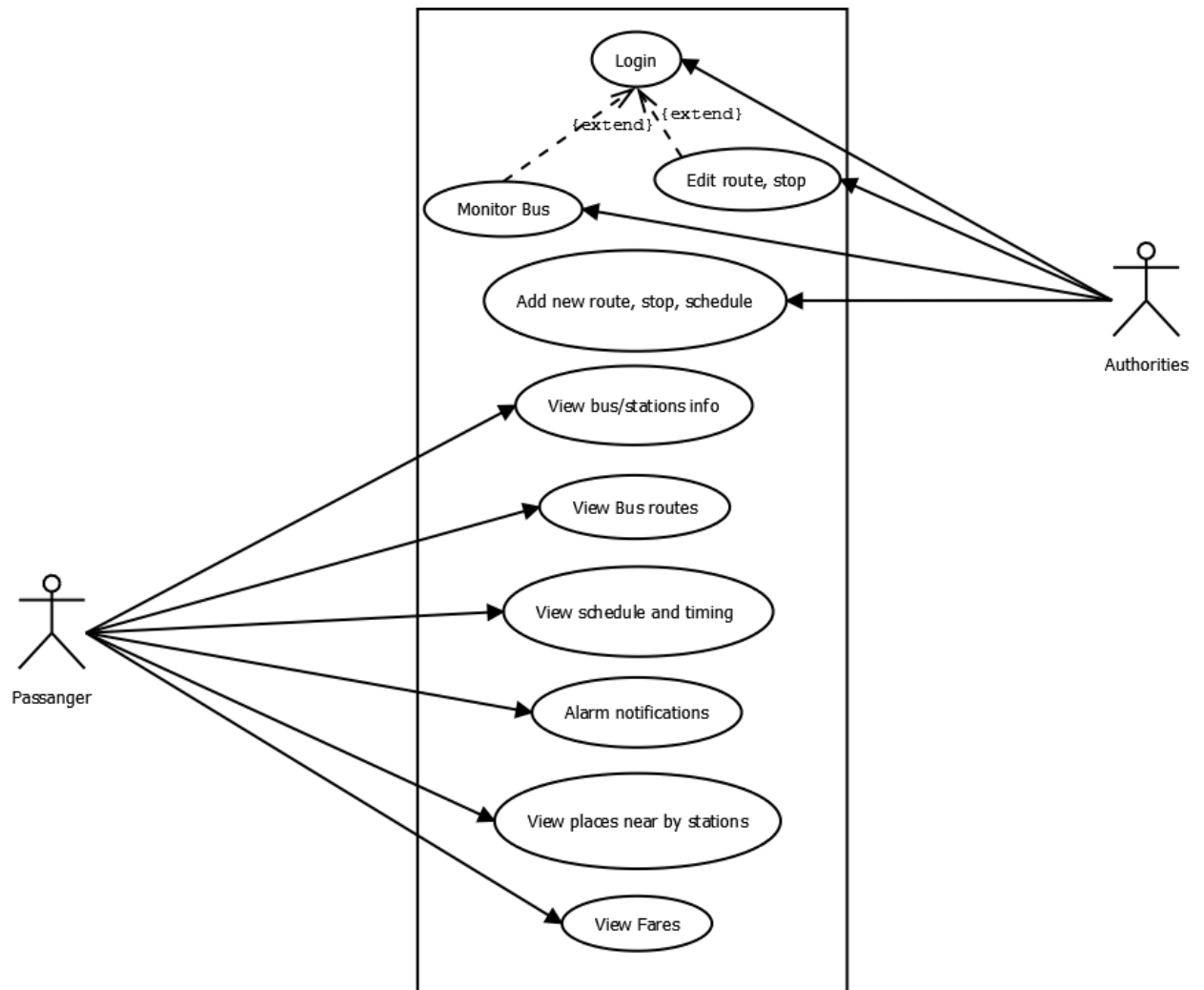


Figure 4-1: Use cases of the Windhoek City bus application

Figure 4-1, shows the application functionalities. These functionalities are expressed as use case scenarios and they are explained in detail below:

User (Passenger)

- View bus stop – The first user case describes a scenario where a user views information of a given bus stop. This is achieved by tapping on a given bus stop. The user can also use the search

functionality to find the bus stop they are looking for. The location of the bus stop can be seen in Google maps.

- Search route – The search route user-case enables users to obtain information about routes. In order to find a route, the user has to provide the origin and destination bus stops. Thereafter he/she should be able to see the next available departures. The user shall also be able to see the time the bus will arrive at the destination bus stop.
- View schedule and timing – Use case 3 enables a user to see bus schedules information. However, to view schedules, the user has to specify a bus whose schedule they would like to view.
- Alarm notification - use-case number 4 provides the functionality to alert the user when he/she reaches their endpoint bus stop.
- Nearby places – provide users with localized content of places nearby bus stops where they can grab something to eat or drink.
- View fares – ability of the system to provide information regarding bus fares from point A to point B. Here the user shall also be able to see which tickets apply for which areas within the city.

Administrator (CoW)

1. Add new route/stop/schedule – an administrator shall be able to create new routes, bus stops and schedules in the system.
2. Edit route/stop – this will enable an administrator to make changes to existing routes, bus stops and schedule information.
3. Monitor bus – the ability to monitor real time data regarding the movement of bus fleets.

Though before an administrator can carry out any of these operations described in figure 4.1, he/she needs to log in first. This security measure ensures that only authorised personnel can perform such operations. As

for the passengers, they do not need to log in to access the bus routes information and schedules. However, in the near future, once the payment functionality is implemented, they would be required to log in in order to be authorised to top up on their transport wallet.

The next section discusses the non-functional requirements of the system.

4.3 Non-Functional requirements

Unlike functional requirements, non-functional requirements refer to specifications that define system property and constraints rather than specific system behaviour. Just as functional requirements are important, non-functional requirements are equally important, although they do not concern system behaviour. A system or application that offers great functionalities, yet is not secure nor is it easier to use. Such an application or system may not be very useful to its users (Sommerville, 2010). Therefore, these non-functional requirements were thoroughly reviewed and considered during the design and implementation of the application. Non-functional requirements considered are those defined in the ISO (International Organisation for Standardisation) 9000 handbook for quality systems (Hoyle, 2001). They are:

- Reliability – Errors are inevitable during system implementation. However, the rate of failure occurrence should be minimal.
- Usability – Not all users have used a smartphone or computer before. Thus, application functionalities and interfaces should be simple and easy to use. During the design and implementation of the system ‘ease of use’ should be taken into account. In order to make sure that the system is user friendly, it is recommended to make use of familiar interface icons and terms to represent similar actions.
- Performance – System performance includes the speed at which transactions are processed, responses are given and the activity refreshes. Performance is a very important aspect as users will not

want to use a system that is slow and takes a long time to respond because time is of the most essence. The system should manage bottlenecks efficiently and effectively. The interactive nature of the system and importance of reducing delays was given a lot of thoughts during design and development.

- Security – only those who are authorised should have access to the data.
- Scalability – System requirements are fast changing, hence it is very important for the system to be flexible in order to accommodate future changes and system growth. The ability of the system to handle large volumes of work was also considered. To achieve this, the system should try to leverage on existing platforms that are scalable and can support the processing of any volume of work. Moreover, high cohesion and low coupling among system modules is ideal.
- Availability – the ability of the system to be operational when users want to use the system. Availability can also be measured as a factor of system reliability.

The long-term success of the system highly depends on the ability of the system to fulfil emergent system characteristics such as performance, reliability, usability and security as described above.

4.4 Summary

In this chapter we have defined the functionalities, characteristics and behaviours of the system, including what the system should do, services it offers and limitations or constraints. The defined requirements do not only express the desire of the customers but they are also very helpful to guide the design and implementation of the system, as well as to verify whether the implemented system meets the actual needs. The next chapter describes how the prototype application was designed.

5. Prototype Design

This chapter explains the design decisions and techniques employed to design the mobile application aimed at enhancing public bus services within the city of Windhoek. The developed application is designed for smartphones running on the Android mobile operating system.

5.1. System development environment

A mobile application, also referred to as Windhoek city bus app, was developed by the author in the context of the research project for a master's program at the Namibia University of Science and Technology (NUST). The system was designed and developed as a set of increments, starting with version 0.1 to the much stable current version presented in this research work. The basic functionalities of the system are explained in chapter 4. Although the architecture of the system is platform independent, the prototype was implemented for the Android mobile platform, using android studio as the integrated development environment (IDE). Android, a mobile application development platform was opted as the development platform because of its large and fast growing base. However, in the near future, a HTML5 version of the app will also be developed to cater for the other mobile OS such as IOS, windows phone and blackberry.

Android studio through the android studio designer tool (ADT) provides an advanced design editor, which enables developers to easily design their user interfaces without writing any code. This speeds up design and increases productivity. Additionally, android studio also incorporates material design, which is a design language developed by Google aimed at improving the visual, motion and interaction look and feel across platforms and or devices.

In the following section we discuss the architecture of the system.

5.2. System architecture

The system architecture outlined in this section provides high-level system overview, which gives more insights about the various system

components. Moreover, the system architecture also provides a high level overview of the interactions between the different system components.

In order to ensure the reliability and accuracy of location information, absolute positioning information will be acquired through smartphone GPS sensors. The acquired position information is then plotted on a map for the graphical representation of the user's location. Moreover, in the absence of absolute position, relative position information can be very helpful in determining the position of the user. So in this case, relative position information will be obtained from the nearest network base station to which the user is connected.

It is common knowledge that a good design reduces implementation risks and speeds up implementation because less time will be spent on redesigning. A bad system design however may result in increased redesign costs due to changing requirements. Figure 5-1 illustrates key modules that make up the system.

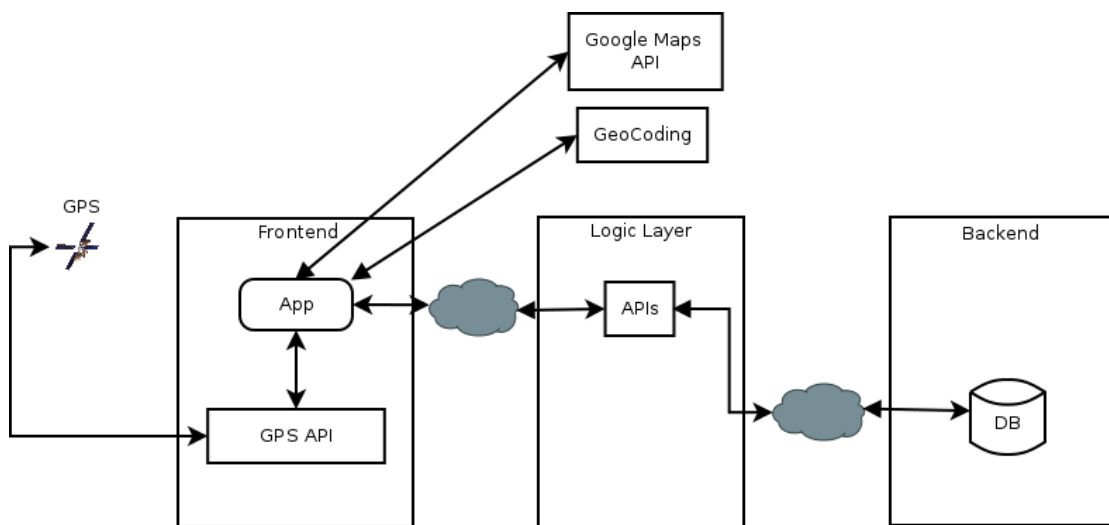


Figure 5-1: System architecture & modules

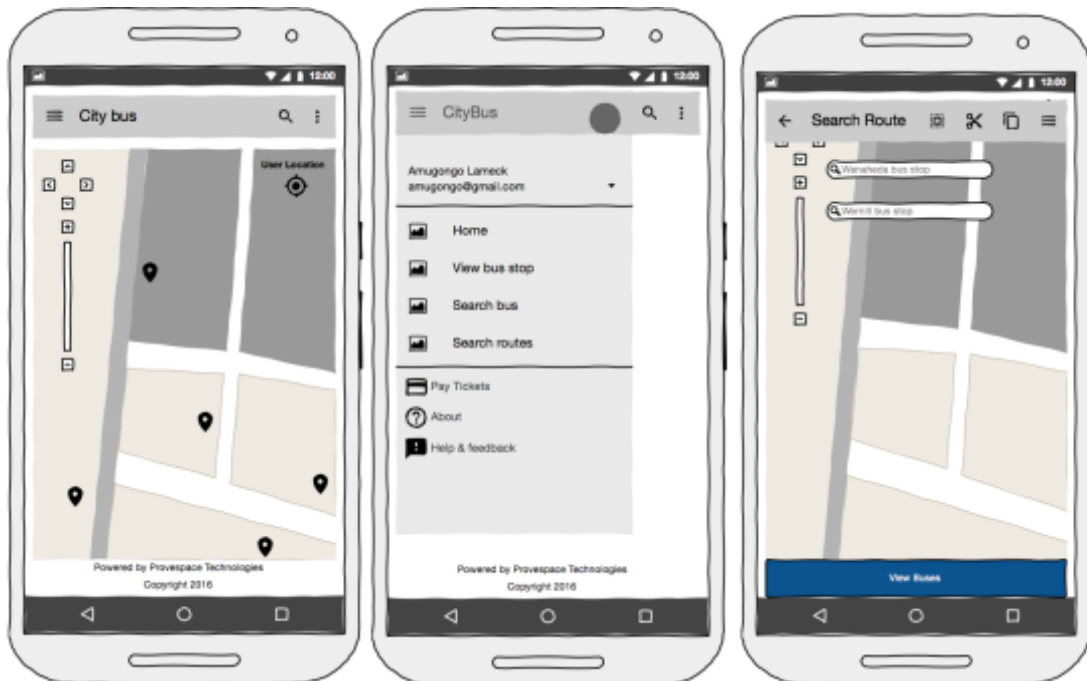
From Figure 5-1, we can identify the different system components and abstract communication among these components. Below we explain in detail each of the technical components that make up the system.

A. GPS

The application exploits the device's GPS sensor to obtain the coordinates of the user and bus stop. Using coordinates provided by the GPS, calculations are then made to find out how far the user is from the bus stop and using GPS navigation the user is guided to where the bus stop is found.

B. App

The app acts as an interface between the database and the user, presenting the route and schedules information returned by the API to the user. Through the mobile application, the user will access the services offered by the system. These services are discussed as requirements in chapter 3. Figure 5-2 shows the user interface design of the mobile application. The Wireframe Sketcher mock tool was used to design the screenshot illustrated in Figure 5-2.



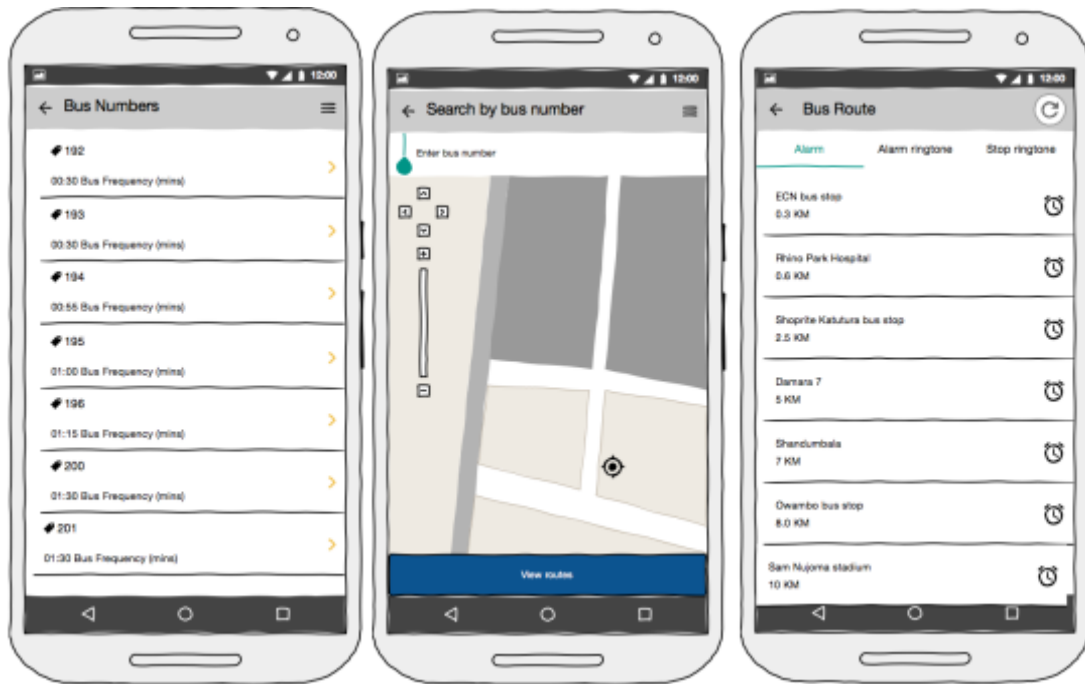


Figure 5-2: Mobile application user-interface designs.

C. APIs

The Application Programming Interface (API) is a very important system component. The API acts as the interface between the database and the application, enabling communication between the client and database. It is through the API that users get information regarding buses, stops, routes and schedules.

D. Database (DB)

The database stores data pertaining to bus stops, routes and schedules. The database structure was designed using the Dia tool, which enabled the researcher to effectively map all the different objects that make up the database. Detailed information regarding the database model and structure is discussed and explained in section 6.5.

E. Google Maps API

Google Maps API is a special android application programming interface (API) developed by Google, available for Android, IOS, HTTP web

services and web to power user's location based experiences. This API will be used to allow users to view the obtained location information on Google maps. Through the Google Maps API we can obtain and accurately estimate the distance between two bus stops and navigation information to guide the user from point A to point B.

F. Geocoding

The translation of bus stops addresses into coordinates made it possible to calculate the distance between two points and determine the distance. During implementation, Google Maps Geo-coding service was used. This was designed using one to one mapping, where each bus stop name was mapped to corresponding geo-location coordinates.

5.3. Conceptual data model

Modelling the data is often the first step in the development of any database system. Conceptual data modelling helps clarify how the different entities and or objects relate to each other. In this study, to illustrate these relationships a tool known as Dia was used. Using Dia, the envisioned abstract data model was represented in the form of entity-relationship diagram (ERD). Three main components; entities, attributes and relationships were used to visually represent the database model.

Associations also known as relationships depict links among entities in the model. The most important aspect of this relationship is the cardinality constraints, which maintains logical integrity in the data. Before the model was designed, all data to be stored and utilised in the system were collected. Moreover, all relevant objects, events and stakeholders were identified. Figure 5-3, illustrates and describes the conceptual data model in detail.

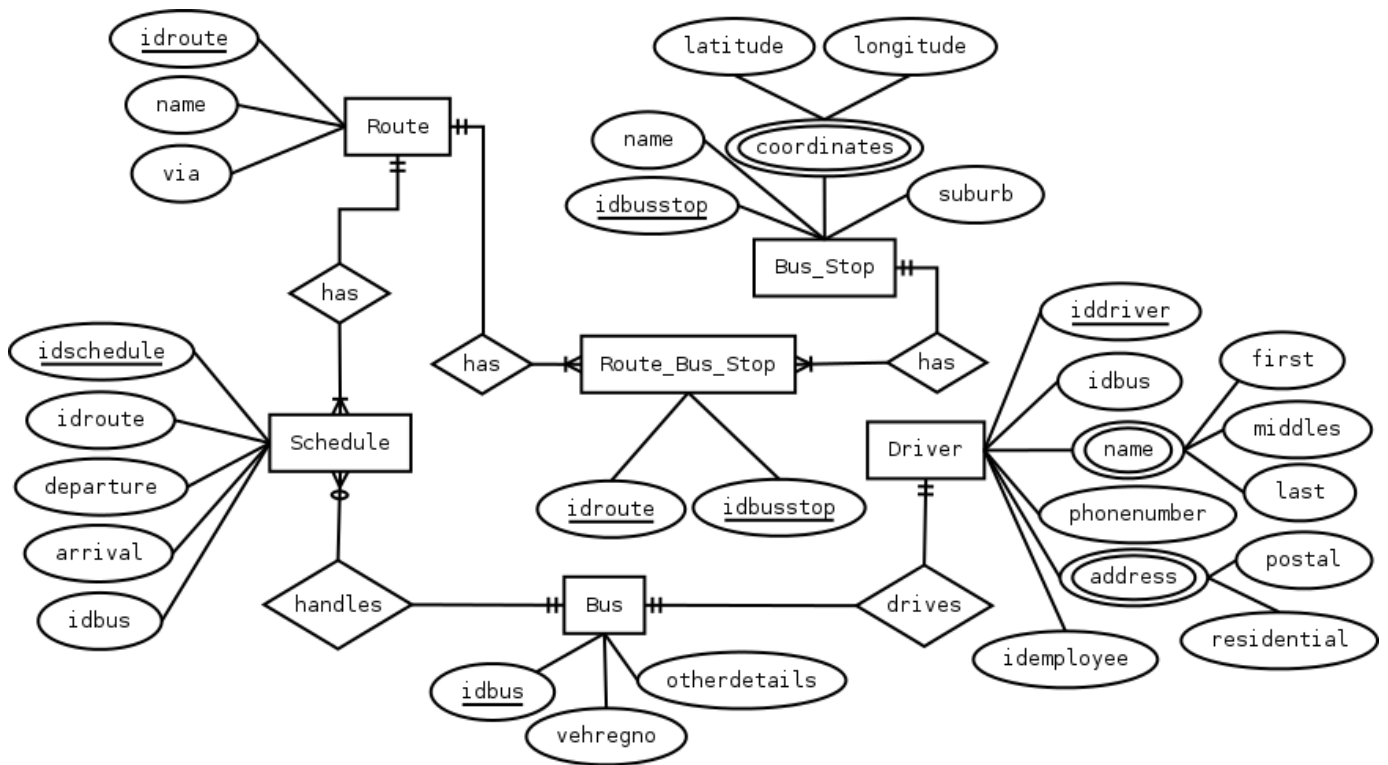


Figure 5-3: Conceptual data model for the Windhoek City bus application

The structure of the database as depicted by the conceptual data model in figure 5-3 is relatively less complex, very easy to understand and designed for optimal efficiency and effectiveness of the database. Below, essential database entities are explained in more detail.

Schedule entity represents information pertaining to the service plan for all municipal buses within the city of Windhoek. The ER diagram above illustrates that one or more schedules can be assigned to one route. This implies that a route can have one or more schedules. However, one schedule can only be assigned to one route. Moreover, a bus can service more than one schedule.

Another important entity is the bus entity, which denotes a bus. As depicted in our entity relation diagram, a bus can service one or more schedules but a schedule must only be for one bus. A bus driver who is a city of Windhoek employee drives a bus. A bus driver can drive one or more buses. All the bus stops information is stored in a table called bus stop. A bus stop refers to a point where a bus drops off and picks up

passengers. A route can have at least one or more bus stops connected together and one or more routes can use a given bus stop.

The conceptual model explained in figure 5-3 was then converted into the logical model, which further provides detailed description of the data in terms of database technology to realise the envisaged data store.

5.4. Summary

In this chapter the system architecture that fulfils the requirements in chapter 4 was designed. Several designed alternatives of how the system should operate were tried, analysed and the best alternative adopted. Google Maps was used to GeoCode bus stop addresses into coordinates; calculate the distance between two bus stops and estimate the time it will take. We found that a no SQL database was the best option for storing bus stops and routes information.

6. Implementation of Prototype

In this chapter we explain and describe the tools used to develop the mobile application. Furthermore, we describe the implemented database structure. Finally, the challenges that the researcher encountered while developing the application are highlighted.

6.1. Development environment

This section briefly discusses the development environment of the three key system components, including tools used to implement our best practice example.

6.1.1. Frontend

The mobile application is implemented in Android, using android studio as the IDE. Android is a java based object-oriented programming language for mobile devices. We chose android because of its popularity, with a market share of about 52% of the smartphone market. Android also has a robust SDK (Software Development Kit), enabling developers to develop good applications easily and faster (Google, n.d.). The author also has extensive knowledge about android programming, which was one of the reasons for choosing the Android platform. In order to evaluate the application, a Sony Experia Z2 and android emulator (Nexus 6) were used.

6.1.2. API

Firebase REST API was used to save and query data from the database. Through the Firebase REST API, the system will be powered with real-time information. No tool was used to develop the Firebase REST API as this API is made available by the Firebase library incorporated in Android Studio (Firebase, 2015; Narayanan, 2013). We chose Firebase REST API because it is easier to use and does not require any prior experiences with APIs.

6.1.3. Backend

The database is hosted through the Firebase cloud hosting service, which provides fast, secure and reliable storage. Firebase caches stored files,

ensuring faster access, which improves system performance. Google Chrome browser was used to create the Firebase database.

The following section explains in detail the implementation of the graphical user interface in detail.

6.2. User interface (GUI)

Technology has become an enabler, easing access to services, and improving the lives of many ordinary people. Consequently, for any technology to be adopted by users, it should be usable by all irrespective of the physical conditions. There is a growing demand for systems that combine more than one input method to enable users to easily and efficiently interact with the system (Oviatt, 2002). Multimodal systems are believed to be very robust; they reduce errors and help the user to easily use and navigate the system (Sebe, 2009). The prototype application supports multimodal modes of communication, mainly touch gestures and visual components, with the aim of improving user communication capabilities and provide the user experience.

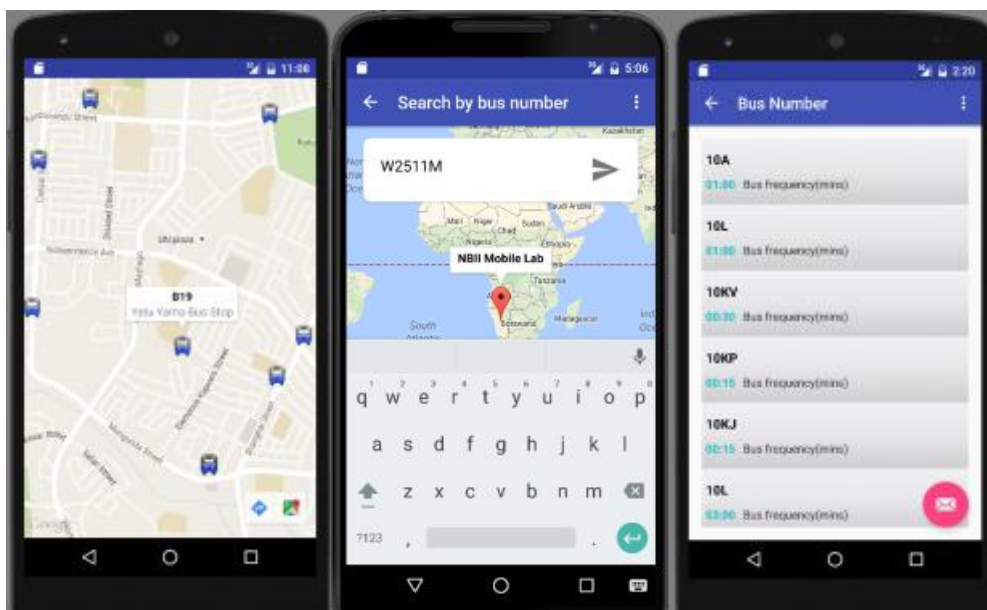


Figure 6-1View bus stops.

Figure 6-2Search a bus

Figure 6-3View bus info by bus no

Figure 6-1 shows bus stops on a map; this will enable a user to easily locate them. In figure 6-2, we see the implementation of the bus search functionality. Figure 6-3 illustrates how often a bus operates a given route.

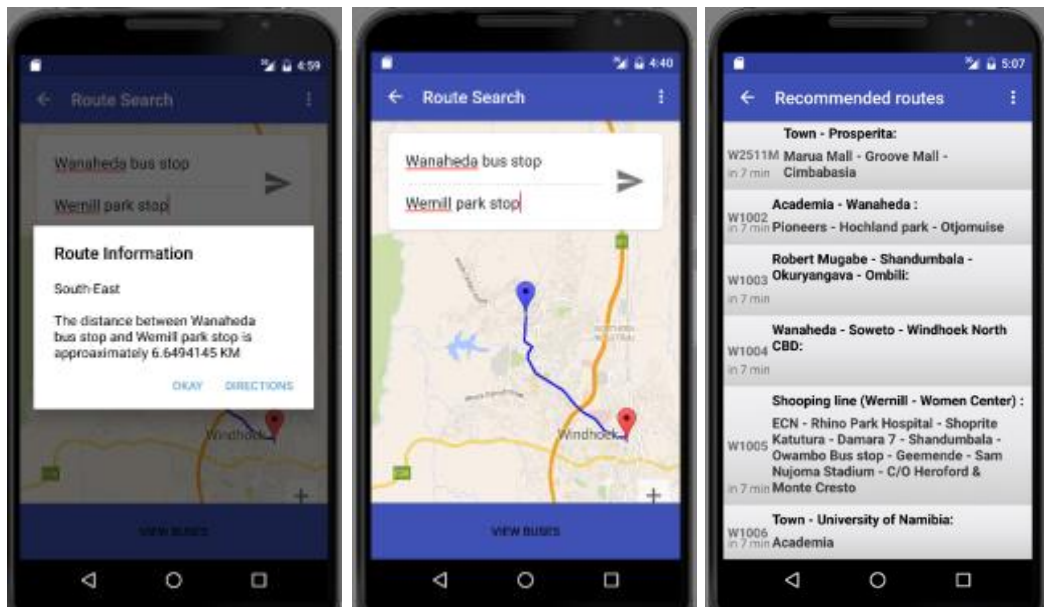


Figure 6-4 Distance between two stop.

Figure 6-5 Search route

Figure 6-6 View routes.

The screenshot in figure 6-4 shows the calculation of the distance between two bus stops. Figure 6-5 illustrates how a user can search a route by providing the source and destination bus stop. In the next screen, the user is presented with recommended routes information as illustrated in figure 6-6.

Most smartphone devices available on the market today are equipped with touch gestures, keyboard input and text to speech capabilities. These modes of communication are meant to make it possible for the application to support the different user circumstances. In the prototype application developed in the context of this application, text to speech was not opted because it was regarded as a future implementation because of the complexity involved in developing a good speech recognition system. The supported communication modes are explained in detail below.

6.2.1. Gestures

Gestures are very important components of an application, as they greatly enhance the usefulness, look and feel of an application. The most common gesture is the touch gesture; this occurs when a finger is detected on screen. Combinations of touches on the screen are understood to be a gesture. To enable the support of gestures, `MotionEventCompat` and `GestureDetectorCompat` classes provided in the Android support library were used.

```
@Override
public boolean onKeyDown(MotionEvent e) {
    return true;
}

@Override
public boolean onFling(MotionEvent e1, MotionEvent e2, float velocityX, float velocityY) {
    boolean result = false;
    try {
        float diffY = e2.getY() - e1.getY();
        float diffX = e2.getX() - e1.getX();
        if (Math.abs(diffX) > Math.abs(diffY)) {
            if (Math.abs(diffX) > SWIPE_THRESHOLD && Math.abs(velocityX) > SWIPE_VELOCITY_THRESHOLD) {
                if (diffX > 0) {
                    onSwipeRight();
                } else {
                    onSwipeLeft();
                }
            }
            result = true;
        }
        else if (Math.abs(diffY) > SWIPE_THRESHOLD && Math.abs(velocityY) > SWIPE_VELOCITY_THRESHOLD) {
            if (diffY > 0) {
                onSwipeBottom();
            } else {
                onSwipeTop();
            }
        }
        result = true;
    } catch (Exception exception) {
        exception.printStackTrace();
    }
    return result;
}
```

Figure 6-7: On swipe gesture

Figure 6-7 shows a snapshot of the code used to implement an on swipe gesture, which enables a user to swipe from the left to right. This is very helpful as it allows a user to smoothly switch between multiple views. Another gesture implemented in the application is the scrolling gesture, which enabled the user to scroll down long activities or views.

6.2.2. Visual components

Visual components are key elements of user interfaces in any given software system as they present information in a consistent way. In order

to ensure that the user interface is consistent, easily recognisable icons known by users to represent common actions were used to represent similar actions within the application. This enabled the application to be predictable, thus making it easier for the users to use it. Additionally, material design elements available in Android 5.0 and above were used to ensure that the application interface is appealing to the user.

Therefore, to ensure that the Windhoek city bus application developed in the context of this study is appealing to users, three basic Android design principles were considered and applied.

1) A balance was strived for between the look and feel and ease of use of the application. While ensuring that the application looks beautiful, it was also important to ensure that it is not too complex for users to use, thus it provided extraordinary experience to the users (Google, n.d.).

2) Ensuring that the application is easier to understand and that it makes life easier for the user. Navigation drawer, a panel that displays application key navigation options thus makes it easier for the user to navigate between the main system functionalities.

3) Ease of use alone does not make an application amazing; thus notifications were incorporated in the implementation to inform the user when they have reached their destination.

These notifications are helpful for users, especially tourists who are not familiar with the city. Furthermore, notifications can also be helpful when a user is asleep in the bus; the notification can act like an alarm to wake the user. Furthermore, to fully support material design, android UI flexible layouts were used to enable the application to support multiple screen sizes and devices.

The bus application developed in this study comprises of 8 activities and a location background service. The first activity is the splash screen activity, which contains handlers used to wait for a specific time in order to load

certain application network resources before the main activity is launched. The main activity displays a map of moving buses as they drive from one bus stop to another. From the main activity, the user can choose the next activity as clearly illustrated in the application workflow below.

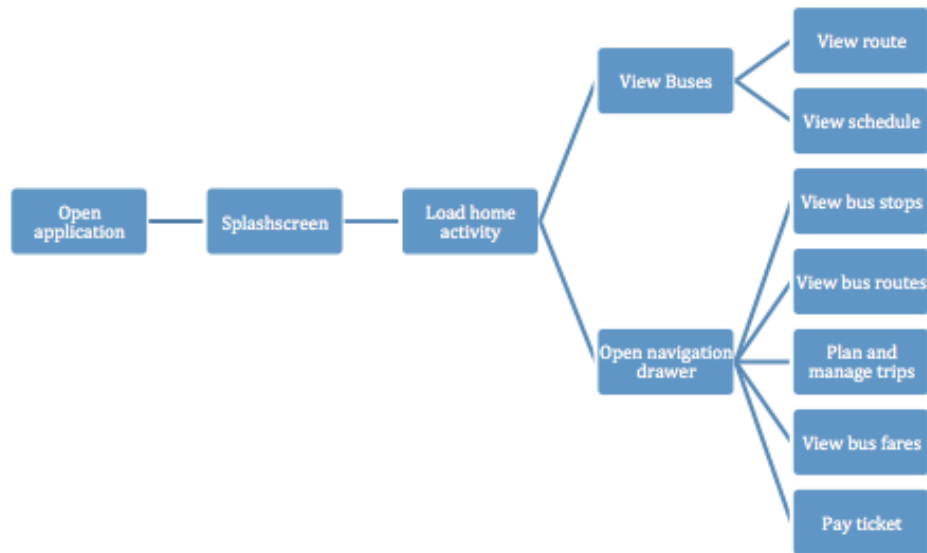


Figure 6-8: Application workflow

The navigation drawer found on the home page makes it easier to present multiple options in an easier and useful way without confusing the user. The drawer panel also makes it easier to add new features at a later stage. The first fragment activity on the navigation drawer displays bus stops on a map. The second fragment screen displays information about bus routes. The last fragment activity in the navigation drawer is the payment system.

6.3. GPS

Most mobile devices manufactured today have a GPS chip embedded in them. GPS provides navigation assistance to users through their mobile phones. In the context of this study, the GPS is used to help users easily locate where they are and how to get to bus stops. The location coordinates provided through the GPS were then put into Google Maps in order to make more sense to the users, thus allowing users to know

Figure 6-10 shows an example of the Google maps API that was used to calculate the distance and the direction in which the user has to travel in order to reach the destination bus stop. In order to acquire this information, a Google Maps direction request is needed, which takes three parameters: source coordinates, destination coordinates and mode of travel.

6.5. Database implementation

The backend is implemented in Firebase to enable database scalability and easier data synchronisation. The model comprises of bus information, bus stops, bus schedules information and information pertaining to the driver who drives the bus. Information is sent to the application only when requested, thus reducing network connectivity and it saves the user's mobile data. Although the application provides real time information regarding the location of a user, information obtained from the database is not dynamic but it is manually entered by the administrator. This is because currently buses in the city of Windhoek are not interconnected to any system, making the process of obtaining real time data of bus location nearly impossible.

The ability of the application to acquire real time information ensures that users have up to date information regarding bus schedules and routes always. Furthermore, in the future when the monitoring server for the buses is ready, the application will pull this information from the database, ensuring that users have real time information, enabling them to locate buses on the map. City officials can also use this information to verify that buses are adhering to their routes and to monitor the movement of buses within the city.

Unlike relational databases, for example MySQL, Firebase stores application data in JSON format. This makes it easy to synchronise the data. Below we describe the structure of the implemented database objects. Figure 5-11 shows a snapshot of how the collected bus stop information looks like in the database.

```

    "id": "B3",
    "name": "B3 Herero bus stop",
    "latitude": "-22.527984619140625",
    "longitude": "17.053117752075195",
    "location": "Herero"
  },
  {
    "id": "B4",
    "name": "Single quarters Engine Service",
    "latitude": "-22.53233268",
    "longitude": "17.04952635",
    "location": "Single Quarters"
  },
  {
    "id": "B5",
    "name": "Council of Church Namibia bus stop",
    "latitude": "-22.314266204833984",
    "longitude": "17.023405075073242",
    "location": "Grysbloek"
  },
}

```

Figure 6-11: bus stop details

As shown in Figure 6-11, every bus stop object stored comprises of the following field names, an id which uniquely identifies each bus stop, a bus stop name which refers to the name of the stop and the longitude and latitude coordinates, which is very helpful in placing the marker of bus stop at its precise location on the map. The last field name is the location where the bus stop is located; this helps the user know the part of the city where that bus stop is found.

```

{
  "path": {
    "route": [
      {
        "id": "1/01",
        "name": "Town - Prosperita",
        "via": "Marua Mall - Groove Mall - Cimbabasia",
        "bus": "W1001"
      },
      {
        "id": "1/02",
        "name": "Academia - Wanaheda ",
        "via": "Pioneers - Hochland park - Otjomuise ",
        "bus": "W1002"
      },
      {
        "id": "1/03",
        "name": "Robert Mugabe - Shandumbala - Okuryangava - Ombili",
        "bus": "W1003"
      },
      {
        "id": "1/04",
        "name": "Wanaheda - Soweto - Windhoek North CBD",
        "bus": "W1004"
      },
      {
        "id": "1/05",
        "name": "Shooping line (Wernill - Women Center) ",
        "via": "ECN - Rhino Park Hospital - Shoprite Katutura - Damara 7 - Shandumbala - Owambo Bus stop
          - Geemende - Sam Nujoma Stadium - C/O Heroford & Monte Cresto",
        "bus": "W1005"
      },
      {
        "id": "1/06",
        "name": "Town - University of Namibia",
        "via": "Academia",
        "bus": "W1006",
        "#text": ">
      "
      }
    ]
  }
}

```

Figure 6-12: bus routes information

Figure 6-12 shows information about bus routes; from this information a user can see which bus services which route and which route to take in order to reach their destination. Additional to the routes, what is equally important is the bus schedule information, which shows the estimated arrival times of a bus at each bus stop as shown in Figure 6-13.

```

{
  "timetable": {
    "schedule": [
      {
        "id": "T100",
        "origin": "Wernill",
        "destination": "ECN",
        "departures": "10h00",
        "arrival": "10h05",
        "route": "1/05"
      },
      {
        "id": "T101",
        "origin": "ECN",
        "destination": "Rhino Park Hospital",
        "departures": "10h07",
        "arrival": "10h10",
        "route": "1/05"
      },
      {
        "id": "T102",
        "origin": "Rhino Park Hospital",
        "destination": "Shoprite Katutura",
        "departures": "10h12",
        "arrival": "10h15",
        "route": "1/05"
      },
      {
        "id": "T103",
        "origin": "Shoprite Katurura",
        "destination": "Shandumbala",
        "departures": "10h17",
        "arrival": "10h20",
        "route": "1/05"
      },
    ]
  }
}

```

Figure 6-13: bus schedule

Despite the dynamic nature of the database, one important aspect is data security. Data security is discussed in the following section.

6.5.1. Data security

Data security is a very critical aspect in the successful operation of a database system as it ensures data integrity. In order to enforce data security in our application, a powerful security and rules language provided in the Bolt Compiler tool was used. This ensured that data is only accessible by authorized users, and preventing suspicious users from gaining access to the data. This rule-based language is flexible and provides great control over read, write and validation operations across the database.

Low-level rules become complex and hard to maintain especially in complex applications (Koss, 2015). However, in this study the application structure is very simple, thus these low level rules work perfectly well in securing the information. In order to ensure that the system data is

secured, rules were defined as shown in figure 6-14 to define how the data should be structured and when the read and write operations can happen on the data.

```
FIREBASE RULES
1 {
2   "rules": {
3     ".read": true,
4     ".write": false
5   },
6   "users": {
7     "$uid": {
8       ".read": "auth != null && auth.uid == $uid",
9       ".write": "auth != null && auth.uid == $uid"
10    }
11  }
12 }
13 }
```

Figure 6-14: Rules

The rules illustrated in figure 6-14 are very simple; these rules grant every request read permission to our database. The last rule enables users, especially the administrators to write information to the database such as to add new routes and schedule information.

6.6. Implementation challenges

This section highlights some of the observed challenges along with the envisaged solutions. One of the very first challenges we faced was providing accurate positioning to the user. Thus, a tracker service was developed to enhance the accuracy and trustworthiness of the positioning of users and buses, which are the focal points of the discussion in this section.

Acquiring real time data about buses and their arrival times was another challenge, because no such system exists where this information could be obtained. However, to overcome this challenge, static arrival estimate

times were used based on the distance and the speed that buses are allowed to drive within the city, taking into consideration the traffic during rush hours (busy times). But in the future work, we hope to mount buses with GPS sensors, which will enable us to collect bus location information in real time.

Not all bus stops names and places could be geocoded using the Google Maps API, because Google does not know all bus stop names, neither does it know all the places in Windhoek. Thus it was important to improvise the design of the database to map bus stop names to their respective geo-location coordinates.

Connectivity was also another challenge we encountered in some parts of the city, resulting in the slow loading of stops, bus routes and schedule information from the database. In order to overcome this challenge, we implored a tactic to save information that does not frequently change on the user's device at first use. Therefore this reduced the bandwidth consumption.

6.7. Summary

In this chapter a system, which we believe best fulfils the requirements described in chapter 3 was developed. Some challenges that we encountered during the implementation phase were outlined and possible solutions highlighted. The developed system will be tested and its components evaluated against the defined requirements in the next chapter.

7. Test and Demonstration

This chapter starts by describing the testing methodology applied. The developed prototype application was tested to assess its performance and to improve its functionalities. The chapter concludes with the presentation of the obtained results.

7.1. Introduction

The goal of this study was to design a mobile application as a best practice example to increase the awareness and consumption of open data. As complex entities, human beings can only be effectively persuaded when they see the results and benefits that they can resonant with. The mobile application developed in the context of this study intends on just doing that. In order to develop this application, geo-location position information of 100 bus stops within the city of Windhoek were acquired to practically show citizens how mere data can be transformed into real applications and solutions. In this study, the acquired bus stops location, route and schedule data were visualised into an application that will ease access to public transportation within the city of Windhoek.

The acquired bus stops data are evenly distributed, ensuring that most bus stops data in all major suburbs within the city of Windhoek were available. However, during data collection we discovered that the majority of the current bus stops are located within the rich suburbs, due to the fact that this is where most bus users commute to every morning for work. Therefore, to improve public transportation within the city, more bus stops should be created closer to the people, reducing the distance that bus users travel from bus stops to their homes. Thus, improving municipality bus services within the city; making public transportation more efficient and reliable.

The following subsections evaluate the testing and demonstration of the implemented prototype.

7.2. City bus application testing and demonstration

Testing is a very important procedure, as it ensures that the system functions and operates as expected. This was achieved by assessing whether the results obtained during the experiments fulfil the requirements of the application as stipulated in chapter 4. Both functional and non-functional aspects of the system were considered to determine whether the system meets the requirements.

After the development of each system unit, such unit was tested and evaluated separately in order to measure its performance. This process ensured that defects in each unit were discovered and solved early. The first testing exercise took place within a controlled environment, at the Namibia Business Innovation Institute's mobile lab. This was useful in testing how well the Location Service performs in enclosed environments such as buildings. The second testing took place in an open space (field test) in Katutura. Combinations of black and white box testing techniques were used, ensuring that the internal structures and application functionalities perform as ought to.

7.3. Test criteria

Before presenting experimental results, we briefly discuss how each requirement was evaluated to measure whether the application feature that intends to satisfy that requirement passed the tests.

7.3.1. Functional requirements

Functional requirements are presented in the form of use cases in section 4.2; requirements are presented as use cases because use cases make it easier to identify the different stakeholders and their interactions with the system. These use cases were then translated into system functionalities. In section 7.4, the prototype application was evaluated using test cases that emulate real life cases by comparing the results of the prototype with expected results to determine whether the application fulfils specifications.

7.3.2. Non-functional requirements

Non-functional requirements are inevitable for the success of any system or application. As stated and clarified in chapter 4, non-functional requirements can determine the overall behaviour of the system. Although some non-requirements are difficult to quantify, in this section we will discuss each one of them individually. Usability is a very important aspect in any system, thus it was important to make sure that the design of the prototype application was kept simple. In terms of performance, we opted to host the database on Firebase which offers great performance, and can support up to 100 000 concurrent users.

7.3.3. Test trials

Tests undertaken in this section were carried out to validate the implemented solution against the promised system functionalities.

7.3.4. Acceptance test

Real life scenarios were used to evaluate whether the system meets the needs for which it was designed. The tests were conducted using the following scenarios.

- Scenario 1 - In the first scenario we demonstrated a case where a user searches for a route between two places, origin to destination bus stop.
- Scenario 2 – The second test case showed how a user can be navigated to a bus stop based on his/her location.

During testing simulation, the tester will move from where he/she is to a bus stop following the directions as provided by the system. Guided by the mobile application, the user will know exactly how far he/she is from the bus stop and when he/she arrives at the stop.

Scenario 1

In this scenario, our user is located at A Shipena bus stop and would like to go to Wanaheda bus stop to get some *Kapana* (a barbeque meat delicacy in Namibia). Once the user has entered the origin and destination bus stops, the

best route from source to destination is illustrated on the map. Additionally, users can view buses and the arrival time stamps of all buses that service that specific route. The results of our test case are shown in table 1 below.

Objective Search a route	
Prerequisites <ul style="list-style-type: none"> ● <i>The application has been successfully installed on the user's mobile device</i> ● <i>Internet connection</i> 	
Procedure	Expected result
1. Enter source and destination location 2. Click on the icon representing an arrow to search for the best route 3. Click on the view buses button at bottom of the screen	In the map view the best route as drawn and represented by a blue line Distance between the two points is shown in a dialog box See a list of buses that service that specific route and the times of departure
Post conditions None.	
Pass / Fail Pass	

Table 1: Testing the search route functionality

Scenario 2

In the second scenario, we demonstrated the ability of the user to navigate from their current location to a given bus stop. In this case, our user is located at Namibia University of Science and Technology (NUST) and would like to go to Government Park. This test case emphasises more on the flexibility of the search method to provide alternative ways of navigating to a given bus stop based on their location. This functionality is helpful to help users who are not familiar with bus stop names. Table 2 shows the results obtained from the test.

Objective Navigation from one place to another	
Prerequisites <ul style="list-style-type: none"> ● <i>The application has been successfully installed on the user's mobile device</i> ● <i>GPS has been enabled</i> ● <i>Internet connection</i> 	
Procedure	Expected result
<ol style="list-style-type: none"> 1. Enter destination place 2. Click on the icon representing an arrow to search for the best route 3. Click on the view buses button at bottom of the screen 	<p>In the map view the best route is drawn and represented by a blue line</p> <p>View direction from your location to your destination</p> <p>Distance and how long it will take to travel between the two points is shown in a dialog box</p> <p>See a list of buses that service that specific route and the times of departure</p>
Post conditions None.	
Pass / Fail Pass	

Table 2: Testing the places search functionality.

The obtained results show that the application's search method is flexible to accommodate different ways of searching for a bus stop. In the following section we describe the results obtained from the performance analysis of the system.

7.3.5. Performance test

In order to evaluate the time, the performance of the system, the time taken to load data from the backend into the application was measured. We also

evaluated the time it takes to load Google Maps content via the Google Maps API.

Method name	Arguments	Time (in sec)
getDistance	LatLng my_latlong, LatLng stop_latlong	1.99
getBearing	LatLng begin, LatLng end	0.89
getJSONFromUrl	String url	6.05
drawPath	String result	5.78
makeURL	double sourceLat, double sourceLog, double destLat, double destLog	3.34
getDirection	Document doc	4.60
decodePoly	String encoded	5.80

Table 3: Testing API in seconds

Generally, we observed that users with faster bandwidth download the content faster to their devices compared to users with slower connections. However, our data is stored as JSON objects in the database, reducing the performance overheads; although a variance exists between the times it takes to load different content from the database base, mainly due to the fact that resources have different sizes. However, to overcome this delay, we identified resources that will not change often - such as bus stops and routes information. This resource will be downloaded once, then it gets stored in application memory and only updates when there are new changes in the database. Thus this saves the bandwidth of the user and also increases performance.

The following section describes how the experiments were carried out.

7.4. Demonstrations: Scenario examples

This section describes whether the system features performed as expected. The system functionalities were evaluated in a form of user stories or scenarios. This approach was adopted because it simulates how the users will be using the application in a real life setting. Let us consider the first scenario, where a user opens the application. The main activity is loaded, which displays the user's current location and the location of the buses in real time. This feature will enable the user to see how far the bus is from the bus stop and approximately how long it will take for the bus to reach the bus stop. The municipal official can also use this feature to monitor if all buses are punctual and that they are following the designated routes.

In order simulate this behaviour; an indoor navigation simulation was used. Using this approach, two mobile phones with GPS sensors were used and their movement tracked to simulate a moving bus. Through the application, the user can see the position of the simulated bus on the map and once they click on the icon, information as to where the bus is heading to will be given in the form of a dialog box. Figure 7-1 shows the screen shot of the application displaying moving buses and the user's current location. In a case where the user wants to view information pertaining to bus stops, on the landing page (main activity) the user clicks on the navigation drawer panel on the left edge of the screen. Once the navigation panel is open, the user then clicks on view bus stops menu option. An activity as the one shown in figure 7-2 will appear.

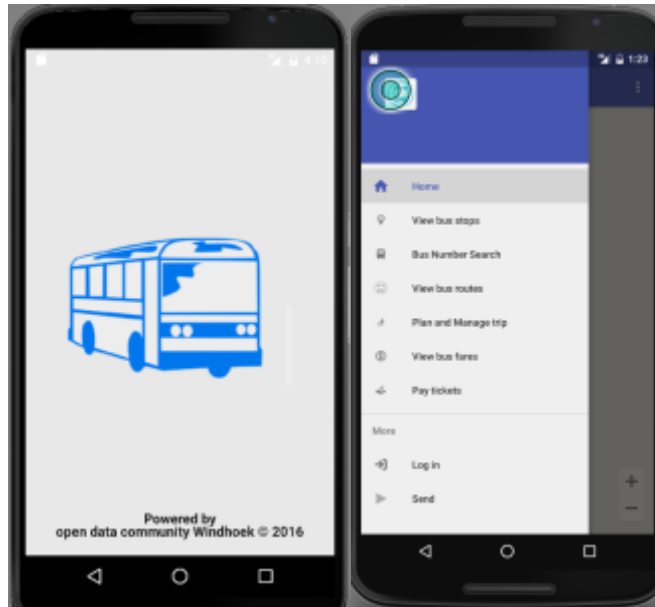


Figure 7-1: Information regarding the current location of the user.

The current location of the user is represented by the red mark on the map, while the blue marker represents bus stops as illustrated in Figure 7-1. Additional information regarding a particular bus stop can be acquired by tapping on the bus stop marker icon as illustrated in figure 7-2.

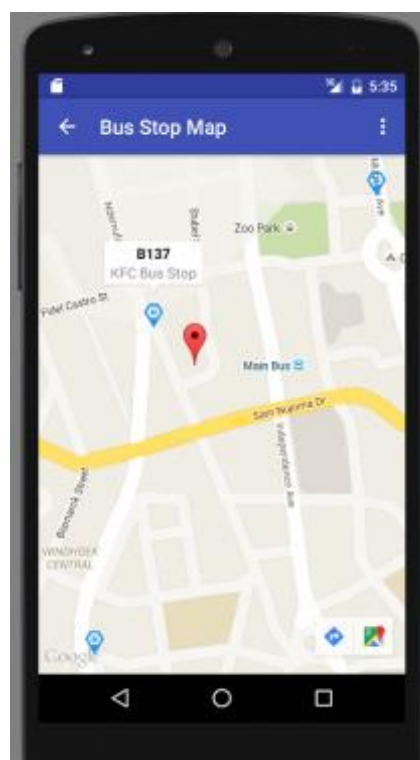


Figure 7-2: Bus stop details

The fourth scenario simulates a case where the user wants to search a particular bus. Once the user selects Search bus number, a list view will be displayed comprising of all buses and how often they service a particular route. To obtain information pertaining to bus schedules, a user selects a bus from the list. The user is directed to a new activity, displaying information regarding routes and bus timetables. Figure 7-3 shows a list of buses and how frequently they drive.

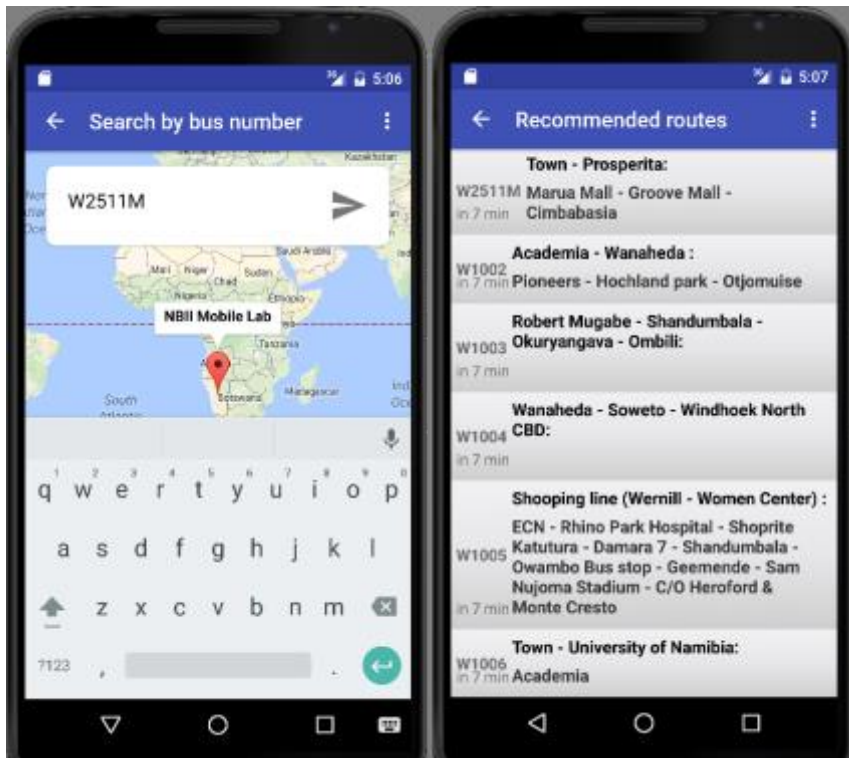


Figure 7-3: Information on bus numbers.

In a case where a user wants to search for a specific route directly, on the navigation drawer panel, a user selects the view bus routes menu option. This opens a new activity where the user is prompted to enter the bus station they would depart from and the bus station they would like to arrive at. The user should also be provided with information regarding the distance of how far they intend to travel, how long it will take them to move from point A to B and the best option (for example taking one bus or multiple buses).

To prevent users from entering unknown or non-existent bus stops, autosuggestion as can be seen in figure 7-4 helps the user to enter the right bus stop information. This reduces the error rate.

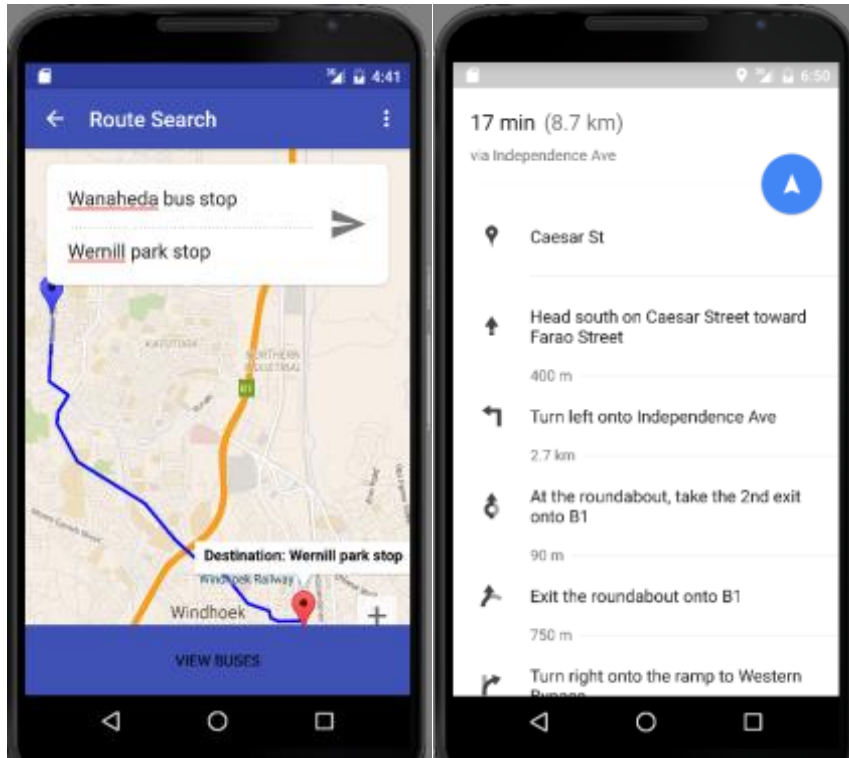


Figure 7-4: Screenshots showing how to search a route

The results are presented to the user on Google maps, which has been incorporated in the application. Google maps service is used because of obvious reasons; one being that it works on most platforms: mobile, desktop and web. Secondly, Google maps service has rich navigation resources.

7.5. Summary

In this chapter, the assessment of the system was presented following the measurements of its performance tests that were done. In order to determine whether our system meets the requirements stated in chapter 4, we ran test cases. The system managed to pass all executed test cases, however problems with GPS accuracy were encountered especially when dealing with navigations in enclosed environments. The performance of the system was reviewed, taking into consideration how long it takes to load routes and bus stops information from our database. Therefore, in order to improve performance, we opted to use Firebase as database. Firebase objects are stored in a JSON file, which is small in size, thus allowing system resources to be loaded into the application faster.

8. Conclusion and future work

This chapter summarises the results and lessons learned while undertaking this study and finally concludes with recommendations for possible improvements of the mobile application to incorporate a real time payment module and other enhancements.

8.1. Summary

Lack of information often leads to uninformed decisions, and subsequently to poor planning. In a pursuit to become more informed, citizens are increasingly demanding for the release of more public datasets (Tydd, 2014). This is due to the well-established benefits and the impact that sharing and use of public datasets can have on any given society. Despite the usefulness and benefits of open data being present, a lot of people especially in developing nations, including Namibia, are not aware of open data and its benefits. Without awareness, the true potential of open data cannot be realised. We cannot prove that the developed mobile application created awareness and increased the consumption of open data, but the application practically illustrates how citizens can utilise open data to develop a useful solution.

In this study we reviewed the benefits and challenges of open data, adequate knowledge of how technology can be used as a tool to influence people was established, notwithstanding the challenges and hurdles encountered while undertaking this study. Through a comprehensive evaluation of various literature and constant engagement with citizens, a concrete understanding and knowledge regarding open data and how visualising the data into applications can be the most effective manner to unleash the true potential of open data was established; as well as make citizens aware of the value of data, thus encouraging them to consume open data in pursuit of these incentives. By designing the city bus application, the main research objective was achieved.

The aim of the developed mobile application was to use open data to solve public transportation woes in Windhoek. Secondly, it was to make citizens

vigilant about what open data is, its incentives and how these benefits can be obtained. Through the hackathon sessions held in the context of this study, citizens were encouraged to visualise open data into innovative applications that help communities overcome real problems they are facing. Although several approaches exist to entice both citizens and government to buy in open data initiatives; visualising and mashing up the data into solutions, for example a mobile application proves to be the most convenient approach.

In the following section tangible results accomplished in the context of this study are outlined.

8.2. Accomplishments / Deliverables

As stated in section 1.4, the main goal of this thesis was to develop a mobile application that uses open data to connect citizens to public transportation services in Windhoek.

We designed a robust application, which we hope to launch in the near future. The application will make public bus services accessible to people of all walks of life, enabling them to discover bus stops around them, view bus routes and other information pertaining to the municipal buses. Additionally, we have also hosted two open data innovations hackathons where developers, designers, statisticians and citizens co-created to come up with solutions that solve local challenges using open data. These solutions were explained in one of our earlier works (Amugongo *et al.*, 2015).

In chapter 7, the developed Android mobile application was evaluated. During the evaluation, we demonstrated that the application is able to pull schedules and route information from our database. Moreover, using real life scenarios, the application proved to provide meaningful and accurate information to users and it enabled users to easily locate bus stops in their vicinity or close to them. In the context of this study, we also developed Namibia's open data portal, which intends to serve as a central repository for public data in Namibia. The portal will also ease access to reusable

public datasets through APIs. The demo version of the portal can be found here: <http://demo.namopendata.com/>.

8.3. Lesson learned

In this section, we reflect on the lessons learned based on the researcher's experiences while undertaking this study. One of the most crucial lessons learned in this study is that open data is holistic in nature, thus it requires a well-thought, inclusive approach to increase open data awareness and consumption. Despite the crucial role played by technology in order to make the data available and easily usable, policies and citizens have a key role to play in ensuring that open data initiatives are successful. Moreover, when dealing with data, there is a high need to address trust and privacy issues.

In this study we also affirmed the belief that although different approaches can be taken in order to create awareness about the importance of open data, the visualisation of public data into a format that is easily understandable by all, such as a mobile application proved to be the most effective approach. As this does not only result in the creation of a solution that solves a social problem but also demonstrates how public data can be transformed into a useful product. Furthermore, we have also learned that awareness is not a once off process but a continuous process. Therefore, it was important beyond this study to ensure continuity.

This study has not only designed an easy to use application for the municipal bus service in Windhoek, it has also proliferated interest in open data from both the public and private sector in Namibia.

Visualising or transforming data into applications proved to be an effective way to illustrate the value in data. Positive feedback was obtained regarding how the application developed in the context of this study and those developed during the hackathons hosted in the context of this study made citizens become aware of the value of open data. Using this practical approach, citizens became aware of the opportunities that open

data present. Moreover, this high interest from both government and citizens in open data was very clear in the hackathon sessions.

8.4. Future work

The city bus prototype application was designed with novice users in mind; hence the simple designs. At present the system is still in prototyping phase, improvements need to be made in the future before the application is ready for public use. Though the accuracy of the LocationService and performance of the prototype was very impressive; the algorithm that calculates the shortest path from one station to another still needs to be enhanced for efficiency. The algorithm currently only calculates the distance from start station to end station, but it does not calculate the distance of the stations in between. As per feedback obtained from stakeholders, a payment module needs to be developed in the future to facilitate the sales and purchasing of bus tickets. This requires that the algorithm must be improved to enable it to calculate interstation distance.

With the awareness created in this study, we are beginning to see more innovations transforming public datasets into solutions and products. This continuous use of public data will drive the adoption of policies and legislation, which will further amplify the success of open data initiatives in Namibia. Finally, to ensure continuity of the open data movement in Namibia, every year a hackathon will be held coinciding with the International open data day.

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Appendix A : Tools

In this Appendix A, tools used in the context of this study are listed.

Development tools

Mac: All works pertaining to this thesis have been carried out using a Apple MacBook Pro running X Yosemite Operating system version 10.10.5. Additionally, all applications used ran from mac os.

Wireframe Sketcher: Wireframe Sketcher was used to design the screen layouts before they were implemented using Android studio.

Dia: Dia was to design the entity relationship diagram (ER-D).

Mendeley tool: Mendeley a tool

Android Studio: Android studio, an intergrated development environment (IDE) provided Google for Android mobile applications development was used.

Appendix B : Code

```
private String getDistance(LatLng my_latlong,LatLng stop_latlong){
    Location l1=new Location("One");
    l1.setLatitude(my_latlong.latitude);
    l1.setLongitude(my_latlong.longitude);

    Location l2=new Location("Two");
    l2.setLatitude(stop_latlong.latitude);
    l2.setLongitude(stop_latlong.longitude);

    float distance=l1.distanceTo(l2);
    String dist=distance+" M";

    if(distance>1000.0f)
    {
```



```

        distance=distance/1000.0f;
        dist=distance+" KM";
    }
    return dist;
}

```

Figure B-1Method used to calculate distance between two points.

```

private String getDirection(LatLng origin_latlong,LatLng dest_latlong) {
    double start_lat=origin_latlong.latitude;
    double start_long=origin_latlong.longitude;

    double dest_lat=dest_latlong.latitude;
    double dest_long=dest_latlong.longitude;

    double radians=getAtan2((dest_long-start_long),(dest_lat-start_lat));
    double compassReading = radians * (180 / Math.PI);

    String[] coordNames = {"North", "North-East", "East", "South-East", "South", "South-West", "West",
"North-West", "North"};
    int coordIndex = (int) Math.round(compassReading / 45);

    if (coordIndex < 0) {
        coordIndex = coordIndex + 8;
    };

    return coordNames[coordIndex]; // returns the coordinate value
}

```

Figure B-2Function used to determine the direction the user needs to take to get to bus stop.

```

public void drawPath(String result) {

    if (line != null) {

        mMap.clear();

    }
}

```

```

mMap.addMarker(new MarkerOptions().title("My Location: "+starttext).position(startLatLng).icon(
    BitmapDescriptorFactory.defaultMarker(BitmapDescriptorFactory.HUE_BLUE));

mMap.addMarker(new MarkerOptions().title("Destination: "+endtext).position(endLatLng).icon(
    BitmapDescriptorFactory.defaultMarker(BitmapDescriptorFactory.HUE_RED));

try {
    // Transform the string into a json object

    final JSONObject json = new JSONObject(result);

    JSONArray routeArray = json.getJSONArray("routes");

    JSONObject routes = routeArray.getJSONObject(0);

    JSONObject overviewPolylines = routes
        .getJSONObject("overview_polyline");

    String encodedString = overviewPolylines.getString("points");

    List<LatLng> list = decodePoly(encodedString);

    PolylineOptions options = new PolylineOptions().width(10).color(Color.BLUE).geodesic(true);

    for (int z = 0; z < list.size(); z++) {

        LatLng point = list.get(z);

        options.add(point);

    }

    line = mMap.addPolyline(options);

} catch (Exception e) {

    e.printStackTrace();

}
}

```

Figure B-3Function used to draw the route of the bus on map.

Appendix C : Test cases

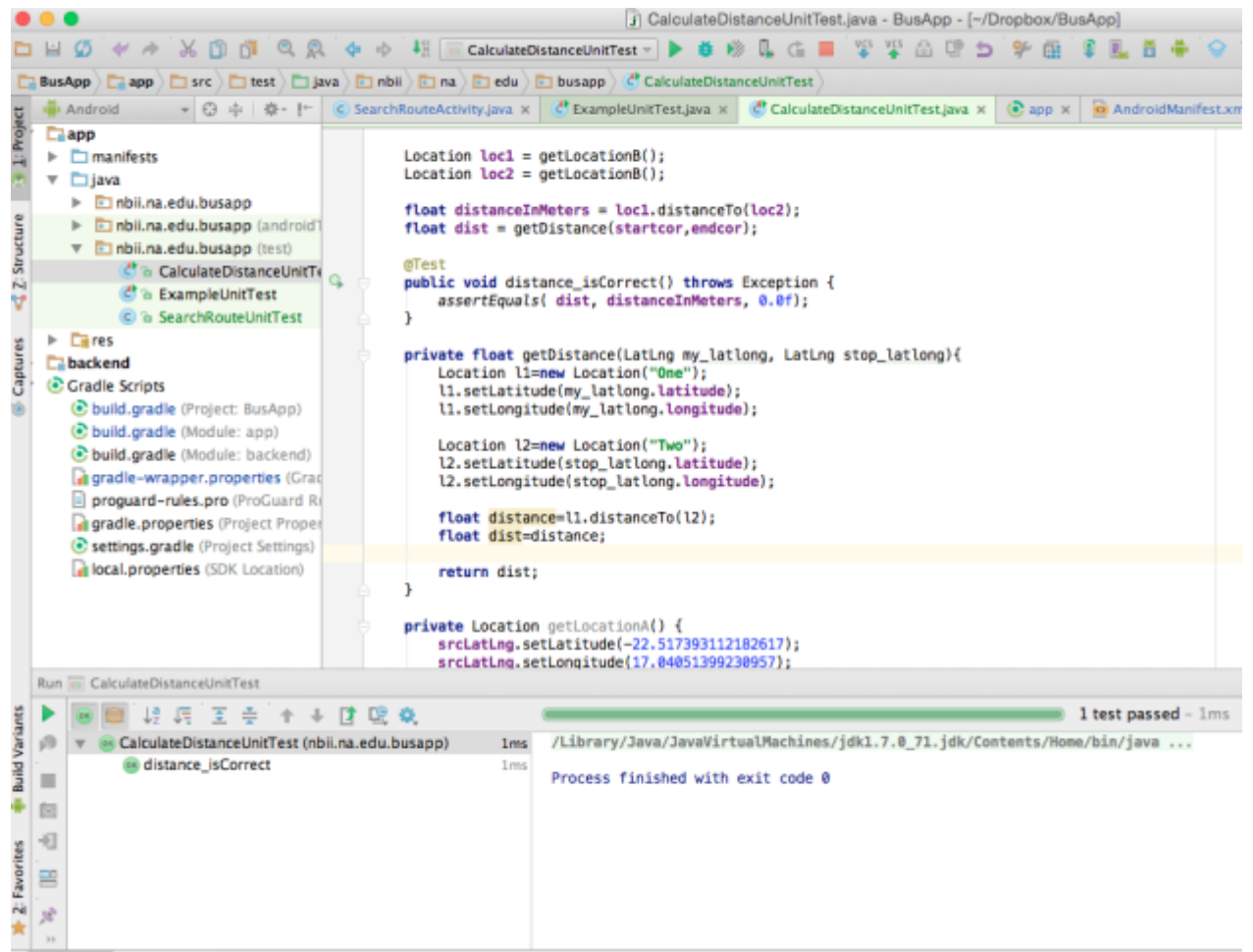


Figure C- calculate distance between two points test case.

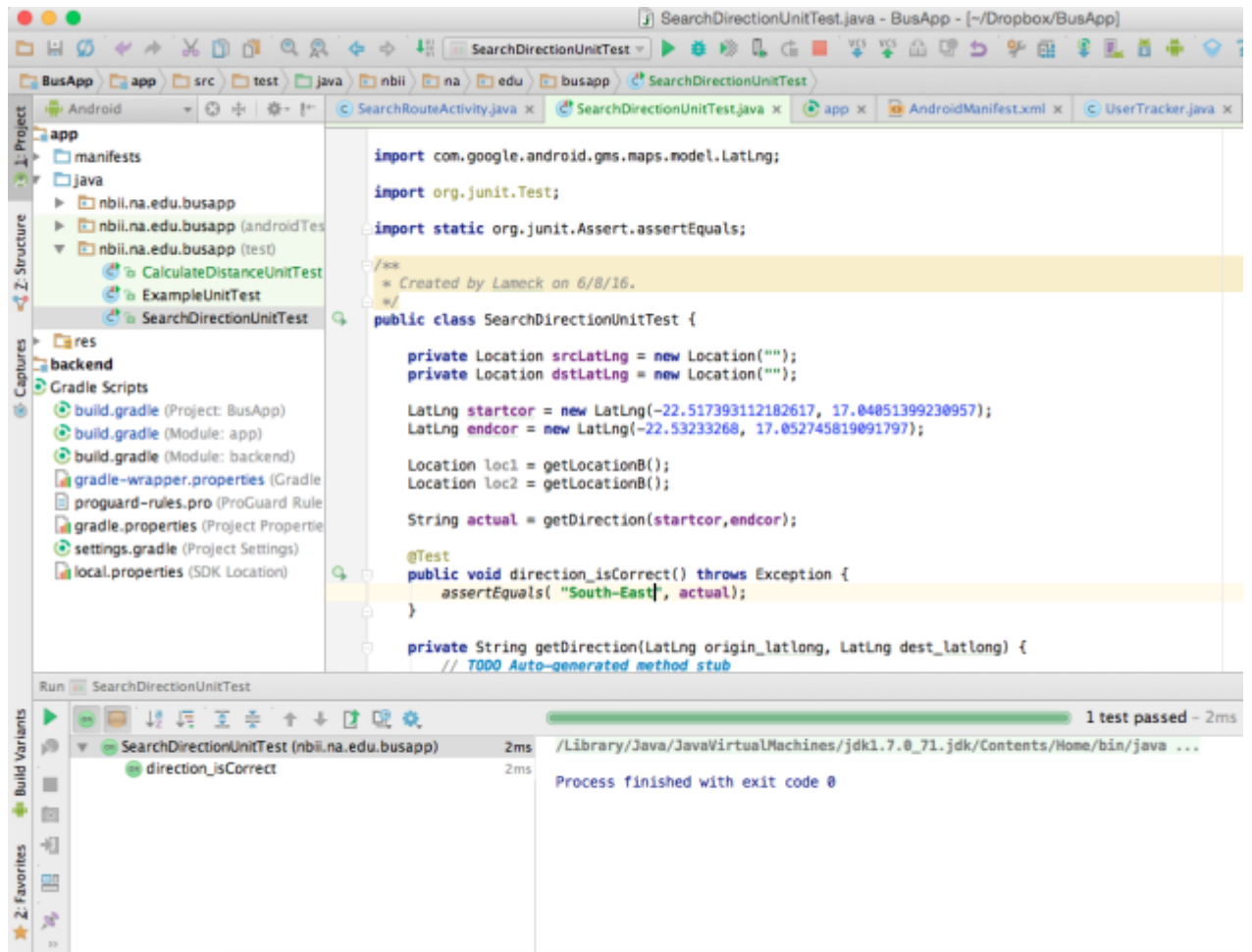


Figure C- Direction test case.