UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service

Research submitted to the College of Law and Management Studies

As fulfilment

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By

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DECLARATION

I **Vicent Mbonye** declare that

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APPROVAL

This research and dissertation titled "UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service" has been done under my supervision and guidance is now submitted for examination.

Signature…… Date: 08/March/2019

Supervisor C.S. Price

School of Management, I.T and Governance

College of Law and Management Studies

DEDICATION

This dissertation is dedicated to my parents, Miss Evangelista Munderi and Julius Basaza Ganza who have always encouraged me to focus on my dreams, goals and ambitions. I also dedicate it this to my two lovely sisters Devine Dorothy Kabera and Mrs. Agatha Razano and my two grandparents Mrs. Juliana Munderi and Mrs. Margret Basaza. And finally, I dedicate this research to all my cousins, nieces and other relatives.

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May God bless you all.

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AP	Access point
BSS	Basic service set
DSSS	Direct sequence spread spectrum
ESS	Extended service set
FHSS	Frequency hopping spread spectrum
Gbps	Gigabits per second
GHz	Gigahertz
Hz	Hertz
ICS	Information and Communication Services Division of UKZN
IEEE	Institute of Electrical and Electronics Engineers
IQ	Interaction quality
IT	Information technology
KMO	Kaiser-Meyer-Olkin
LAN	Local Area Network
LANs	Local Area Networks
LMS	Learning Management System
Mbits/s	Megabits per second
Mbps	Megabits per second
MHz	Megahertz
MIMO	Multiple input - multiple output
OFDM	Orthogonal frequency division multiplexing
OQ	Outcome quality

PCs	Personal computers
PEQ	Physical environment quality
RAM	Random access memory
RF	Radio frequency
RMS	Risk Management Services
SISO	Single input - single output
SPSS	Statistical Package for Social Science
SQ	Service quality
SRC	Student Representative Council
UKZN	University of KwaZulu-Natal
Wi-Fi	Wireless fidelity
WLAN	Wireless local area network
WLANs	Wireless local area networks
WPA2	Wi-Fi protected access 2 encryption

ABSTRACT

As Higher Learning Institutions set up Wi-Fi infrastructure in different locations on-campus, they need to provide high quality services to support students' learning. However, there has been little effort to ascertain how students use Wi-Fi on-campus, and how they perceive the quality of Wi-Fi in specific campus locations. Most research provides general information which makes it hard for Wi-Fi implementers to pinpoint the exact locations where services may need to be improved. This study follows a mixed method approach to present quantitative results from a representative sample of 373 students on UKZN Westville campus to understand how they use of Wi-Fi and their perceptions of service quality in different locations on-campus. It also presents qualitative information from interviews with two ICS administrators to understand Wi-Fi deployment strategies adopted on-campus and what Wi-Fi related problems students report.

The most-used Wi-Fi locations were the on-campus residences (29.2%), the library (24.1%), computer LANs (17.4%) and lecture venues (17.2%). The worst Wi-Fi quality was reported in the Cafeteria (36.3%), the library (20.6%), and the Quad (15.4%). The best Wi-Fi quality was found in the computer LANs (34.2%), lecture venues (21.8%) and on-campus residences (11.8%). The Wi-Fi usage patterns are described according to the students' accommodation type, as these patterns are very different. Best and worst times for using Wi-Fi in various locations is also given. The study showed that while students used various Wi-Fi devices to access Wi-Fi services on campus, the majority of them did not know the Wi-Fi standards, memory and speeds supported by their devices.

When students faced difficulties, they stopped using Wi-Fi (38.6%), changed location (25.4%) or changed position in the same location (14.9%). Very few (8.6%) reported it to ICS. 86.3% did not know how to log a call with ICS. On-campus residence students reported Wi-Fi difficulties the most to ICS and they experienced the least difficulties in their residences. This shows that the ICS training for these students has paid off.

The study bases its conceptual framework on the Brady & Cronin Jr. (2001) service quality model, which includes factors of outcome quality, physical environment quality and interaction quality. Outcome quality was used to understand students' perception of the stability, availability reliability and timeliness of Wi-Fi services. Physical environment quality was used to understand the ambient conditions, social factors and design of the locations in which Wi-Fi is used. Interaction quality was used to understand the students' perceptions of the behaviour, attitude and expertise quality of their interactions with ICS administrators. Overall, students rated the perceived Wi-Fi quality at just over 4.5 on a 7 point Likert scale. While this is greater than neutral, it can be improved.

In a regression analysis of the constructs as a whole, the constructs account for 59.5% (R^2 = .595) of the variance of service quality, F (3, 369) = 180.527, p<.0005. Outcome quality (β=.667, p<.0005), and interaction quality (β=.402, p=<.0005) are both significant predictors of service quality. However, physical environment quality is not. When regression models were generated for individual locations, for the most part, the R^2 value improved.

This study can be used by ICS to improve the Wi-Fi quality of service on campus, especially in areas where students use it the most, like in the library. ICS can also improve awareness of call logging amongst students, and how their choice of devices could affect their perceived Wi-Fi quality. The model could be used iteratively in future to test and monitor the quality of Wi-Fi services on campus, as well as in other environments, e.g. hospitals, hotels and airports.

1 INTRODUCTION

1.1 Introduction and overview of the study

Computer networks allow people and equipment to connect to each other regardless of their location in the world. This has motivated people to establish networks in many environments (Călin-Alexandru, Cristian-Adrian, Fuicu, & Marcu, 2015; Fitzgerald & Dennis, 2005). For example, people install computer networks in schools, airports and railway stations to enable users to share and access network services.

While many network types exist in the world today, Local Area Networks (LANs) are the most widely adopted networks. They provide faster information flow from one point to another using wired connectivity (Fitzgerald & Dennis, 2005; Stallings, 2004). This allows users to share files, programs and other resources within a small geographical area (Fitzgerald & Dennis, 2005).

Since the start of the 1990s, there has been a gradually increasing interconnectivity of LANs to create the Internet (Fitzgerald & Dennis, 2005). This has been due to the growth of the World Wide Web (web resources) and other Internet technologies (Cheung & Huang, 2005; Leiner et al., 2009). Computers on LANs do not need Internet connections to communicate with other computers on the same network. However, by connecting them to the Internet, users can access published documents, high-level services and other content, worldwide (Adekunmisi, Ajala, & Iyoro, 2013).

In institutions of higher learning, the Internet provides accessible and cost-effective ways in which students can access an interactive learning experience (Garrison & Kanuka, 2004). For example, it facilitates access to web resources that offer educational material to supplement what students learn and enables communication with educators (Chhachhar, Khushk, Chachar, & Qureshi, 2013). The Internet has steered the development of online approaches to teaching and learning. This increases the flexibility and freedom with which students can access information (Hicks, Reid, & George, 2001). Consequently, this has increased students' demand for online access in institutions of higher learning (Song, Singleton, Hill, & Koh, 2004). Institutions of higher learning are therefore challenged to cater for the connectivity demands of new students and to meet the rising expectations and demands for higher quality

learning experiences and results (Garrison & Kanuka, 2004). Moreover, once they provide appropriate and sufficient educational technology within the institutions, students are motivated to learn to use the technology to support their studies (Yau, Cheng, & Ho, 2015).

However, a major concern with the use of LANs to access Internet resources is that users can only use the computers in one physical location, thus limiting their mobility and flexibility. This is because communicating over the local area network requires the computer user to be in one physical location, which is limited by the length of the network cable connected to the computer. This has led to the wide adoption of wireless local area networks (WLANs) to extend the reach of local area networks (Chen, Jin, Suh, Wang, & Wei, 2012; Macha & Damodaram, 2016; Reynolds, 2003). WLANs enable users to access services on LANs, like the Internet, while on the move, by providing wireless connectivity to LANs over the air (Ali & Mustafa, 2015; Doufexi et al., 2002; Held, 2003). The wide adoption of WLANs is due to the development of the IEEE802.11 WLAN standards by the Institute of Electrical and Electronics Engineers' (IEEE) (IEEE 802.11 Working Group, 2009; Keranidis et al., 2014; Macha & Damodaram, 2016; Malik, Qadir, Ahmad, Yau, & Ullah, 2015). Most wireless local area network technology is referred to as 'Wi-Fi' (Macha & Damodaram, 2016). Hence, this study defines Wi-Fi as any wireless local area network that operates using an IEEE 802.11 standard (Aime, Calandriello, & Lioy, 2007).

Wi-Fi is a major driver in the growth of many sectors worldwide. It is used for many purposes across the globe (Bing, 2002). For instance, it allows users to access low-cost, high-quality services and is an important part of daily web browsing, file exchange, texting and e-mailing (Macha & Damodaram, 2016). Wi-Fi services enable users to access live audio or video streams in homes, parks, offices, enterprise environments, retail stores and hotels (Fitzgerald & Dennis, 2005; Macha & Damodaram, 2016).

Similarly, institutions of higher learning provide Wi-Fi services to students on campus to keep up with the students' online connection demands to support their learning (Chen et al., 2012; Han, 2008; Tella, 2007). This expands students' learning to beyond the normal class schedule (Bidin, Shamsudin, Hashim, Farid, & Sharif, 2011). For instance, in South Africa, universities provide Wi-Fi to students to facilitate access to course material and other learning resources (University of Cape Town, 2017; University of KwaZulu-Natal, 2017; University of Pretoria, 2017).

As users access wireless networks, they expect the network providers to give them guarantees of the quality of the service (Malik et al., 2015). The quality of service guarantees given to the users of a service allows them to compare the quality promised to what they get. They enable network providers to measure user perception of the performance levels of the services delivered to them. While services that deliver high-performance levels encourage the use thereof, users may stop using those services that deliver poor performance (McDougall & Levesque, 2000). Hence, understanding user perception of the service quality can help service providers understand what service improvements are needed.

However, while the IEEE aims to improve the quality of wireless access methods to deliver better quality wireless services, users do not always receive good quality Wi-Fi services (Lindgren, Almquist, & Schelén, 2003; Malik et al., 2015; Zhai, Chen, & Fang, 2005). This is because there are several factors that may affect the outcome quality of Wi-Fi services. For example, when users have Wi-Fi devices with standards that are not compatible to the Wi-Fi standard adopted on the Wi-Fi network, they will not access Wi-Fi services (Abdelrahman, Mustafa, & Osman, 2015; Soyinka, 2010). In addition, different Wi-Fi standards provide varying benefits and limitations that arise from the use of different spectrums, modulation techniques and antenna technology (Abdelrahman et al., 2015; Macha & Damodaram, 2016; Soyinka, 2010). As such, some standards provide better resistance to signal interference, longer signal range, and better signal penetration through obstacles than others. In addition, the speed of the Wi-Fi device and the amount of memory it has can affect how Wi-Fi services are processed.

Network providers set up Wi-Fi access points in different locations to broadcast wireless signals over the air to Wi-Fi-supported devices. Thus, the configuration choices made at access points, like the spectrums and antenna, may affect the quality of the Wi-Fi outcome received by users. In addition, the choice of Wi-Fi location for access points may affect the quality of Wi-Fi services received. For example, Wi-Fi locations may have obstructions to, and sources of interferences with, Wi-Fi signals; hence hindering the efficient transmission of Wi-Fi signals between devices (Fitzgerald & Dennis, 2005; Macha & Damodaram, 2016).

Initial investigations to determine quality of service identified that the characteristics of the physical environment in which users receive a service affects the perceived quality of the service (Bitner, Booms, & Tetreault, 1990; Parasuraman, Zeithaml, & Berry, 1988). These

results are supported in a more recent study by Brady and Cronin Jr (2001). In their study, they argue that factors like the design of the environment and ambient conditions, such as temperature, may affect the perceived quality of services delivered. They add that social factors, such as the behaviour of people in the service environment, may also affect the perceived quality of the service delivered.

Users may interact with Wi-Fi service providers as they use services. These interactions may take place at the help desk or in the service locations. The quality of the interaction, in terms of the expertise, behaviour and attitude of the service provider, influences the way users perceive the quality of the service (Bitner et al., 1990; Booms & Bitner, 1981; Brady & Cronin Jr, 2001).

Wi-Fi deployment is a major component in delivering Internet-based services in many countries. If it is to improve the effectiveness and efficiency of institutions of higher learning, it is important to investigate how it is applied to support the teaching and learning process (Vajargah, Azadmanesh, & Jahani, 2010). However, it has not yet been established if outcome quality, the quality of the physical environment and interaction quality affects the way users perceive the quality of Wi-Fi services in Wi-Fi locations. Network providers may monitor the network through site surveys and the collection of infrastructure-side data to improve the quality of networks. However, neither of these methods can completely and constantly reflect the real network conditions experienced by the users the network is supposed to serve (Shi et al., 2016). This is because some factors which may affect the quality of Wi-Fi services, as perceived by users, result from their usage experiences; such as being out of range of the Wi-Fi signal; choosing which Wi-Fi devices to use on the Wi-Fi network; and interactions with administrators and others (Bing, 2002; Soyinka, 2010).

Although it is not yet well understood how to determine and improve the quality of Wi-Fi network services (Zhai et al., 2005), technology and governance organisations propose solutions. For example, the Information Systems Audit and Control Association (2012) argue that organisations can improve the quality of a particular service by understanding how users use the service and by measuring their degree of satisfaction. Hence, as students use Wi-Fi services on campus at institutions of higher learning, it is important to understand how they use it in different locations. This will allow institutions of higher learning to understand factors that may influence student perceptions of quality and the difficulties they face when using Wi-

Fi. By understanding students' perception of service quality, institutions will have a benchmark against which to manage and improve the quality of the Wi-Fi services they deliver. It will also ensure that the technology delivered is dependable and transparent, thereby assisting students in their learning and academic goals – rather than obstructing them (Garrison & Kanuka, 2004). However, no such study has been done in South Africa.

1.2 Background

The University of KwaZulu-Natal (UKZN) provides Internet accessible web resources to students; for instance, the UKZN student e-mail, Student Central and an online library. Students use them to communicate, view marks from registered modules and access electronic resources like journal articles. From 2016, it became compulsory for first- and second-year students to access modules on the Moodle Learning Management System (LMS) Internet web resource (Vithal, 2015).

The university has also invested in Wi-Fi technology to support students' access to the web resources provided. Before the installation of Wi-Fi, students would access web resources in local area networks (LANs) at the university. Between 2010 and 2012, the UKZN Westville campus provided Wi-Fi infrastructure in different on-campus locations using the IEEE 802.11.n standard (IEEE 802.11 Working Group, 2009). At present, the UKZN Information and Communication Services Division (ICS) on the Westville campus provides Wi-Fi in different locations on campus (see Figure 1 for a map of Westville campus). The ICS has installed Internet access points in lecture theatres, administrative buildings, laboratories, lecturers' offices, and in student residences on campus (O, S, P, R and Oval block) (Pers. comm., A Shariff[1]) (see Figure 2 and Figure 3).

To further increase the physical access to network resources, the university has also implemented Wi-Fi in the computer LANs to supplement the physically wired connection. Hence, computer LANs are also Wi-Fi locations on campus (see Figure 2). Wi-Fi can be used on the move. Students use Wi-Fi outside the venues in which access points are installed. For instance, the cafeteria has two locations at which students may use Wi-Fi services: inside the actual cafeteria, and on the outside of the cafeteria (see Figure 3). Other outside locations where students use Wi-Fi services include the Quad, and outside other buildings (see Figure 3).

[1] A. Shariff, Acting manager of ICS, UKZN, 2/9/2015

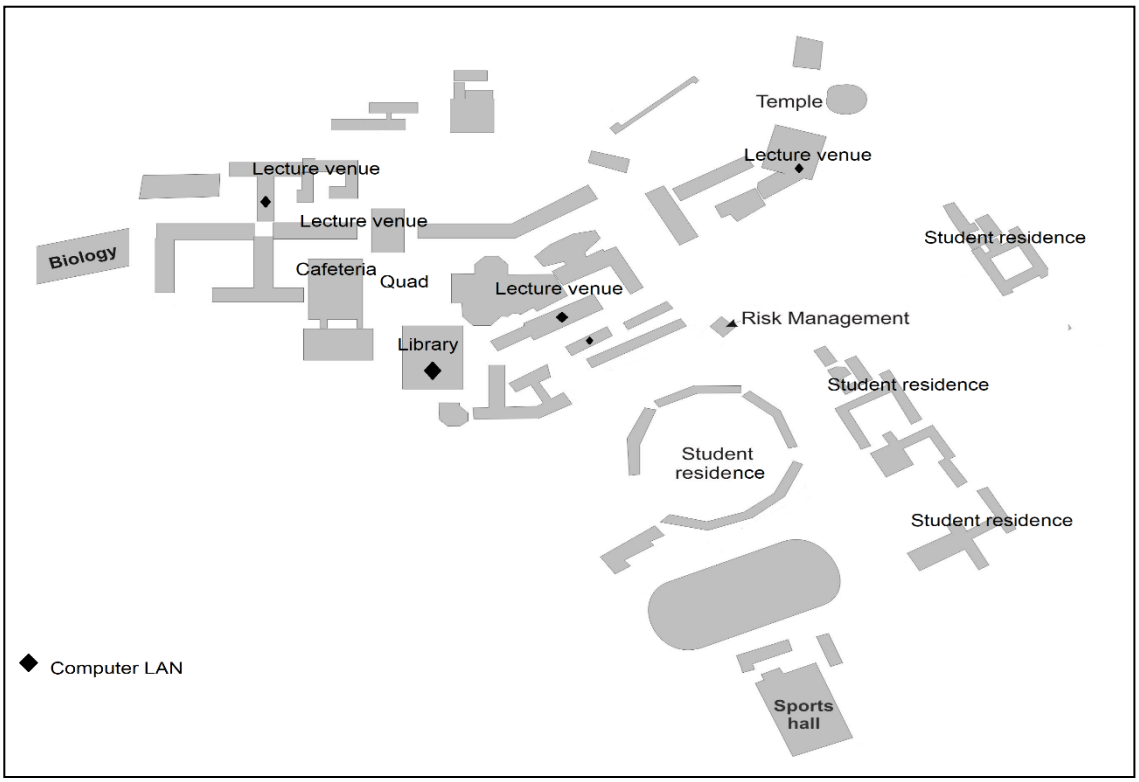

Figure 1: The University of KwaZulu-Natal, Westville campus

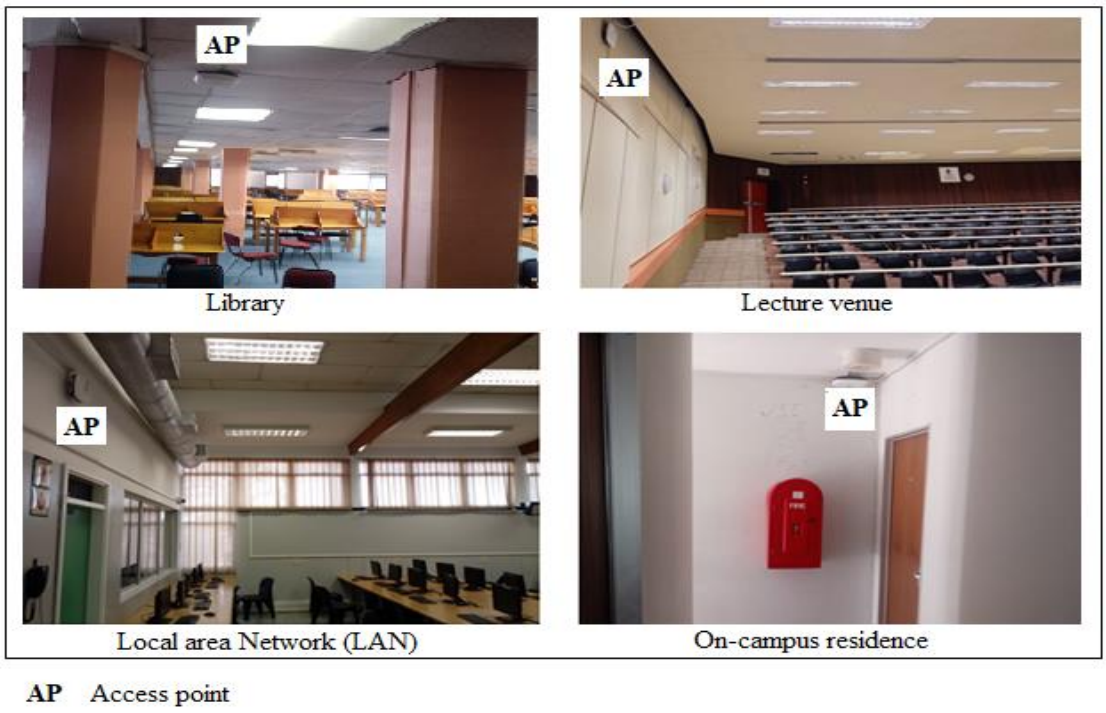

Figure 2: Access points in the library, a lecture venue, LAN and in an on-campus residence.

As can be seen in Figure 2, access points (indicated by the abbreviation AP with a white background) are installed on either the walls or the ceiling inside these locations.

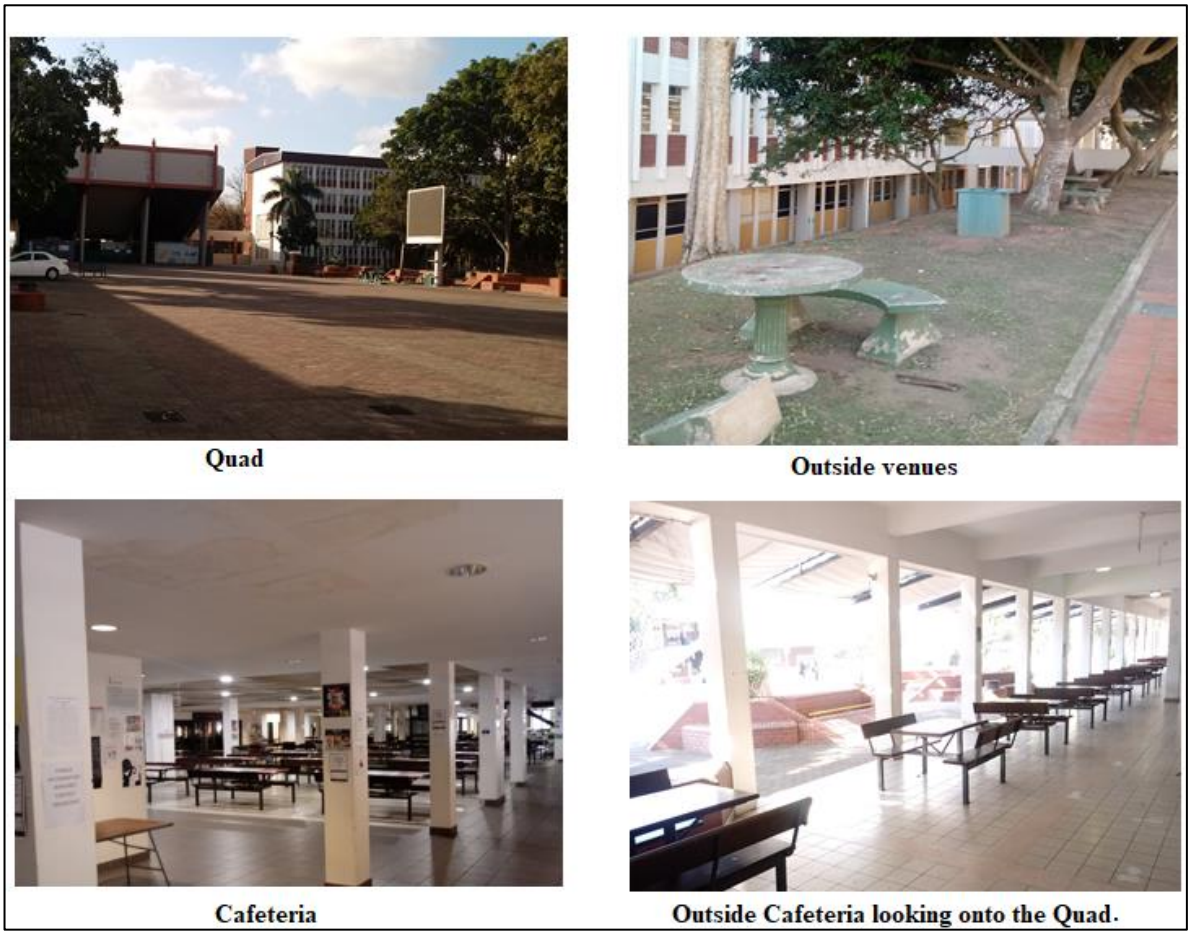

Figure 3: The Quad, outside venues, the cafeteria and outside the cafeteria.

Wi-Fi-enabled devices allow users to connect to Wi-Fi Internet access points. The university has instructed first- and second-year students to bring their own devices to access the Wi-Fi infrastructure provided (Vithal, 2015). In addition, a single student can connect multiple Wi-Fi devices to Internet access points in a location at the same time (Pers. comm., Mdikane[2]). As a result, device numbers may not give a good representation of the actual number of students using Wi-Fi in the locations. A student may access Wi-Fi from one access point and move to another location without losing connection. Hence, the university administration does not know the locations in which students most prefer to use the Wi-Fi resources. Without understanding the locations in which student prefer to use Wi-Fi services, the university may not fully support students' requirements. This may limit the effective allocation of Wi-Fi infrastructure resources on campus and could lead to the delivery of poor quality services. The Westville Student

[2] M. Mdikane, Head of Students Computing and Support, ICS, UKZN 7/7/2016

Representative Council (SRC) of 2015 attributed poor Wi-Fi signal quality in on-campus residences as one of the reasons for Westville students' protests in February 2015 (Student Representative Council, 2015).

Research has shown that several factors may affect the quality of Wi-Fi service provided. For example, other devices using wireless transmission technology may interfere with Wi-Fi signals (Călin-Alexandru et al., 2015). In addition, students face numerous difficulties using Wi-Fi access devices, which may influence Wi-Fi use and their perceived quality of the service (Chu & Lin, 2006). Given these points, Information Technology departments need to understand how users access their services and rate their satisfaction with the service delivered (Conrath & Mignen, 1990). This would provide an indication of how the Information Technology departments may improve the Wi-Fi services delivered to users to serve their needs. While students have access to Wi-Fi on campus, their experiences in using it at different locations on campus are not known. In addition, their perception of the quality of the Wi-Fi service is not known. This study will show locations in which students prefer to access Wi-Fi services on campus. In addition, it will report on students' perceptions of the quality of the Wi-Fi service and their experiences when using it in these locations.

1.3 Problem statement

As institutions of higher learning set up Wi-Fi infrastructure in different locations on campus to support access to course material and to facilitate communication (Adekunmisi et al., 2013; Tella, 2007), they need to deliver high quality services to support students' learning. However, despite the widespread use and adoption Wi-Fi networks, problems occurring in these networks result in poor quality service (Călin-Alexandru et al., 2015).

UKZN has implemented Wi-Fi in various on-campus locations to allow students to access various internet-accessible resources. However, ICS administrators at UKZN do not know how and where students use it. In addition, there has been no study in South Africa to investigate and identify factors that may limit the delivery of quality Wi-Fi services and to understand the user perceptions of its quality. As a result administrators, may not understand the difficulties students face using it. Furthermore, not understanding user perceptions of Wi-Fi quality may limit the evaluation, choice, adoption, and ongoing improvement of Wi-Fi services on campus.

1.4 Objectives of the study

1. Report how UKZN Westville students use Wi-Fi on campus:

    a) To identify the locations at which UKZN Westville students prefer to access Wi-Fi services on campus.

    b) To show how much time UKZN Westville students spend accessing Wi-Fi on campus.

    c) To investigate the Internet resources UKZN Westville students access when using Wi-Fi on campus.

    d) To show the devices UKZN Westville students use to access Wi-Fi on campus.

2. Identify the access point configurations and specifications provided on Westville campus.

3. Report the difficulties UKZN Westville students face when using Wi-Fi services on campus:

    a) To report the difficulties UKZN Westville students experience when using Wi-Fi services on campus.

    b) To investigate the difficulties UKZN Westville students report to ICS about the use of Wi-Fi services on campus.

4. Report on UKZN Westville students' perceptions of the quality of Wi-Fi service on campus.

    a) To report on UKZN Westville students' perceptions of the quality of service when using Wi-Fi services on campus.

    b) To report on UKZN Westville students' perceptions of the quality of the physical environment when using the Wi-Fi service on campus.

    c) To report on UKZN Westville students' perceptions of the interaction quality when using the Wi-Fi service on campus.

    d) To investigate how user system device quality and access point configuration specifications affect outcome quality.

5. Report how outcome quality, quality of physical environment and interaction quality affect students' perceptions of the quality of the Wi-Fi service.

6. Identify the factors that may affect Wi-Fi outcome quality on Westville campus.

1.5 Research questions

1. How do UKZN Westville students use Wi-Fi on campus?

    a) In what locations do UKZN Westville students prefer to access Wi-Fi services on campus?

    b) How much time do UKZN Westville students spend accessing Wi-Fi on campus?

    c) What Internet resources do UKZN Westville students access when using Wi-Fi on campus?

    d) What devices do UKZN Westville students use to access Wi-Fi on campus?

2. What access point configurations and specifications are provided on Westville campus?

3. What difficulties do UKZN Westville students face when using Wi-Fi services on campus?

    a) What difficulties do UKZN Westville students experience when using Wi-Fi services on campus?

    b) What difficulties do UKZN Westville students report to ICS, about the use of Wi-Fi services on campus?

4. What are UKZN Westville students' perceptions of the quality of Wi-Fi service on campus?

    a) What are UKZN Westville students' perceptions of the outcome quality when using the Wi-Fi service on campus?

    b) What are UKZN Westville students' perceptions of the quality of the physical environment when using the Wi-Fi on campus?

    c) What are UKZN Westville students' perceptions of the interaction quality when using the Wi-Fi service on campus?

d) How do user system device quality and access point configuration specifications affect outcome quality?

5. How does outcome quality, quality of physical environment and interaction quality affect students' perceived Wi-Fi service quality?

6. What factors may affect Wi-Fi outcome quality on Westville campus?

1.6 Overview of methodology

The study was conducted at the University of KwaZulu-Natal Westville in KwaZulu-Natal province, South Africa. The study was descriptive in nature, following a mixed methods approach that integrated both quantitative and qualitative research approaches. Quantitative data was collected from students using questionnaires and was then analysed using SPSS (Statistical Package for Social Science). In addition, the qualitative data was collected through two interviews with ICS administrators to gain a better understanding about the on-campus Wi-Fi infrastructure provided by the university. More details about the methodology can be found in Chapter 3.

1.7 Significance/Importance of the study

This study aims to identify locations where Westville UKZN students prefer to use Wi-Fi services. It also shows the locations and the times at which student get good and poor Wi-Fi signals and provides their overall perception of the quality of the Wi-Fi service. In addition, the study will report on difficulties students face while using Wi-Fi services, detailing what actions they take to solve these difficulties. The study identifies the factors that may influence students' perception of the quality of Wi-Fi services on the UKZN Westville campus. Thus, it will provide information that the university can use to improve the quality of the Wi-Fi service delivered to students. The study also proposes a quality of service model that Wi-Fi network providers could use to analyse and improve the quality of Wi-Fi services they deliver at a specific location. From the students' perspective, the study will inform students about the best times and locations at which the on-campus Wi-Fi service can be used. In addition, it will provide useful information regarding the specifications of Wi-Fi devices that students use while accessing Wi-Fi services. This could help students to use the Wi-Fi service more efficiently.

1.8 Justification/Rationale

Although universities offer free Wi-Fi on campus, to our knowledge there is no study in South Africa to find out how students use it on campus and how they perceive its quality. As a result, many institutions may not exploit potential opportunities to improve Wi-Fi services or explore the educational potential that an investment in Wi-Fi technology can have in students' academic life. In addition, there is no quality of service model in the literature that one can use to measure the quality of Wi-Fi services delivered.

On the UKZN Westville Campus, Wi-Fi has been installed for students to use; but no one has investigated how and where they use it. It is also not known how students perceive the quality of this service. The results of this study will provide UKZN administrators with information on how students view the Wi-Fi service provided at different locations, including its strengths and weaknesses. The results may, therefore, help administrators to improve the Wi-Fi services and to decide which infrastructure and administrative resources are needed for quality service delivery. Improved services could reinforce the university's technological ability to deliver quality education to students.

1.9 Organisation of the dissertation

The organisation of this dissertation is as follows: Chapter 1 presents a general introduction and overview of the study. It presents the motivation for carrying out the study, including its objectives and research questions. Chapter 2 contains the literature review. This section first presents literature on the implementation of Wi-Fi networks and elements of communication on Wi-Fi networks. Then it discusses the literature pertaining to factors that influence the adoption of Wi-Fi networks and students' use of Wi-Fi on campus. Then, it reviews the literature on quality of service. The last section focuses on the study's conceptual framework.

Chapter 3 describes the methodology chosen for the study. This chapter presents the research design, the approach, the data collection and the analysis techniques chosen for the study. Chapter 4 presents the results from the analysis of the data collected. It includes both the results from qualitative and quantitative data, presented with to the research questions identified for the study. Chapter 5 further builds on Chapter 4 by discussing the results from the analysis. The dissertation concludes with Chapter 6 which provides a conclusion and recommendations. The next chapter presents the literature review.

2 LITERATURE REVIEW

2.1 Introduction

This chapter summarises research on the use of Wi-Fi and quality of service. It introduces the conceptual framework that provides the focus of the research described in this thesis. The literature documents students' Wi-Fi usage times, and locations at which they use Wi-Fi when on campus. It further presents literature documenting the difficulties students face when using Wi-Fi on campus, and the resources they access when using Wi-Fi on campus.

The study used a range of secondary data sources to find similar work for this review. Publications found in the literature are from academic fields, including computer engineering; management sciences; education and technology; marketing and information systems; and electronic engineering. Most of these publications take the form of published research papers. The literature also includes material from websites.

This literature is organised according to its relevance to the following issues: implementing Wi-Fi networks; elements of communication on a Wi-Fi network; Wi-Fi devices and providing Wi-Fi access points. It reviews literature on the Wi-Fi electromagnetic spectrum, standards and modulation techniques. It also discusses factors that influence the adoption of Wi-Fi networks at institutions of higher learning. It presents literature documenting elements of communication on Wi-Fi networks and quality of service. The next section presents literature to provide an insight into implementing Wi-Fi networks.

2.2 Implementing Wi-Fi networks

Network providers set up Wi-Fi networks using either the infrastructure or ad hoc network modes (Held, 2003). When a Wi-Fi network operates in the infrastructure mode, wireless enabled devices (e.g. laptops, tablets and smartphones) communicate with one another or wired devices through an access point. For instance, network providers may set up an access point between the LAN network and Wi-Fi devices. In this configuration, the access point serves as a bridge that allows Wi-Fi device users to access resources on the LAN, such as Internet connections (Bing, 2002) (see Figure 4 and Figure 5). It is important to note that access points may be used to connect purely Wi-Fi devices to each other without the need for a LAN extension (Reynolds, 2003). By implementing Wi-Fi in the other mode, i.e. the ad hoc mode,

two or more wireless devices can communicate directly without having to use an access point (Held, 2003). This study investigates students' use an infrastructure-based Wi-Fi network on campus that extends LAN services to Wi-Fi devices. The next section discusses various elements involved in the communication over Wi-Fi networks.

2.3 Elements of communication on a Wi-Fi network

Wi-Fi is a wireless technology that allows network administrators to create wireless networks. Wireless networks enable people to use Wi-Fi-enabled devices to send and receive information using Wi-Fi signals.

The communication process on Wi-Fi networks involves three basic elements that enable users to create, transmit, and successfully deliver messages. The first element is the message source or sender. Message sources and senders are Wi-Fi devices (sending devices) responsible for converting the message created by the user into a format that can move across the Wi-Fi network. The second element in communication over a Wi-Fi a network is a channel or a medium; this provides the pathway over which the message can travel. The medium used to move information between Wi-Fi sources and destinations on Wi-Fi networks is air or space (Held, 2003). The third element in the communication process is the destination, or receiver, of the message. These are also Wi-Fi devices operated by users that receive and interpret the messages sent over the Wi-Fi network (Soyinka, 2010).

Wi-Fi senders and receivers are able to send and receive messages between each other only if each of the individual Wi-Fi devices is within range of the Wi-Fi signal (Bing, 2002). Access points are components of a Wi-Fi network that send and receive Wi-Fi signals to and from Wi-Fi devices.

To ensure successful communication between different elements on Wi-Fi networks, network implementers assign roles to Wi-Fi users to act as Wi-Fi administrators to support the efficient delivery of Wi-Fi services. Network administrators repair, maintain and configure Wi-Fi network infrastructure equipment at specific locations. In addition, they support Wi-Fi users in resolving difficulties that they may encounter while using Wi-Fi services (Soyinka, 2010).

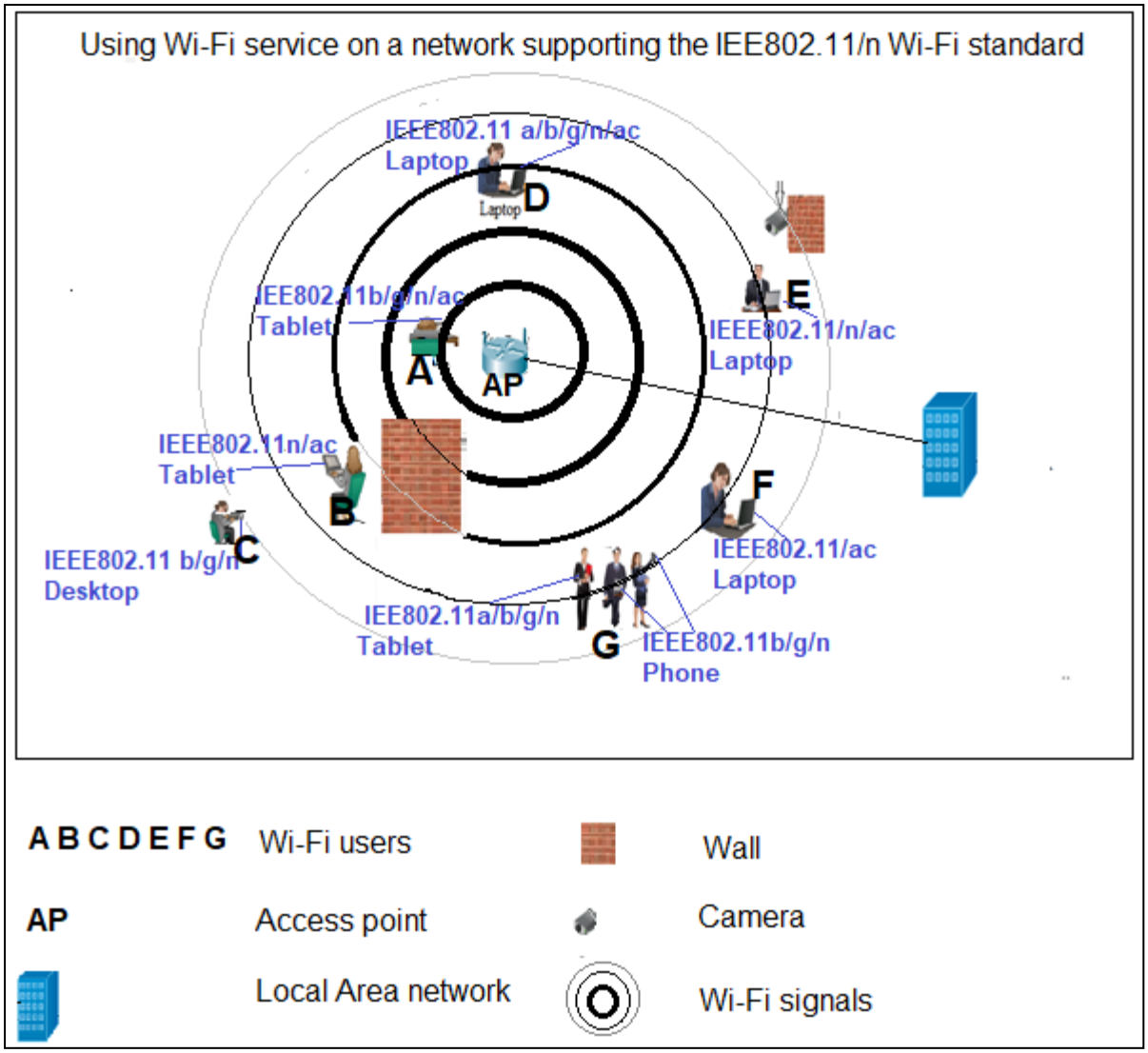

Figure 4: A Wi-Fi network in infrastructure mode with an access point with omni-directional antennas (Source: Author).

Figure 4 shows an example of an infrastructural Wi-Fi network supporting the IEEE 802.11/n network standard. This network supports devices that use the IEEE 802.11a/b/g and n standard. The figure shows an access point (AP) configured with an omni-directional antenna to allow signals to be sent to, and received in, any direction (360 degrees) (Reynolds, 2003; Soyinka, 2010).

The access point is connected to a local area network allowing it to provide services available from the LAN. All Wi-Fi users are able to send and receive Wi-Fi signals to and from each other. However, as Wi-Fi signals travel away from the access point, they become weaker (Held, 2003). Hence Wi-Fi user A will get stronger Wi-Fi signals than user C. While User B is closer to the access point than users, F, A and G, his signals are weaker due to the obstruction from

the wall (Reynolds, 2003). User E will have possible Wi-Fi signal interference because he is close to the security camera that shares the 2.4GHz spectrum (Held, 2003; Soyinka, 2010). The figure also shows signal obstructions, such as the wall on the bottom left, which obstructs the Wi-Fi signal from user B. User A in Figure 4 has greater proximity to the access point than any other users and hence has better signal quality, thus allowing him to get more reliable Wi-Fi service (Soyinka, 2010). User B has a weak Wi-Fi signal and hence may not get Wi-Fi service which is as stable as that enjoyed by the other users (see Figure 4).

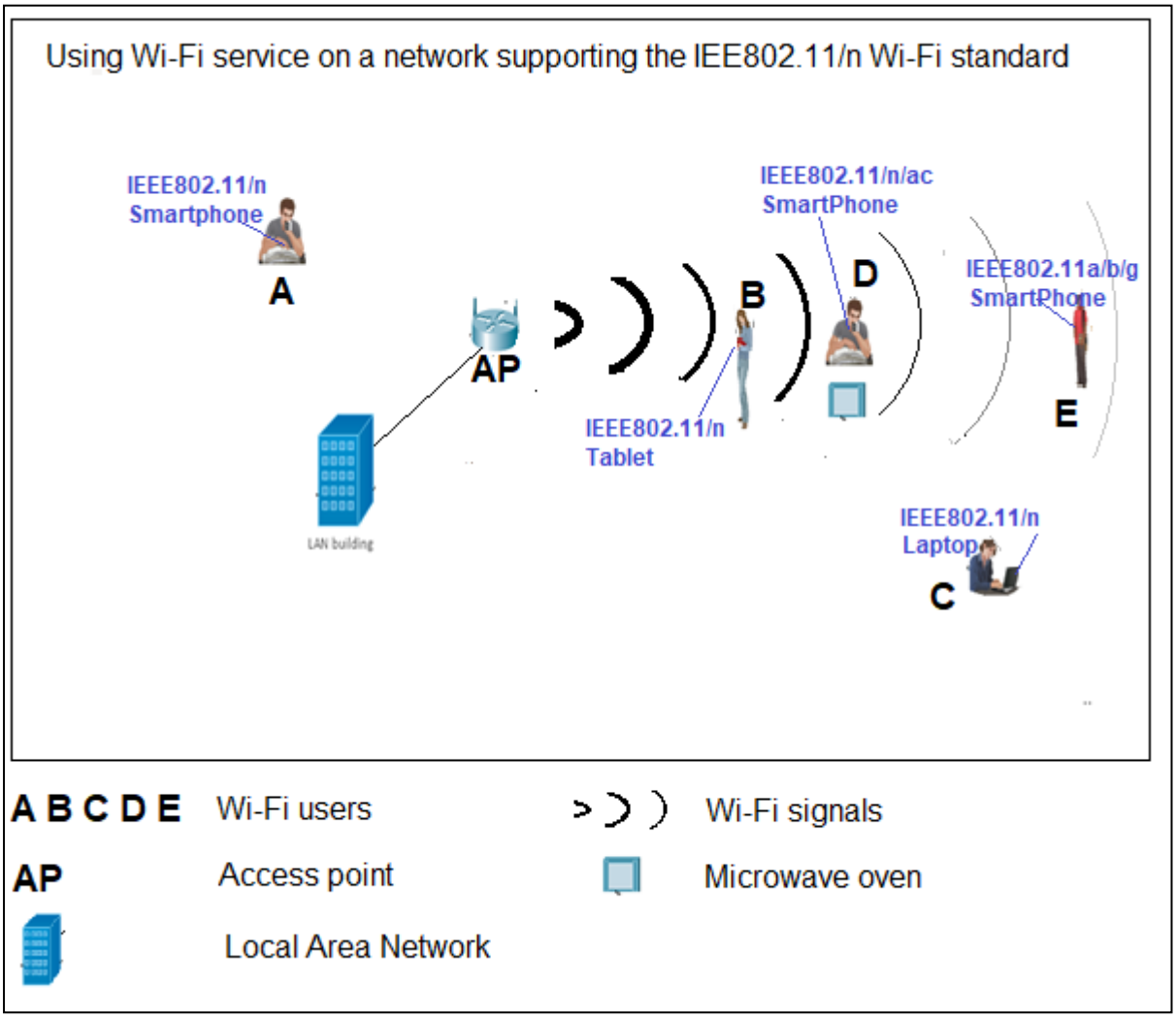

Figure 5: Wi-Fi network in infrastructure mode with an access point with bi-directional antennas (Source: Author).

Figure 5 shows the installation of an access point (AP) configured with a bi-directional antenna. This allows signals to be delivered and received in one direction. At the centre of the figure, it shows a LAN building in which the LAN network is set up.

As can be seen in Figure 5, users A and C are unable to receive Wi-Fi signal as they are out of the line of sight in which the Wi-Fi access point is delivering the Wi-Fi signal. Users B, D and E are able to access Wi-Fi services as they are in the line of sight of the Wi-Fi signals. However, user E will get a weaker Wi-Fi signal compared to user B as she is further away from the access point (Soyinka, 2010) (see Figure 5). There is also a possible interference in the Wi-Fi signal travelling to the device of user D. This is because microwave ovens share the 2.4GHz spectrum in which the Wi-Fi signal is being delivered (Abdelrahman et al., 2015; Verma, Fakharzadeh, & Choi, 2013; Wong, 2003).

The next section describes different the Wi-Fi devices used to send and receive messages over Wi-Fi. It gives details on different types and characteristics of user devices that may influence the use of Wi-Fi services.

2.3.1 Wi-Fi devices

Wi-Fi users need to buy suitable devices installed with wireless cards that support access to network resources (Lehr & McKnight, 2003). These Wi-Fi cards can either be embedded in the device or attached inside the device (Reynolds, 2003). By having Wi-Fi network interface cards installed on devices, messages or information can be converted into signals for transmission over the Wi-Fi network (Bing, 2002; Kotz & Essien, 2005; Panko, 2003).

The growth of the computer industry has led to the development of many different types of Wi-Fi user devices (Reynolds, 2003). For example, desktop computers (PCs) are widely used all over the world today to access Wi-Fi networks. Portable Wi-Fi devices such as smartphones, laptops and tablets allow users to access Wi-Fi without any constraint on location. This has led to an increase in the worldwide adoption of Wi-Fi networks (Kim & Lee, 2015).

A problem with using portable devices is their short battery life. For instance, Yu, Wu, Yu, and Xiao (2006) found that, while clinicians in hospitals required their Wi-Fi devices for the total duration of their working shifts, they faced difficulties in using them because the batteries could only run for three and a half hours. In a similar study, students reported frustrations when using Wi-Fi devices on campus, due to the limited battery life of devices (Chu & Lin, 2006). Because battery life is critical for the performance of portable Wi-Fi devices, network providers may be required to provide charging points for users.

One breakthrough in the development of mobile phones is the production of smartphones and tablets. These have several advantages over other Wi-Fi devices that make them uniquely suited for use on Wi-Fi networks. Firstly, unlike laptops and desktops that users may regularly turn off or put in sleep mode, smartphones always have their power on so that their Wi-Fi cards can scan for Wi-Fi signals in the surrounding areas. This provides easier access to Wi-Fi services. Secondly, as smartphones are highly portable, users are likely to carry them most of the time, so they can be used more often in different locations than other stationary or less-portable devices (Shi et al., 2016). However, unlike desktops and laptops, it is hard to upgrade smartphones and tablets if they do not have an integrated Wi-Fi card. As a solution, users may have to buy new devices which have an integrated Wi-Fi card.

Within the next few years, different types of devices are likely to become an important component in the use of Wi-Fi services in institutions of higher learning. To the best of our knowledge, there has been little discussion on current trends of Wi-Fi devices in the student market to access Wi-Fi services on campus. In addition, there are various specific difficulties (such devices taking long to connect to Wi-Fi, and a limited number of power points) associated with the use of devices in specific locations that may affect the use of Wi-Fi services on campus. However, there has been no study in South Africa to investigate how students use these different types of devices to access Wi-Fi at different on-campus locations. In addition, it has not yet been established whether Wi-Fi users may perceive Wi-Fi quality differently when they use different types of devices to access Wi-Fi services on campus.

The next sub-section describes strategies used to implement access point infrastructure to mediate communications on the Wi-Fi network.

2.3.2 Implementing Wi-Fi access points

Wi-Fi access points are networking devices that link wireless devices to each other or to other devices on the local area network. They can be installed as part of the local area network infrastructure for users to access resources on a LAN (Fitzgerald & Dennis, 2005). Hence, they act as bridges between LAN and wireless devices. Access points broadcast information that flows on the wired LAN; while information received over the air is transmitted on the wired LAN (Held, 2003; Panko, 2003).

Wi-Fi providers have various implementation design factors to consider when setting up access points on Wi-Fi networks (Fitzgerald & Dennis, 2005). For example, they must consider the coverage area of the Wi-Fi signal. If the area to be covered is small, network administrators may implement a basic service set (BSS). This comprises one access point to manage the connection communications for all devices within range (Bing, 2002; Carleen, 2003). However, if the area is large, they may have to connect two or more BSS to the same wired network (LAN) to create an extended service set (ESS). The ESS allows administrators to place more than one access point so that the areas they service overlap slightly, to provide wireless signal coverage over an extended area. This allows users to access Wi-Fi services on the move (Bing, 2002).

Wi-Fi design choices have limitations that may affect the service quality as perceived by users. For example, using the BSS will only allow the user to access services if they are in coverage range of the signal from that particular access point. Conversely, when using an extended service set, the device connection to one access point terminates, and then establishes a new connection as the user moves away from the coverage area of the BSS access point to the next closest access point (Soyinka, 2010). This may create a lag time during the termination and establishment of the new connection to the nearest access point signal. As a result, the Wi-Fi resources that a user is accessing may fail to load or freeze. People may implement ESS to provide reliable connections to students on the move. However, when few access points are implemented in the ESS, it leads to congestion on the access points. For instance, the Chu and Lin (2006) study reported that students' ability to roam was limited and there was increased competition for Wi-Fi services, rendering the services inaccessible on campus. As a control measure to deal with the congestion on access points, some universities have limited student Internet usage time to two hours, thus reducing the time students may have preferred to have spent accessing network resources (Tella, 2007).

Other solutions to increase network coverage and range may include the configuration of access points with antennas, or the addition of other access points at the location. Wi-Fi antennas are vital components of access points that pick up incoming Wi-Fi signals or send outgoing Wi-Fi signals (Held, 2003; Reynolds, 2003). Administrators may configure access points with bi-directional antennas to deliver coverage in one specific direction. In addition, they may employ omni-directional antennas to deliver signals in all directions (Soyinka, 2010). As such,

administrators may have to consider their choices on available antenna types at access points as they may influence the availability of Wi-Fi signals at a location.

In addition, administrators may need to install many access points in a location, to ensure that Wi-Fi users get strong Wi-Fi signals in the Wi-Fi service area. A major challenge is that, after installallation of an access point at a location, the environment may undergo physical changes like construction and re-modelling. As a result, physical obstructions like walls, trees, cardboard or any other material may interfere with the Wi-Fi signal (see Figure 4 and Figure 5). For instance, Călin-Alexandru et al. (2015) analysed how local wireless area networks operate in an environment with several building. The results showed that the width of floor concrete limited the strength of the Wi-Fi signal in one of the on-campus buildings. This result implies that a person with a clear line of sight has a higher chance of getting good signal quality than a person in an environment surrounded by obstacles. Wi-Fi users may need to change their positions, avoid obstacles and move closer to the access point to receive better signal quality.

Unlike signals travelling on local area networks that take one path to the destination device, signals traveling on Wi-Fi networks can use multiple paths as they reflect and bounce off obstructions. In fact, two or more signals may arrive at the Wi-Fi device, one being the direct signal, the other being a reflected signal (O'Hara & Al, 2005). These signals cause multipath effects like delays and reduction in signal strength because they will arrive at different times and have different path lengths (Held, 2003). As a solution, administrators may need to install repeaters to receive a weak Wi-Fi signal, amplify it and then re-transmit the boosted signal to devices (Repeaterstore, 2017).

In conclusion, setting up a Wi-Fi network is a complex matter. Wi-Fi administrators need to make a continual assessment of the performance of the Wi-Fi network to identify possible factors that may limit the delivery of quality Wi-Fi services. However, this requires the co-operation of Wi-Fi users to report any connection difficulties at Wi-Fi locations.

Access points require a networking medium to provide a path over which signals must move information between a source and Wi-Fi devices at destination. The electromagnetic spectrum is the network medium on which Wi-Fi networks operate. It defines a range of frequencies (also called the ‘bands’) used to transmit signals over the air (Bing, 2002; Soyinka, 2010). The next section discusses the electromagnetic spectrum.

2.3.3 The Wi-Fi electromagnetic spectrum

Wi-Fi devices transmit information using signals in the 2.4GHz or 5GHz electromagnetic spectrum band; or both (Bing, 2002; IEEE 802.11 Working Group, 2009; Vladyko, Paramonov, Kirichek, & Koucheryavy, 2016).

The 2.4GHz spectrum provides various benefits to Wi-Fi users over the 5GHz spectrum. For example, information transmitted in the 2.4GHz band can penetrate obstacles like walls and trees with ease, while information transmitted through 5GHz cannot easily penetrate obstructions (Reynolds, 2003). In addition, information travelling in the 2.4GHz spectrum travels for longer distances than that which travels on the 5GHz spectrum (Abdelrahman et al., 2015). However, the 2.4GHz spectrum has a major limitation as it is more congested and more prone to interference than the 5GHz spectrum (Abdelrahman et al., 2015; Verma et al., 2013; Wong, 2003). For example, phones, Bluetooth devices, ovens, digital cameras and access points share the same 2.4GHz spectrum (Fitzgerald & Dennis, 2005). This makes it difficult for access points to deliver quality signals on the 2.4GHz spectrum if they are in the same location as other devices sharing this spectrum (Mourad, Heigl, & Hoeher, 2016).

The IEEE 802.11 standards provide wireless connectivity to local area networks (LANs) and Wi-Fi devices using radio frequency (RF) technology within the electromagnetic spectrum (Held, 2003). The next section will consider the different Wi-Fi standards that network providers may adopt to provide Wi-Fi services on their networks; and how user devices use them.

2.3.4 Wi-Fi standards, modulation techniques and spectrum configurations

A standard defines a set of rules that explain how hardware and software that conform to the standard can communicate with any other hardware and software that conform to the same standard (Fitzgerald & Dennis, 2005). They govern the physical, electrical and procedural characteristics of communication equipment. They ensure that equipment or software will have a large market, thus encouraging mass production. They also allow products from multiple vendors to communicate. This gives the buyers more flexibility when selecting equipment to use (Stallings, 2004). Over the last decade, the IEEE 802.11 has grown to be the most common standard in the wireless arena. Since the release of the first standard version, several amendments have been introduced to improve its performance (Keranidis et al., 2014).

It is important to note that not all standards support access to both the 2.4GHz and the 5GHz spectrums. If the Wi-Fi standard adopted on the network supports both the 2.4GHz and the 5GHz spectrum, the administrators choose whether to provide both spectrums or not. The IEEE802.11 WLAN committee allows the users to decide which standards best fit their needs (Reynolds, 2003). It is possible to achieve varying Wi-Fi quality if Wi-Fi users and network providers do not take into account the different 802.11 standard specifications supported on the Wi-Fi network (Dolinska, Masiukiewicz, & Rzadkowski, 2014)

All IEEE 802.11 standards use digital modulation techniques to represent and encode information into the carrying signal (Held, 2003). These techniques include the direct sequence spread spectrum (DSSS), the frequency hopping spread spectrum (FHSS) and orthogonal frequency division multiplexing (OFDM) (Reynolds, 2003). Because modulation techniques have different ways in which they encode the information, they deliver varying benefits and limitations. For example, they provide different resistance to signal interference and allow different use of bandwidth, thus giving varying quality of service (Reynolds, 2003). The next sub-section provides the IEEE 802.11 standards, identifying the different modulation techniques used on different spectrums to provide Wi-Fi services.

2.3.4.1 The 802.11 standard

The IEEE 802.11 standard was released by the IEEE (LAN/MAN) standard committee on June 1997. The standard functions in the unlicensed band of 2.4GHz. To ensure quality signal propagation, the standard utilises the frequency hopping spread spectrum (FHSS) and the direct sequence spread spectrum (DSSS) modulation techniques (Reynolds, 2003). The FHSS allows the access point to transmit signals by allowing the signal to hop between the available frequencies on a specified channel in a pseudo-random way. This allows transmitting devices to minimise signal interference, since the interference will occur at that specific frequency, thus only affecting the signal during that short interval (Soyinka, 2010). The DSSS spreads signals on one wide channel so that all information is transmitted at once on the chosen frequencies, instead of hopping on different frequencies on a specific channel. While this allows Wi-Fi devices to transmit more information, the signals are more susceptible to interference (Macha & Damodaram, 2016).

The IEEE has released multiple upgrades to the 802.11 standard to deliver better Wi-Fi quality services to users. The first upgraded standard was the 802.11a standard.

2.3.4.2 The 802.11a standard

The IEEE released the IEEE 802.11a in September 1999. It operates in the 5GHz spectrum of the electromagnetic spectrum, supporting data throughput of up to 54 Mb/s (O'Hara & Al, 2005). This provides Wi-Fi users with benefits like reduced signal interference, by accessing the 5GHz. However, users face several limitations when using the 5GHz spectrum, like short signal range and poor signal penetration of obstacles.

This standard employs single input - single output (SISO) antenna technology. This antenna technology enables the transmitting and receiving device to send out and receive the signal using one antenna. However, this makes it vulnerable to problems caused by multipath effects. The standard uses the orthogonal frequency-division multiplexing (OFDM) modulation method. In comparison to the other standards using the FHSS and DSSS modulation techniques, OFDM modulation techniques provide various benefits that may influence the quality of service perceived. For instance, the OFDM technique allows multiple carrier frequencies to transport information from one user to another (Soyinka, 2010). Each sub-carrier that transports information is far apart from other sub-carriers to avoid interference. This enables devices to get better signal throughput than the devices supporting DSSS and FHSS modulation (Reynolds, 2003). In addition, the multipath effects are not as pronounced as those standards that support DSSS and FHSS modulation techniques (Reynolds, 2003).

Wi-Fi network providers did not fully utilise the 802.11a standard. This was due to the high cost of WLAN implementation, based on the 5GHz spectrum, in the early 2000s (Abdelrahman et al., 2015). This led to further development of the 802.11b standard.

2.3.4.3 The 802.11b standard

The IEEE released the 802.11b standard in September 1999. It operates in the 2.4GHz spectrum of the electromagnetic spectrum, at a speed of 11 megabits per second (Mbits/s) (O'Hara & Al, 2005). The 802.11b uses only the DSSS (Direct Sequence Spread Spectrum) modulation technique and employs single input - single output (SISO) antenna technology (Abdelrahman et al., 2015). It is important to note that devices that support the 802.11b standard will not

operate on Wi-Fi networks that support the 802.11a standard. This is because they operate at different frequencies in the spectrum and use different modulation techniques (Soyinka, 2010).

2.3.4.4 The 802.11g standard

The 802.11g is an upgrade of 802.11b. It operates in the 2.4GHz spectrum delivering a data throughput of 54 Mbits/s, compared to 11 Mbits/s delivered by the 802.11b standard. It uses the OFDM and DSSS modulation techniques and employs single input - single output (SISO) antenna technology (Abdelrahman et al., 2015; Reynolds, 2003). Devices that support the 802.11g standard will operate on Wi-Fi networks that support the 802.11b standard. However, when a user connects a device supporting the 802.11b standard to a Wi-Fi network supporting the 802.11g standard, the device will still achieve the speeds of the 802.11b standard of 11Mbit/s instead of the better throughput supported by the 802.11g standard (Soyinka, 2010).

2.3.4.5 The 802.11n standard

The 802.11n standard is an update of the 802.11a, b, and g standards and was released in October 2009. The IEEE 802.11n standard has many advantages in delivering quality Wi-Fi services in comparison to earlier standards. It allows devices supporting the 802.11a, b and g standards to operate on it and provides Wi-Fi access on both the 5GHz and 2.4GHz spectrums. This allows users and providers to benefit from the advantages of both spectrums. In addition, network providers can increase the channel bandwidth from 20MHz to 40MHz, providing better throughput of 600 Mbits/s (Abdelrahman et al., 2015). Furthermore, it uses the OFDM modulation technique. This supports the use of multiple input - multiple output (MIMO) antenna technology instead of the single output (SISO) antenna technology supported by the 802.11a, b and g standards. This antenna technology allows the 802.11n, and similar technologies using MIMO, to send and receive multiple, simultaneous radio signals using multiple antennas instead of one antenna. The 802.11n standard uses four spatial streams, meaning that Wi-Fi devices will have four antennas, each broadcasting signals on a different channel (Brent, 2016). Hence, devices resolve more information than is possible when using a single antenna (Ali & Mustafa, 2015; Kim & Lee, 2015).

2.3.4.6 The 802.11ac standard

The IEEE released the 802.11ac standard in January 2014. It only operates in the 5GHz spectrum; and is backward-compatible with devices supporting the 802.11n standard.

However, devices will perform at the speeds of their respective standards. Hence, users will only get the full benefits of this ac standard by connecting an 802.11ac access point to an 802.11ac device (Ali & Mustafa, 2015).

This standard has several strengths that enable it to provide better service and improved coverage, compared to the IEEE 802.11a, b, g and n standards. For example, it supports a wider channel bandwidth up to 160 MHz (Bejarano, Knightly, & Park, 2013). It supports up to eight MIMO spatial streams compared to the four streams supported by the 802.11n. This means that an 802.11ac device will have eight antennas, each broadcasting signals on a different channel (Brent, 2016). It is capable of 1300 Mbits/s, giving devices better throughput than can be achieved with the IEEE 802.11n standard (Ali & Mustafa, 2015). In addition, while it uses the OFDM modulation approach like the 802.11ac, it increases the number of bits per sub-carrier from six to eight, resulting in a 33% increase in the amount of information that can be carried by signals, over the IEEE 802.11a, b standard (Ali & Mustafa, 2015).

Research has shown that Wi-Fi network providers set up Wi-Fi services that support a particular standard. It is important that users know the Wi-Fi standard used by network providers so that there they can use devices that enjoy all the available benefits delivered by the network standard. For example, connecting a device that supports access to the 802.11ac standard to a Wi-Fi network supporting the same standard will allow faster communications than connecting a device supporting the 802.11n, a, b and g standards. However, to the best of our knowledge, no publications have identified the level of awareness among Wi-Fi users regarding the standards their devices are able to access when using Wi-Fi services.

Institutions of higher learning like the University of KwaZulu-Natal, the University of Pretoria and the University of Cape Town have set up Wi-Fi on campus to give students access to Internet resources. The next section documents factors that influence institutions of higher learning to set up Wi-Fi networks.

2.4 Factors that influence institutions of higher learning to adopt Wi-Fi

Institutions of higher learning adopt Wi-Fi for several reasons. Firstly, Wi-Fi connectivity provides location flexibility and enables users to connect at any location as long as they are within the range of the Wi-Fi signal (Lehr & McKnight, 2003). In addition, Wi-Fi supports

cellular mobile device connectivity, allowing mobile devices to send and receive information with ease (Chen et al., 2012).

Secondly, Wi-Fi reach enables connecting Wi-Fi devices to access resources on local area networks in locations where it is difficult or not suitable to install them. For example, universities install access points in cafeterias and in libraries to provide access to web resources on local area networks (Chen et al., 2012; Han, 2008). In addition, Wi-Fi networks deliver a wide network coverage both inside and outside buildings. Kotz and Essien (2005) found that the interior Internet access points installed on campus covered inside the buildings and most of the outside environment around the university.

Thirdly, Wi-Fi delivers dependable service connectivity to devices, allowing users to move devices around while accessing resources. Multiple wireless access points ensure that users stay connected while on the move and have more convenient access to services available on the local area network (Han, 2008). The ability to implement multiple access points with ease further improves flexibility in expanding a Wi-Fi service in a new location since the network medium (air) is everywhere (Gast, 2005).

As institutions of higher learning provide Wi-Fi services, they may need to understand how students use them to support their learning. The next section presents literature documenting students' use of Wi-Fi on campus.

2.5 Students' use of Wi-Fi on campus

Students use Wi-Fi services on campus for various reasons. For instance, students use Wi-Fi to access the Internet connection provided on the local area network to communicate via e-mail and to chat (Gururaj, Arun, & Lokesha, 2016; Tella, 2007). In addition, students use Wi-Fi to access resources for a variety of academic purposes. For instance, students use Wi-Fi to search for information relating to subjects (92.5%), to talk with teachers and friends (24%) and to search for tutorial and power point presentations (50%) (Gururaj et al., 2016). They also access information to supplement that provided by lecturers (Tella, 2007). Students also use Wi-Fi for entertainment and social interaction on several media like YouTube, Facebook, Google Plus and LinkedIn (Gururaj et al., 2016).

2.5.1 Devices used by students to access Wi-Fi

Students use both mobile handheld devices like smartphones, and wireless non-handheld devices like Windows and MacBook laptops to connect to Wi-Fi services (Chen et al., 2012). However, the usage of Wi-Fi devices varies. For example, in India, a study reports that 71% of the students preferred to use laptops when accessing Wi-Fi. Another 14% used other devices that were not listed in the research (Singson, 2011). However, in a more recent study in India, while 49.2% of the 120 respondents reported that they used laptop computers to access the Wi-Fi network, the majority (71.7%) used smartphones; and 8.3% of the students used tablets to access Wi-Fi (Gururaj et al., 2016).

2.5.2 Students' usage times, and time spent, on Wi-Fi

Students use Wi-Fi services at different times and for different lengths of time. Han (2008) identified the issues arising from the use of WLANs from the perspective of students from the Mt. Albert and Waitakere campuses of Unitec, New Zealand. There, students' Wi-Fi use was highest between 9:00 and 10:00, followed by 12:00. The study also showed that, as the number Wi-Fi users decreased, the duration of usage increased. Most participants used WLANs for half the day (4-5 hours), and all day. In a more recent study by Gururaj et al. (2016) in India, 35.8% of students used Wi-Fi for one to two hours and only 2.5% of the users used the Wi-Fi service for three to four hours per day. Of the respondents, 6.7% said that they used it for four to five hours and 55% of the students used the Wi-Fi facility whenever they wanted it. However, it is important to note that students may use on-campus Wi-Fi during weekdays and weekends. In addition, universities have students staying at different locations during the academic terms, at varying proximity to the campus. It is not clear if their Wi-Fi usage periods during weekdays and weekends are different or similar.

2.5.3 Locations at which students use Wi-Fi

Institutions of higher learning provide Wi-Fi services that can be accessed at different locations. Gururaj et al. (2016) reported that 95% of students could access Wi-Fi anywhere on campus, and 72.5% of students agreed that they had access to Wi-Fi in the library. Nevertheless, while Wi-Fi may be accessed at many locations on campus, students prefer to use Wi-Fi in some locations more than others. For instance, the Han (2008) study revealed that 80% of students selected to participate in the study used Wi-Fi in the school library and three in the café.

Contradicting this finding is the study by Singson (2011), which found that 66% of the students preferred to access Wi-Fi in their hostels. A major reason was that Wi-Fi access in the hostels allowed students to access Internet resources within their comfort zone. Despite the wide implementation of Wi-Fi networks at institutions of higher learning in South Africa, there has been little discussion on students' use of Wi-Fi at on-campus locations.

Students face several difficulties while accessing Wi-Fi. In the Gururaj et al. (2016) study, 48.3% of students had problems with their Internet access speed; 28.3% experienced frequent Wi-Fi disconnections and 35.8% had limited Wi-Fi connectivity. Of the students, 86.7% had site restriction problems and 14.2% had other problems.

In addition, students experience technical difficulties when using Wi-Fi on campus. The Chu and Lin (2006) study reports that 7% of students at Pennsylvania State University never used wireless access devices because they lacked the technical knowledge to use them. Similar results are reported by Singson (2011), who found that 55.2% of postgraduate students felt that they definitely had technical problems while accessing Wi-Fi; whereas only 11% felt that they had not had technical problems.

The next section discusses quality of service, explaining factors that institutions of higher learning may need to consider when planning for quality of Wi-Fi service.

2.6 Quality of service

As institutions of higher learning provide Wi-Fi services, they should be concerned with the quality of service they deliver (Pitt, Watson, & Kavan, 1995). Users may decide to use the service in the future, based on the quality of service they experience (McDougall & Levesque, 2000). Quality of service is derived from service performance, which determines the degree of satisfaction users get from the service (Independent Communications Authority of South Africa, 2013).

Some preliminary work was carried out in the early 1980s to understand service quality. For instance, Parasuraman et al. (1988) carried out a broad exploratory inquiry of quality in four service businesses to develop a model of service quality. They argue that service quality has three main characteristics: intangibility, heterogeneity and inseparability. To explain the

intangible characteristics, Berry (1980) contends that businesses may find it hard to know how consumers perceive their services and assess the quality of the service provided. This is because most services are performances and not objects. Because they are intangible, they cannot be counted, measured, inventoried, tested and verified before provision to assure quality (Zeithaml, 1981).

Secondly, services are heterogeneous as they regularly vary among producers and among customers. This is because what the firm aims to deliver may differ from what the consumer receives (Booms & Bitner, 1981). Thirdly, the production and consumption of services are inseparable (Upah, 1980); manufacturing firms do not plan quality in services and deliver it intact to the consumer.

In fact, the service firm could have less managerial control over service quality where consumer involvement is very high, since the client affects the process. It is important to note that in these situations, the consumer's input to describe how service providers should deliver the service becomes critical to the quality of the service (Parasuraman et al., 1988). This can be achieved by understanding perceptions of service quality resulting from a comparison of consumer expectations and actual service performance (Parasuraman et al., 1988). Moreover, by understanding service perceptions, the service provider will know how the consumer evaluates the service. Consequently, it will allow the service provider to influence these evaluations in the desired direction (Cascetta & Cartenì, 2014; Grönroos, 1984).

Brady and Cronin Jr (2001) propose a hierarchical model to understand service quality. The model suggests that service providers can determine the quality of a service by evaluating the primary constructs of outcome quality, quality of interactions and quality of the physical environmental.

In the next sub-section, factors identifying the outcome quality, that may influence the perceived Wi-Fi quality, are discussed.

2.6.1 Outcome quality

Outcome quality is the perceived quality which users get, based on the actual use of the service or the service product itself (Brady & Cronin Jr, 2001). Customers may base their evaluation

on the service they receive as an outcome of the production process and the production process itself (Grönroos, 1984).

Various technical and functionality quality factors may influence Wi-Fi outcome quality. Factors concerning technical quality influence the service, or what the customer receives when he uses the service (Brady & Cronin Jr, 2001). In this study, these factors may include the different network services or resources a user accesses to use the Wi-Fi services. For example, users may rate the outcome quality of Wi-Fi services based on how they evaluate the quality of web resources they access. In addition, functionality factors affect how service providers deliver the service. Thus, they determine customers' perceptions of the interactions that occur during service delivery (Brady & Cronin Jr, 2001).

Brady and Cronin Jr (2001) suggest that future research should expand their model to understand user perceptions of quality in different industries. Malik et al. (2015) provide Wi-Fi quality of service metrics that can be used to understand user perception of Wi-Fi outcome quality. They argue that, from a Wi-Fi network perspective, outcome quality factors like availability, reliability, timeliness and stability affect the quality of Wi-Fi services.

In this study, availability refers to the ability of users to access Wi-Fi resources in the correct format at an identified location (Techopedia, 2017). While Wi-Fi signals may be available, studies document that students may have limited access to Wi-Fi services. For instance, the study by Chu and Lin (2006) reports that students had Wi-Fi available at on-campus locations, but they used it less due to the high cost of the wireless devices. In a similar study, students reported that, although Wi-Fi was available at locations, they could not access it due to restrictions on the times the Wi-Fi locations were open for use (Han, 2008).

Timeliness in this study refers to the availability of the output information at a time suitable for it to be used. Wi-Fi services must be made available at the right time, at an accessible location, and in the right format. Network reliability is the likelihood that a network can support a chosen network operation in an environment of casual component failures (Colbourn, 2010). In addition, stability relates to the ability of Wi-Fi services to remain unchanged over time under stated, or reasonably expected, conditions of use.

The quality of the devices used to access the service may affect the outcome quality and the user's perception of the quality of service (W. H. DeLone & McLean, 1992). Accordingly, the access points and user's Wi-Fi device quality may affect the availability, reliability, timeliness and stability of Wi-Fi services. Consequently, this may affect user perception of the quality of Wi-Fi services. The quality of Wi-Fi access points and Wi-Fi devices is dictated by their configurations. The next section presents access point configurations that may affect the outcome quality of Wi-Fi services.

2.6.1.1 Access point configuration and outcome quality

Administrators adopt various configurations at the Wi-Fi access points to deliver Wi-Fi services. These configurations dictate how access points will transport information to and from users' Wi-Fi devices. Hence, they may affect the outcome quality of the Wi-Fi services, as perceived by users. For example, the choice of which channel to use at access points influences the Wi-Fi performance (Bing, 2002; Held, 2003). When network administrators configure the same channels at access points, it causes cross-channel interference, thus affecting the timeliness of Wi-Fi services. As Wi-Fi providers install Wi-Fi services, they need to ensure that they minimise interference between the access points in the extended service set (Bing, 2002; Held, 2003). For instance, if a channel is reused, it is best to assign it to access points where the signals are least likely to interfere with one another (Sanjaya, 2009).

Wi-Fi administrators configure Internet access points to broadcast and receive signals on the 2.4GHz or 5GHz spectrums, or both (Bing, 2002; IEEE 802.11 Working Group, 2009; Vladyko et al., 2016). The choice of which spectrum to configure may influence the reliability, timeliness, stability and availability of the Wi-Fi service. For example, the 2.4GHz delivers signals over longer distances than the 5GHz spectrum. For this reason, the 2.4GHz spectrum is more convenient to use at outside Internet access points; and may provide better reliability in areas with many possible signal obstructions. In contrast, the 5GHz spectrum configuration is more convenient for use indoors and may not provide reliable Wi-Fi connections in locations with many obstructions. In addition, information travelling on the 2.4GHz spectrum is prone to interference. Consequently, this configuration may not provide reliable, stable and timely Wi-Fi connections in areas with many possible sources of interference. In contrast, the 5GHz spectrum is less prone to interference, and thus more suitable for locations with many possible sources of interference (Abdelrahman et al., 2015; Wong, 2003).

Table 1: Advantages and disadvantages of the 2.4GHz spectrum

Advantages	Disadvantages
2.4GHz has a long signal range and hence is convenient for use at outside access points.	It is prone to interference from many other devices.
It exhibits good penetration through obstacles; as a result it is convenient to use in locations with many physical objects.	There is a lot of congestion in the 2.4GHz spectrum because it is shared by many devices.

Table 2: Advantages and disadvantages of the 5GHz spectrum

Advantages	Disadvantages
The spectrum is less prone to interference since it is not shared by many devices. A majority of devices (cameras, microwaves, smartphones and tablets) do not use the 5GHz spectrum.	It has a short signal range and hence it is not convenient for use outdoors.
There are few devices that share this spectrum and hence it has less congestion.	It exhibits poor penetration through obstacles and hence is not convenient for use in areas with many obstacles.

Bandwidth is the amount of information that can pass through a chosen channel. The choice of which bandwidth size is supported at the access point influences how much information access points can transmit; and the speed of transmission. All Wi-Fi devices accessing resources through an access point must share the total bandwidth allocated to the access point. Thus, users may achieve better Wi-Fi service quality when the bandwidth on the spectrum is large, because more information and faster speeds may be achieved during data transmissions (Fitzgerald & Dennis, 2005). However, sharing a small bandwidth among many devices causes oversubscription. In addition, oversubscription on wireless access points leads to congestion and limits the quality of the Wi-Fi service delivered in various locations (Malik et al., 2015).

Access points operate using a specific Wi-Fi standard. Accordingly, the choice of which standard to adopt on the network is very important since every Wi-Fi standard provides different benefits and limitations to network providers and users. The benefits include fast data

throughput; the use of MIMO antenna technology that allow devices to send more than one signal; and the use of OFDM modulation techniques that minimise interference. A limitation is that some standards are more prone to interference and multipath effects than others. Standards dictate the spectrums with which devices will access Wi-Fi services and hence may deliver a varying quality of service (Abdelrahman et al., 2015).

While it is true that access points require antennas to propagate Wi-Fi signals in the air, different Wi-Fi antennas provide different benefits that influence the signal quality. For example, bi-directional antennas focus more energy in one direction. However, because Wi-Fi signals cannot be seen by users, there is a possibility that users will face away from the direction from which antennas are directing the Wi-Fi signal (7signal, 2016). This may lead to limited availability of Wi-Fi signal and affect the perceived quality of the Wi-Fi service. As a solution, administrators may implement omni-directional antennas to provide and receive signals across 360 degrees to allow devices to access signals from multiple directions (Reynolds, 2003; Soyinka, 2010). This is also a less costly option than installing many different access points with bi-directional antennas. However, because omni-directional antennas spread their signals across 360 degrees, the strength of the signal is lower than bi-directional antennas that focus more energy in one direction. Hence, bi-directional antennas may be installed to provide a connection where omni-directional antennas are not able to broadcast their signal, like at the corners of buildings.

Because all information travelling on the Wi-Fi network moves in the air, everyone can access it. Hence, Wi-Fi networks providers set up encryption and user authentication to secure information that travels on it. For example, the Wi-Fi protected access encryption (WPA2) allows users to access Wi-Fi services after passing authentication (Soyinka, 2010). While this provides Wi-Fi security, it increases the amount of time it takes to connect to Wi-Fi services.

Bruns (2005) argues that students experience a more positive learning environment if they have the freedom to access educational resources with uninterrupted, fast, convenient connectivity. However, some students report slow access to Wi-Fi resources. For example, they report difficulties with web pages taking too long to load; and having trouble logging into the WLAN (Gururaj et al., 2016; Han, 2008). They also experience weak signals which lead to unstable Wi-Fi connections and short communication distances (Chu & Lin, 2006).

Most studies on Wi-Fi have used qualitative and quantitative methods, with designs informed by an initial survey to understand the use of Wi-Fi on campus. Moreover, the qualitative interviews of students produced informative results like duration of Wi-Fi use, the resources accessed and difficulties students face using Wi-Fi services. The literature has shown that configuration choices made at access points in the Wi-Fi environment by network administrators may affect Wi-Fi quality (Bing, 2002; Fitzgerald & Dennis, 2005; Wong, 2003). However, the researchers did not interview network administrators to understand how they deployed Wi-Fi in the service environments.

Han (2008) argues that further research could be done to investigate how users use Wi-Fi and how network providers deliver it. This study hopes to fill this methodological gap by carrying out an interview with a Wi-Fi administrator to understand the deployment strategies involved in setting up the Wi-Fi network on campus. This will allow the researcher to correlate configuration settings with perceived outcome quality at locations in which students use Wi-Fi the most. Furthermore, the study will report the Wi-Fi standard adopted on the Wi-Fi network to ascertain if there are compatibility difficulties between the network standard adopted and the standards user devices support.

In the next section, user device specifications that may affect the perceived Wi-Fi outcome quality are discussed.

2.6.1.2 User device quality and its effect on outcome quality

Device specifications dictate the quality of Wi-Fi devices. The specifications describe and give important details of the external and optional internal characteristics of a device that affect the performance levels of the device (Bizmanualz, 2017). Users need to use devices that are equipped with various specifications, such as memory size, and speed of processor; since every task may have a different performance requirement. It is therefore important that Wi-Fi users know their device specifications, as this may influence the overall quality of Wi-Fi the users receive. For instance, Wi-Fi devices support different processing speeds determined by the central processing unit. The central processing unit is the core of the computer system that processes the data in user devices. The term ‘Hertz’ (Hz), or ‘Gigahertz’ (GHz), is a measure of how fast the computer processor processes information. The faster the processor, the faster tasks can be completed. It is important that users know their processor speed before purchasing

any Wi-Fi device, as it will have a profound effect on task performance (Thakur, Rai, Kumar, & Pawar, 2013). In South Africa, student awareness of their Wi-Fi device operating speeds is not known. Moreover, it is not clear whether device speeds may affect the efficiency of Wi-Fi services.

User devices need computer memory, called random access memory (RAM), to store all programs temporarily as they run. Memory levels dictate how many programs can run smoothly at the same time when a user is multitasking. For example, a user may run email programs, Instant Messenger applications, and anti-virus tools or firewall software at the same time. The differences in computer memory affect the performance of a computer, the amount of information it can process, and the time taken to give results to the user (Chanchary & Islam, 2009; Facer, Faux, & McFarlane, 2005). This is because devices with large memories will store more programs during operation than devices with low memory size. Students report difficulties while downloading learning materials due to low memory sizes of devices (Chanchary & Islam, 2009). However, it is not clear whether device memory size may affect the efficiency of Wi-Fi services.

To access Wi-Fi, the Wi-Fi device needs to support a standard that is compatible with the Wi-Fi standard adopted on the network. However, because device manufacturers build devices to access multiple Wi-Fi standards, this may give rise to compatibility difficulties. For example, a Wi-Fi device that supports access to only the 802.11a standard may not access resources on networks using the 802.11b and g standards, because information travels on different spectrums. Also, if a device that supports access to the IEEE 802.11b and IEEE 802.11g network accesses resources on a network running the 802.11n standard, it will only access services on the congested 2.4GHz spectrum and not the 5GHz spectrum that is less congested (Soyinka, 2010). A compatibility mismatch between standards supported by the user devices and the standards provided on the network may influence Wi-Fi outcome quality. However, no study has been conducted in South Africa to investigate students' awareness of the different standards that their devices support.

All user devices must run an operating system to mediate communication from the hardware interface and software applications. Different operating systems exist in the market. For example, Microsoft produces the Windows operating system, like Windows 7, Windows 8, Windows 8.1 and Windows 10 (Microsoft, 2017b). In addition, Apple produces Mac operating

systems for Apple devices (Apple, 2017c). Other handheld devices use operating systems like Android and Symbian. Students use different operating systems to access Wi-Fi on campus. There has been no study to understand the operating systems used over Wi-Fi networks on campus. Moreover, different operating systems have different Wi-Fi connection-related problems that may affect the availability, reliability, stability and timeliness of Wi-Fi services. For instance, when using the Microsoft Windows operating system, the Wi-Fi profile to track the Wi-Fi connection may fail to connect the device to Wi-Fi, indicating that the profile may be corrupt (Microsoft, 2017a). In addition, Wi-Fi connection difficulties experienced by users of the Apple Mac operating system may arise from not having the latest version of the Apple IOS operating system; or the access point may not support the Apple device (Apple Inc, 2017).

The last few years have seen an increase in computer and smartphone production, giving rise to many production companies manufacturing various makes of Wi-Fi device (see Appendix 7). It is important to note that these devices have different specifications that may affect the perceived Wi-Fi quality. The differences are in terms of speeds, memory sizes, operating systems and Wi-Fi standards they support. For example, the Dell Corporation manufactures Dell desktops and laptops that have integrated Wi-Fi capability supporting standards like the 802.11b/g/n and ac.

Within the next few years, Wi-Fi devices could be an important component in the use of Wi-Fi services. However, research has shown that when students experience slow processing of resources on Wi-Fi, they always attribute the slow performance to poor Wi-Fi connections, and not necessarily to their Wi-Fi device specifications (Chu & Lin, 2006; Gururaj et al., 2016; Han, 2008).

Moreover, Wi-Fi devices operate with different operating systems, speeds and standards, and have varying memory sizes that may all influence the perceived quality of resources when accessing Wi-Fi services. In addition, while there are many makes of Wi-Fi devices on the market, their levels of penetration into the student market is not widely understood in South Africa. While this study does not investigate the different models of devices, it will broaden current knowledge of the level of penetration of different makes of Wi-Fi devices by different companies.

There is much literature that documents factors that affect Wi-Fi outcome quality. While some aspects are not represented by some scholars in their studies and publications, the majority agree on the same factors (see Table 3).

Table 3: A summary of factors affecting Wi-Fi outcome quality

Reference	Interferences in Wi-Fi locations	Obstructions in Wi-Fi locations	Choice of spectrum	Wi-Fi standards	Signal range	Antenna type employed	Congestion at access point
Macha and Damodaram (2016)	X		X	X			
(7signal, 2016)	X	X				X	
Vladyko et al. (2016)							X
Malik et al. (2015)							X
Abdelrahman et al. (2015)	X		X	X	X		
Călin-Alexandru et al. (2015)	X	X					
Bing (2002)	X	X	X		X		
Soyinka (2010)	X		X	X	X	X	X
Fitzgerald and Dennis (2005)	X		X	X	X	X	X
Sanjaya (2009)	X		X	X	X	X	X

Reference	Interferences in Wi-Fi locations	Obstructions in Wi-Fi locations	Choice of spectrum	Wi-Fi standards	Signal range	Antenna type employed	Congestion at access point
Held (2003)	X	X			X	X	X
Reynolds (2003)		X				X	X

2.6.2 Physical environment quality

The quality of the physical environment in which a service provider delivers a service can have a major influence on the users' perception of the quality of service delivered (Brady & Cronin Jr, 2001). Few physical indicators of good quality exist when purchasing services. However, the place where the customer receives the service cannot be hidden, and hence the cues in these environments have a strong influence on customers' perceptions of the service experience (Bitner et al., 1990; Parasuraman et al., 1988).

The first investigations into the quality of service delivery found that physical environmental factors, like the physical design of the environment, the ambient conditions (such as lighting and temperature) and social aspects (like the number of people in a location) may affect users' perceived quality of service (Biggers & Pryor, 1982; Bitner et al., 1990). The physical design of the environment refers to the arrangement or architecture of the environment and can be either functional (practical) or aesthetic (visually pleasing). Service-encounter environments exist to satisfy the needs of consumers, often through the successful completion of service users' actions. Functional layouts provide environments which facilitate performance and the accomplishment of goals (Bitner et al., 1990).

Wall and Berry (2007) investigated the combined effects of the physical environment and employee behaviour on customer perception of restaurant service quality. They investigated design and ambient factors in the service environment, including equipment, facility layout,

lighting, and colour. Results showed that the physical layout of the service location affected the perceived service quality.

Physical elements, such as the level of comfort of furnishings, could influence perceived performance in the service encounter (Biggers & Pryor, 1982). Regarding the use of Wi-Fi services, students require places to sit to access Wi-Fi. They state that finding a comfortable place is most important because they spend much time sitting in front of devices like laptops (Han, 2008).

In addition, most Wi-Fi devices, especially those that have an internal battery, like laptops and phones, can run on the battery for only a limited time. Hence, students may need to recharge their devices to continue using resources. Electrical designers of the environment are responsible for the installation of electrical circuits and power throughout the environment to support this functionality (Binggeli, 2003). Network installers need to co-ordinate with electrical engineers to ensure that the electrical installations meet the connectivity demands of students in Wi-Fi environments. However, in one study carried out in the United States of America, students did not use Wi-Fi devices due to a lack of sufficient power outlets in the building to connect their wireless access devices (Jones, Johnson-Yale, Millermaier, & Pérez, 2008). In a similar study by Han (2008), a student could not use Wi-Fi because he could not find an electrical outlet for his laptop. He either had to wait his turn to use a power plug-in point, or look for a power supply for his laptop. In addition, visually pleasing factors, including the cleanliness of a place, can affect perceptions of the experience; independently of the real outcome (Biggers & Pryor, 1982; Ryu, Lee, & Gon Kim, 2012).

Ambient conditions that pertain to non-visual aspects in the environment affect the perceived quality of a service environment (Brady & Cronin Jr, 2001). They are intangible background features which include lighting, noise, scent and air quality, which have a sub-conscious effect on customer perceptions and reactions to the environment (Baker & Cameron, 1996; Nguyen & Leblanc, 2002). Bitner et al. (1990) argue that environmental features, like lighting, that are part of the service environment, may influence internal responses. They further suggest that these features can be controlled by the firm to enhance (or constrain) employee and customer actions. This is because individuals may desire a certain level of lighting which is conducive

to a particular activity, and if the lighting is below or above the desired level, it may have a negative effect (Baker & Cameron, 1996).

Wall and Berry (2007) report that lighting, as an ambient factor in the service location, affected the perceived service quality. In addition, the temperature in a service environment can affect the perception of the physical environment quality. A study by Sureshchandar, Rajendran, and Kamalanabhan (2001) advances a framework that could provide a better understanding of customer-perceived service quality and its determinants. The study suggests that temperature in the physical service environment may be used to understand the users' perception of the quality of the physical environment.

The last factor, social conditions, refers to the number and type of people present at the service location, as well as their behaviour (Aubert-Gamet & Cova, 1999; Grove & Fisk, 1997). It also includes the behaviour of service users: noise levels may influence perceived service quality (Biggers & Pryor, 1982). A review of the literature has shown that there are many factors in the environment that affect the perceived physical environment quality. However, there has been no study to investigate if these factors may affect the perception of service quality at Wi-Fi locations in South Africa.

2.6.3 Quality of interaction with service providers

As users use services, they are bound to interact with service providers. This is a way for users to test the quality of the service delivered, by judging the quality of interaction with the service provider. Users judge the expertise, attitude and behaviour of the service providers as they interact with them when getting the service (Ekinci & Dawes, 2009). In the use of technology and information systems, users expect the information technology department to support them in performing tasks such as software and hardware selection, problem resolution and connection to LANs (Pitt et al., 1995). As such, the interpersonal interactions that take place during service delivery may have a significant effect on perceptions of service quality (Brady & Cronin Jr, 2001).

Wi-Fi users need assistance and regular service to overcome their difficulties when using Wi-Fi services (Singson, 2011). However, while universities provide hardware and software configuration support services to facilitate the use of Wi-Fi devices like laptops, students are

inconvenienced when there is no support from the IT department on weekends; and IT help is only available in office hours on weekdays (Han, 2008). Similar results are reported by Chu and Lin (2006) in their study to investigate the use of Wi-Fi by junior and senior students at the School of Information Sciences and Technology at Pennsylvania State University. The results showed that nearly 2.9% of students were frustrated with using Wi-Fi because they did not get technical support from the university. The Wall and Berry (2007) study looked at the combined effect of the physical environment and employee behaviour on customer perception of restaurant service quality. In their study, employee behaviour was defined by body language, tone of voice, and level of interest. The results showed that positive employee behaviour affected the perception of the restaurant service and determined the customer's final assessment of the restaurant's service.

2.6.4 Perceived service quality

Perceived service quality is a customer's impression of the quality of the service provided. Cascetta and Cartenì (2014) argue that the perceived service quality influences the level of quality required by customers and their choices when using the service. They add that these choices, in turn, effect the service quality delivered and service planning activities through monitoring. To deliver good quality Wi-Fi services, those organisations delivering Wi-Fi services should implement strategies that support high quality service delivery as per differences in the servicing environments.

Students may face various difficulties when using Wi-Fi in different environments. This may influence the perceived service quality and limit the actual use of the service at Wi-Fi locations. There is a need to identify and solve these difficulties, from both user and provider perspectives. This would facilitate the effective use of Wi-Fi services, which might increase user productivity while accessing Wi-Fi services. Han (2008) argues that WLANs have become widespread in institutions of higher education. He proposes that further research could be done on more campuses and in different countries. While studies have been conducted to investigate the quality of service delivery, there has been no study to investigate the use of Wi-Fi and students' perception of on-campus Wi-Fi service quality in South Africa.

2.6.4.1 Students' perceptions of Wi-Fi service quality

Understanding student perceptions of Wi-Fi quality should indicate how services may be improved. Nearly 95% percent of students at Pennsylvania State University strongly agreed that an increase in Wi-Fi speed was important (Chu & Lin, 2006). An investigation into student use of the Wi-Fi service showed that students reported varying degrees of satisfaction with the Wi-Fi services received. A study by Singson (2011) found that only 2% of students felt that the speed of the Wi-Fi was excellent; 37% felt that the speed was good and 33% felt that it was poor. In a similar study, Gururaj et al. (2016) reported that, out of 120 respondents, 25.8% stated that the Wi-Fi provided an excellent network connection; followed by 44.2% who rated it as good. However, 2.5% of the respondents thought that the Wi-Fi connectivity was very poor.

While studies have reported varying perceptions of Wi-Fi quality, there is still a need to identify the times and locations at which students form these perceptions. In addition, the literature shows that there are other factors not directly related to the Wi-Fi connection, like the quality of the locations where students access a service, and the quality of interactions, which may affect perceptions of service quality

2.7 Conceptual framework

The proposed conceptual model (see Figure 6) adopts three primary constructs of service quality from the hierarchical-approach model (Brady & Cronin Jr, 2001). These constructs include outcome quality, physical environment quality, and interaction quality. The model suggests that the perceived quality of a service is clarified by the evaluation of these three primary constructs. Each of the primary constructs is evaluated using sub-constructs that represent the characteristics of the associated primary construct. For example, the outcome quality construct is explained by evaluating the availability, reliability, timeliness and stability of the Wi-Fi network.

As there were no quality of service models to understand user perceptions of the quality of Wi-Fi services in the literature, the author used existing literature to identify the primary constructs and sub-constructs (see Figure 6).

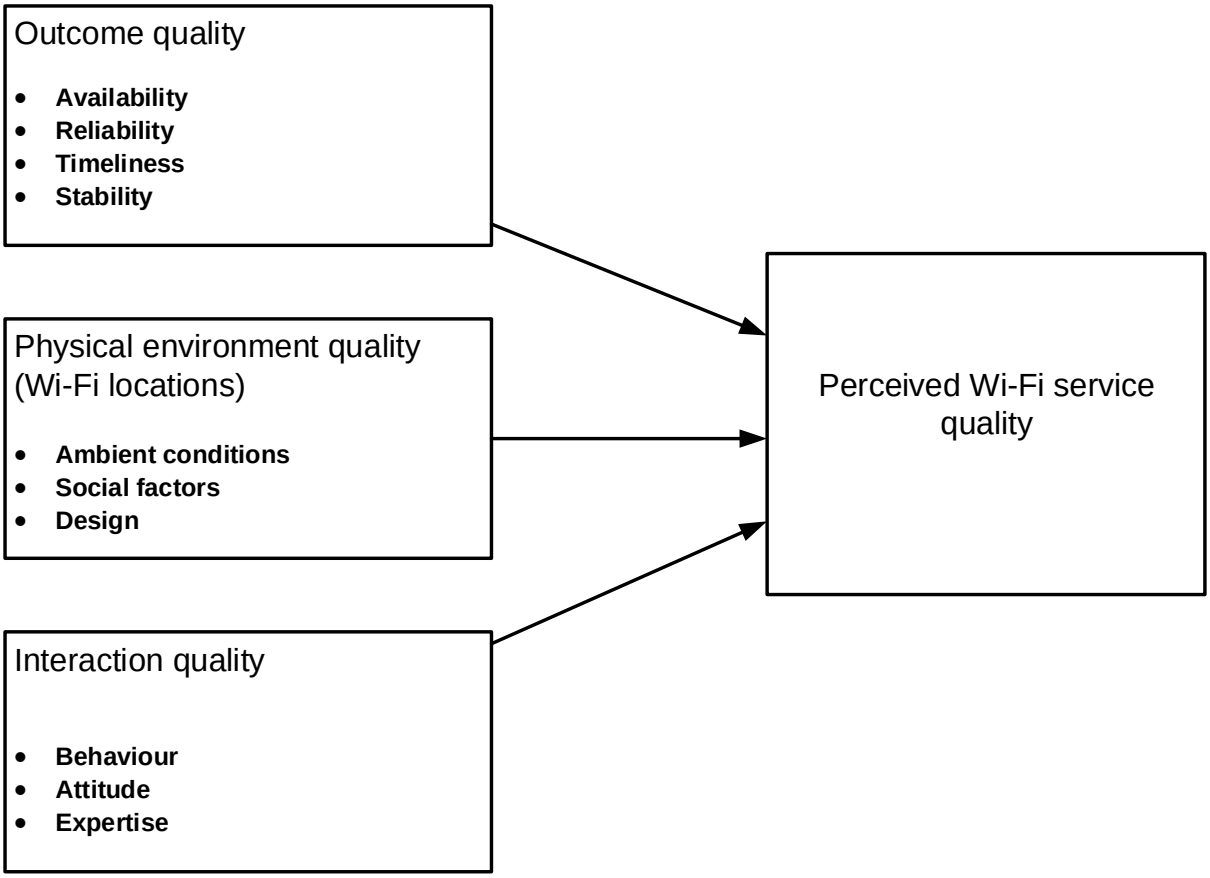

Figure 6: The primary constructs and perceived service quality

As can be seen in Figure 6, the model suggests that the three primary constructs, viz. outcome quality, physical environment quality and interaction quality, affect perceived Wi-Fi service quality.

2.7.1 Outcome quality

The first primary construct affecting perceived quality of service is outcome quality. This quality focuses on the actual use of the service, or the service product itself, and defines how people gauge the service delivery itself. (For a description of these factors, see Section 2.6.1.) To assess student evaluations of this construct, this study adopts the quality of service metrics incorporated by the IEEE standard as sub-constructs. They are Wi-Fi availability, reliability, timeliness and stability (Malik et al., 2015) (see Figure 6). The metrics are intended to rate the service delivery in the IEEE 802.11 standard wireless network (Malik et al., 2015).

2.7.2 Physical environment quality

The second primary construct that influences the quality of Wi-Fi service is the physical environment in which network provider delivers Wi-Fi services. In the context of this study, the university has installed Wi-Fi in different locations (LANs, cafeteria, laboratories, lecture venues and residences). The sub-constructs of physical environment quality are ambient conditions, social conditions and physical designs of the Wi-Fi locations as they may affect the rating of Wi-Fi service quality on campus (Brady & Cronin Jr, 2001).

2.7.3 Interaction quality

The third primary construct that affects the Wi-Fi service quality is the interaction quality, which focuses on the interaction that takes place between the users of the service and the service providers (Brady & Cronin Jr, 2001). These interactions may be in the form of providing guidance, education, and support to assist with using the service. In the context of this study, the sub-constructs of interaction quality are behaviour, attitude, and expertise of the ICS administrators within the university in resolving problems or offering help to students. These may influence their perception of the quality of Wi-Fi service offered (see Figure 6).

2.7.4 Perceived Wi-Fi service quality

Perceived service quality is the dependent variable. It depends on outcome quality, physical environment quality and interaction quality in this model.

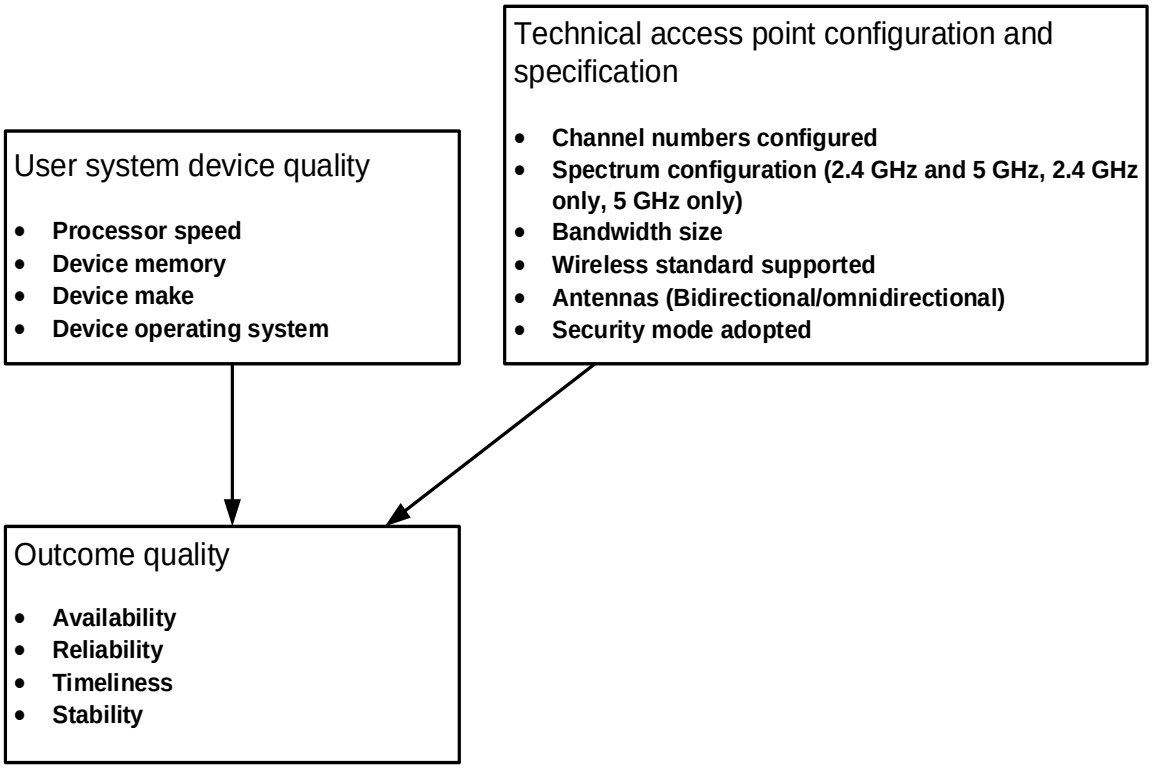

Figure 7: The effect of users' system device quality and technical access point configurations on outcome quality.

The second part of the model proposes that the user's system device quality and technical access point configurations may affect the Wi-Fi outcome quality (see Figure 7). The two additional variables are discussed below.

2.7.4.1 User system device quality

With respect to outcome quality, the system quality of the devices with which a user accesses the service may influence the outcome quality, and therefore the user perception of the quality of service (W. H. DeLone & McLean, 1992). This study posits that the user system device quality construct, as an independent variable, affects the outcome service quality, since students may use different devices to access Wi-Fi in different on-campus locations. User system device characteristics include the processor speed, device memory, device make and device operating system.

2.7.4.2 Technical access point configurations and specifications

Wi-Fi local area networks rely on an access point as a central node through which all communication is routed. Hence, an access point can become a bottleneck for the entire

network (Bernaschi, Ferreri, & Valcamonici, 2008). Access point specification and configuration settings may therefore influence the outcome quality and consequently the user perception of the quality of service. An example of these configurations and specifications includes the access point channels configured, the spectrum accessed, the bandwidth size, the wireless standard supported, the antenna type and the security mode adopted.

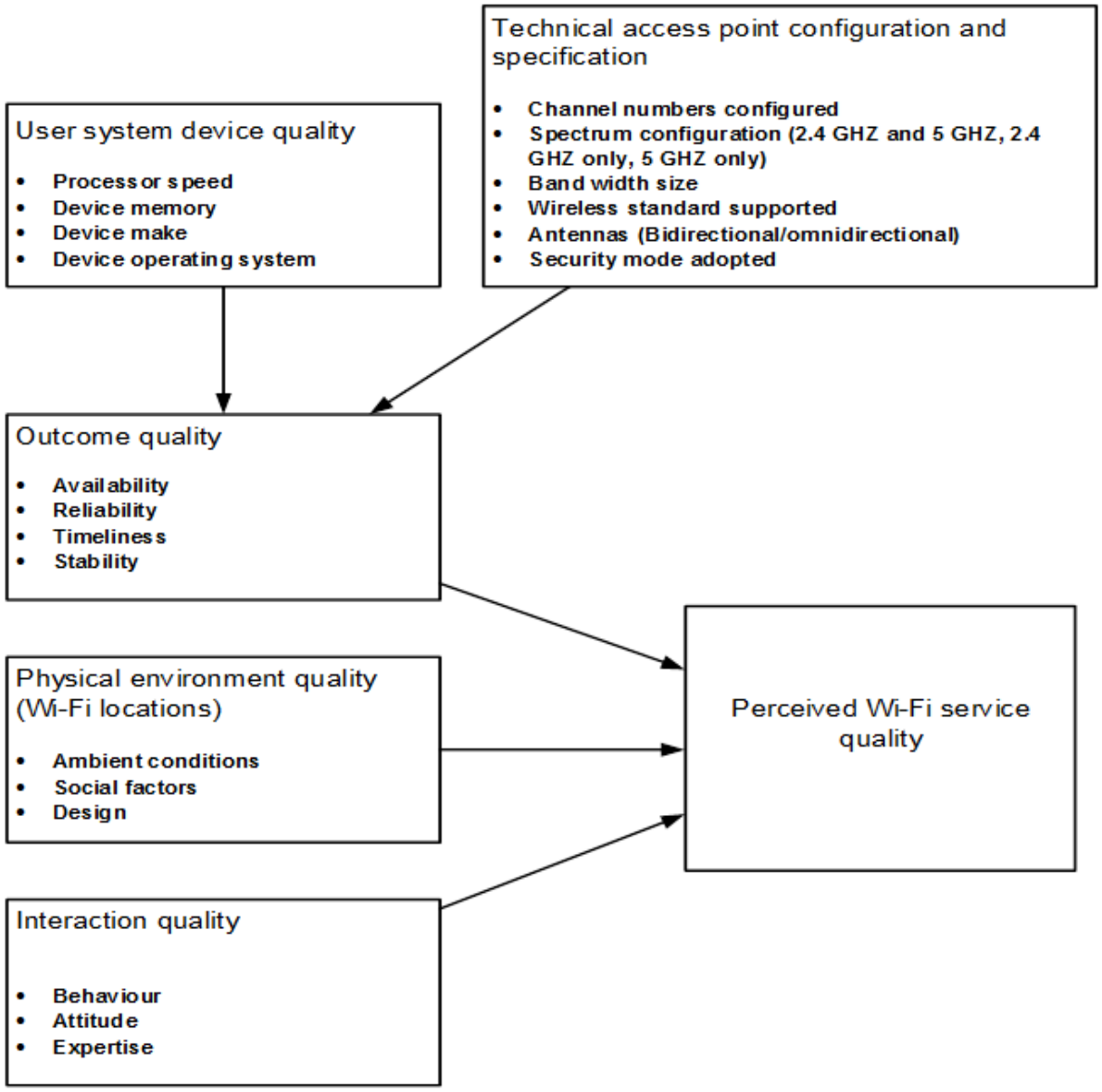

Figure 8: Conceptual model drawn from the hierarchical-approach quality of service model (Brady & Cronin Jr, 2001); the information systems success model (DeLone & McLean, 1992); and quality of service metrics adopted by the IEEE 802.11 wireless standard (Malik et al., 2015); sub-constructs provided by the author.

The full conceptual model adopted (see Figure 8) seeks to understand student perceptions of Wi-Fi quality by understanding their overall perception of the three primary constructs (outcome quality, physical environment quality and interaction quality) as independent variables; and perceived Wi-Fi service quality as the dependent variable. It also seeks to identify a relationship between user system device quality and technical access point configurations; and specifications and outcome quality (see Figure 8).

2.8 Conclusion

Providing Wi-Fi is a complex task. Wi-Fi quality can be affected by many factors. From an infrastructural perspective, the literature has shown that network providers may adopt various access point configurations to deliver Wi-Fi services, which may affect the quality of Wi-Fi services provided (Bing, 2002; Held, 2003; Reynolds, 2003). However, most studies did not carry out interviews with network providers to ascertain the adopted configuration on the Wi-Fi network, to establish if these different configurations may indeed impact Wi-Fi service quality.

From a user perspective, the perceived quality of Wi-Fi may be determined by factors like user proximity to Wi-Fi access points, their choice of Wi-Fi devices and how they operate the devices when accessing Wi-Fi resources (logging in and power configurations on the Wi-Fi cards) (Lehr & McKnight, 2003; Soyinka, 2010).

From an environmental perspective, obstacles and changes in the environment, like the physical positioning walls, may limit the strength of Wi-Fi signals, thus leading to poor Wi-Fi services (Reynolds, 2003).

To deliver good quality services requires user input, in order to close the gap between quality of services promised and what users actually experience. This strategy would allow service providers to make improvements in the quality of the service. However, there is no quality of service model to assist Wi-Fi providers in engaging with users to determine the quality of Wi-Fi service delivered. This could make it costly to implement quality Wi-Fi services; for example, if most providers see the solution in providing better access points and adding more access points; which may not be what is required.

There is limited literature documenting students' Wi-Fi usage, or the characteristics of their Wi-Fi devices, like Wi-Fi standards, memory and speed. Studies view types of devices more generically, like the type and make of devices (Chen et al., 2012; Singson, 2011).

Improving Wi-Fi services would thus require an understanding of how users access the Wi-Fi service in different environments; as well as an understanding of users' perceptions of the Wi-Fi quality, given the installed infrastructure.

The next chapter discusses the methodology.

3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes and presents the methods that were chosen to investigate the UKZN Westville students' use of Wi-Fi on campus and their perceptions of the quality of the service. The target population comprised registered UKZN Westville students and two ICS administrators. The study used a convenience sampling procedure. The sample size, and how the sample was selected, and the data collection methods and instruments, which included questionnaires and interviews, are discussed. The chapter further shows how the quantitative and the qualitative data were analysed. In addition, it covers the ethical considerations that governed the study and the problems that the researcher encountered during the research process.

3.2 Research Design

This study follows a descriptive research design. Sekeran and Bougie (2010) argue that a descriptive research design allows the researcher to describe the characteristics of people in a certain situation. Hence this research design was used, since Wi-Fi use was taking place at the university, and the researcher wanted to investigate how students use it. The research design elucidated associations among variables to describe the population, events or situations. This allowed the researcher to generate informative results that may facilitate certain decisions related to Wi-Fi use on campus.

3.3 Research Approach

This study follows a mixed methods approach. Mixed methods research involves collecting, analysing and integrating quantitative and qualitative research in a single study (Sekeran & Bougie, 2010). The qualitative and quantitative research approaches were used to gain a better understanding of the research problem; compared to using either research approach alone. A quantitative approach enabled the researcher to explain the phenomena by collecting numerical data from students, so that relationships between the conceptual frameworks could be examined statistically (Sekeran & Bougie, 2010). In addition, the qualitative approach allowed the researcher to interview ICS administrators to gain a better understanding of the on-campus Wi-Fi infrastructure provided by the university.

3.4 Study site

The University of KwaZulu-Natal Westville, in KwaZulu-Natal province, in South Africa, is the site of this study.

3.5 Target population

The target population of this study were the registered students of the University KwaZulu-Natal Westville campus. At the time of the study in 2017, the size of this population was 12,660 students (UKZN Institutional Intelligence, 2017). The study also includes two ICS administrators.

3.6 Sampling method

3.6.1 The sampling procedure for the quantitative data

A convenience sampling methodology was used for the study. It is a statistical method of drawing representative data by choosing people based on the ease of their availability (Sekeran & Bougie, 2013). A major reason for using a convenience sampling methodology was because the study aimed at understanding the on-campus use of Wi-Fi and students were readily available at various on-campus locations to provide it.

At a 95% level of confidence, a 5% confidence interval and a population of 12,660 students registered on campus, the total sample size for the study is 373 students (Surveysystem, 2017).

3.6.2 The sampling procedure for the qualitative data

To collect the qualitative data, the study followed an extreme case sampling strategy. Extreme case sampling is a form of purposeful sampling in which a researcher may choose participants based on distinguishing characteristics (Creswell, 2005). The researcher purposefully selected two ICS individuals responsible for the overall administration of Wi-Fi services to students on the campus.

Participant 1 is responsible for Wi-Fi infrastructure installation. Participant 2 is responsible for student support.

3.7 Data collection strategies

3.7.1 Permissions needed

The researchers obtained a gatekeeper's letter granting permission to collect data within the university from the target population. This is attached in Appendix 1. The researcher ensured that the students' rights were protected by stating their rights in a consent form that was attached to the questionnaire (see Appendix 3). All students signed the consent form before they provided data.

Regarding the collection of interview data, the researcher ensured that the consent and permission to participate forms were also signed by the participants (see Appendix 4).

3.7.2 Strategies for recording the data

To record the quantitative data, a questionnaire was developed as a data collection instrument and the data was entered into Microsoft Excel. To gather qualitative data the researcher sent an email requesting an interview appointment with the ICS administrators. After getting confirmation of the dates, the researcher prepared a smartphone as a recording device for the interviews. In addition, the researcher printed the preset questions (see Appendix 4) before the interview process and used a notebook to note down responses and new questions.

3.7.3 The research instruments used in the study

The research instruments chosen for the study were questionnaires and interviews.

3.7.3.1 The student questionnaire

A questionnaire was developed to collect data from students (see Appendix 3). It contained instructions, questions and statements to elicit answers from respondents. Questionnaires were selected as the primary data collection instrument in this study. This was considered suitable since it allowed the university students to complete them at their own convenience. The researcher attached the consent form, gatekeeper's letter and consent to participate form to the questionnaire. These communicated the purpose of the research and highlighted ethical considerations.

The student questionnaire consisted of both open-ended and closed-ended questions. The students were provided a list of alternative responses from which to choose when answering the closed-ended questions. Open-ended questions allowed the respondents to freely note down their responses.

The student questionnaire was designed in three sections (Section I, Section II and Section III). Section I consisted of questions to collect students' biographical data. This section had four questions in total. The section included both open-ended and closed-ended questions. Section II sought to collect information on the students' academic backgrounds. This section had three questions which were all closed-ended in nature. Section III comprised 23 questions for students to report on their use of Wi-Fi on campus. This section included a ranking question (Question 22). The ranking scales used were from 1 = not at all frequently; to 7 = very frequently. This reason for choosing this scale was to be able to better discriminate between responses, hence facilitating better decision making. Furthermore, the section included both open-ended and closed-ended questions. It also had one question (Question 30) that used a seven-point Likert scale. The question used the following points: 1 = strongly disagree; 2 = disagree; 3 = slightly disagree; 4 =neutral; 5 = slightly agree, 6 = agree and 7 = strongly agree. Question 30 captured respondents' perception of the three constructs affecting service quality (i.e. outcome quality, physical environment quality and interaction quality) and service quality itself (see Figure 6). Three items were developed for each sub-construct in Question 30.

Because the items for each sub-construct in the quality of service model in Question 30 were developed by the author, they had to be validated using principal axis factoring in SPSS to ensure that they were suitable for testing user perception of the quality of Wi-Fi services.

With the help of an assistant, the researcher administered 373 printed questionnaires to students on the Westville campus. The questionnaire surveys allowed the researcher to get students' opinions on Wi-Fi use and their perceptions of service quality.

3.7.3.2 The ICS interviews

The researcher carried out two interviews to gain information on the Wi-Fi infrastructure and use within the university (see Appendix 4). The interviews were semi-structured due to the technicality of the topic. This allowed the researcher to prepare predetermined questions for the interview, while also being flexible when asking questions. The interview questions had

two sections. The first section (section IV) aimed at understanding the Wi-Fi infrastructure provided on campus in general. The second section (section V) aimed at understanding if there were any difficulties with Wi-Fi infrastructure from a student point of view.

3.8 Data collection procedures

3.8.1 Procedures for collecting quantitative data

The researcher and assistant went into locations where students are normally found on campus. These locations included the library, cafeteria, lecture venues, on-campus residences, and LANs (local area networks).

Following the chosen sampling strategy, the researcher and assistant approached convenient students and introduced themselves. The study ensured that all the respondents were 18 years, or older, and had read and signed the consent form to participate. This was to ensure that ethical rules had been followed. The filled-in questionnaires were checked to ensure all questions had been answered. The respondents were then thanked for their participation and the completed questionnaires were stored.

3.8.2 Procedures for collecting qualitative data

The researcher introduced himself to the interviewee. The researcher noted down the time and place of the interview before the interview session started (see Appendix 5). At the start of the interview, the interviewee was given time to read through the consent and consent to participate forms. After signing the consent to participate form, the researcher asked for permission to record the interview session on his mobile smartphone. The researcher also recorded responses from the interviewees in a notebook as this allowed questions to be clarified by the researcher.

3.9 Data collection, recruitment and capture

The data collection methods in this research were quantitative and qualitative. The researcher used a sequential approach to collect the data for the study. Quantitative data was collected first and the results were used to inform the collection of qualitative data. The information from the quantitative data highlighted Wi-Fi locations which were of interest for further investigation during the interviews. These locations included the most-used Wi-Fi locations and locations at which students experienced the best and worst Wi-Fi signal quality. In addition, it became the foundation for understanding how Wi-Fi is used on campus, thus

providing guidelines for asking the ICS administrator for the exact configurations of Wi-Fi access points in those locations.

The quantitative data were collected in two phases, from 26 May 2017 to 31 August 2017, at the University of KwaZulu-Natal Westville campus. The first phase of data collection took place between 26 May 2017 and 23 June 2017. This was during the students' exam period. The researcher used both on-the-spot questionnaires and administered questionnaires for later collection. In this phase, the researcher collected 96 questionnaires. The second phase of data collection occurred as the semester started, from 16 July 2017 to 22 August 2017. In this phase, the researcher recruited and trained a data collection assistant. Altogether, in this phase, 277 questionnaires were collected. During the quantitative data collection period a total of 373 questionnaires were completed.

After analysing the quantitative data, the researcher arranged interviews with two ICS personnel to collect the qualitative data. The first interview was held on 23 October 2017 and the second was held on 24 October 2017. A follow-up interview was held on 17 May 2018 with participant 1.

3.9.1 The collection and verification of completed questionnaires

After each questionnaire was collected, the following verification tasks to process the questionnaires received were carried out:

1. Check whether the permission to participate form had been completed. If the participant had forgotten to fill in the form he/she was reminded to fill it in.
2. Store questionnaires, by date collected, at the researcher's residence.

3.9.2 Data coding

The researcher first created a generic coded questionnaire by assigning each possible answer a number or code. This was used as a reference for coding all the collected questionnaires. Each questionnaire that was coded went through data quality control. The researcher checked through each questionnaire to ensure that the codes corresponded to specified codes on the master coded questionnaire.

3.9.3 Data entry

Data entry started after the first phase of data collection and continued until all the questionnaires were captured. Microsoft Excel was used for the data capture procedure. To ensure the accuracy of data capture, the researcher checked each questionnaire entered and compared the entered data of each response. This was to uncover data capture errors. If any differences were found, the researcher made corresponding revisions. Open-ended questions (including a response category of "other: please specify" and narrative descriptions) were entered as text into the Microsoft Excel data file to allow for statistical analysis in SPSS.

Qualitative data was captured through recording interview responses to questions on a phone and writing down notes in a notebook. The recording was transcribed into Microsoft Word.

3.10 Data quality control

To make sure that data quality was maintained, most of the questionnaire response options were named so that they were easy to select using checkboxes with labels instead of asking students to write out their responses.

3.10.1 Validity

Validity checks are performed to see how well a measuring instrument measures the concept it aims to measure (Sekeran & Bougie, 2010).

Content validity: The questionnaire was reviewed to make sure that words and instructions were written, displayed and formatted in clear, standard English. This was done by the researcher, supervisor and a statistician specialising in questionnaire development.

Construct validity: The sub-constructs used in the conceptual model to identify the primary constructs (outcome quality, physical environment quality and interaction quality) were defined in the literature by (Brady and Cronin Jr (2001); Malik et al., 2015).

Because the items for each of the sub-constructs of the service quality model (see Figure 6) were developed by the author, they had to be tested to the show the validity and suitability of the responses collected regarding students' perceptions of Wi-Fi service quality. Principal axis factoring in SPSS was applied to all 35 items that were chosen to understand the perception of

Wi-Fi service quality. The study adopted the Kaiser-Meyer-Olkin (KMO) measurement of sampling the adequacy of the data to extract data reliably.

3.10.2 Reliability

For the questions using Likert scales, the Cronbach alpha function was used to ascertain that they were homogeneous and measuring the same variable (Cavana, Delahaye, & Sekaran, 2000).

3.11 Data Analysis

3.11.1 Quantitative Data Analysis

Data was analysed using SPSS (Statistical Package for Social Science). To answer the research questions, the researcher designed an alignment matrix (see Appendix 7), which identifies which questionnaire or interview questions answer each research question.

This study used both descriptive and inferential statistical analysis to ensure that categorical data was summarised into accurate mathematical numbers and to draw conclusions about relationships between the variables.

3.11.1.1 Descriptive statistics

This study used descriptive analysis to analyse and describe the information collected in the study. The statistics used in this study included means, standard deviations and frequencies. Graphs and tables were used to present this data.

3.11.1.2 Inferential statistics

This study used inferential statistics to uncover the relationships between variables in the study. They included correlations, regressions and other inferential analysis.

These tests are described below:

- The study used linear regression to find out if a relationship existed between two variables. This test was used to determine the effect of the constructs in the conceptual model on the perceived Wi-Fi service quality.

- ANOVA was used to compare two or more groups of cases in one variable. This test was used to see if there was a variance between different groups, with the variability within each of the groups using an F-ratio.
- The Chi-square goodness-of-fit-test was used on categorical variables to test whether any of the response options were selected significantly more/less often than the others.
- The Chi-square test of independence was used on cross-tabulations to see whether a significant relationship existed between the two variables represented in the cross-tabulation.
- The binomial test was carried out to test whether a significant proportion of students selected one of a possible two responses.
- The other inferential statistic used in the study was the one sample t-test, to ascertain whether a mean score was significantly different from a scalar value.
- The independent samples t-test was conducted to compare two independent groups of cases.
- Pearson's correlation was calculated to investigate whether there was an association between two variables. The strength of the association between two variables may be positive or negative and is represented by a coefficient (r) (Cavana et al., 2000).

3.11.2 Qualitative data analysis

Qualitative data analysis was based on the research questions presented in the study. The responses from each of the participants were summarised according to the research questions. Each research question was entered into Microsoft Excel with its associated responses. This was followed by establishing relationships between the research responses, thus allowing the researcher to put together similar responses from the two participants.

3.12 Ethical considerations

The study followed the ethical requirements of the School of Management, IT and Governance. The ethical clearance for the study was approved by the UKZN Humanities and Social Sciences Research Ethics Committee on 18 May 2017. The approval number for the study is HSS/0550/017M (see Appendix 2). The gatekeeper's letter was approved on 2 May 2017 (see Appendix 1).

Data collection started after the researcher had obtained the gatekeepers' letter and the ethical clearance. Participants were authorised to take part after they had read and understood the terms and conditions in a consent form. Participants had the freedom to stop participation in the study at any time they wished. The researcher maintained the confidentiality of the data collected. Questionnaires and data collected were given to the school administration to be kept for five years after completion of the study.

3.13 Summary

This chapter explained how the research was conducted. The study followed a descriptive design, using both questionnaires and interviews as data collection instruments. The study comprised a sample of 373 students at the University of KwaZulu-Natal and two ICS staff members. The data collection instruments consisted of self-administered questionnaires and interviews with two participants. The questionnaire was administered to the survey participants, while the interviews were conducted in the offices of the participants. The quantitative data analysis was done using the SPSS software for data analysis, while the qualitative data analysis used Microsoft Excel. Ethical considerations were attended to and the researcher adhered to the rules and practices of ethical research.

The next chapter presents results from the data collected, in the form of descriptive and inferential statistics.

4 PRESENTATION OF STUDY RESULTS

4.1 Introduction

The purpose of this study was to investigate students' use of Wi-Fi on campus, and their perceptions of quality of service. The assessment of the quality of service is built on the conceptual framework presented in the literature review section (see Chapter 2, Section 2.7). Primary data was collected by administering questionnaires to students registered on the University of KwaZulu-Natal Westville campus. To supplement the data collected from the questionnaires administered to students, two ICS staff members were interviewed.

The results from this study are aligned to the following objectives:

1. Report how UKZN Westville students use Wi-Fi on campus:

    a) To identify the locations in which UKZN Westville students prefer to access Wi-Fi services on campus.

    b) To show how much time UKZN Westville students spend accessing Wi-Fi on campus;

    c) To investigate the Internet resources UKZN Westville students access when using Wi-Fi on campus.

    d) To show the devices UKZN Westville students use to access Wi-Fi on campus.

2. Identify the access point configurations and specifications provided on Westville campus.

3. Report the difficulties UKZN Westville students face when using Wi-Fi services on campus:

    a) To report the difficulties UKZN Westville students experience when using Wi-Fi services on campus.

    b) To investigate the difficulties UKZN Westville students report to ICS about the use of Wi-Fi services on campus.

4. Report on UKZN Westville students' perceptions of the quality of Wi-Fi service on campus:

    a) To report on UKZN Westville students' perceptions of the outcome quality of service when using Wi-Fi services on campus.

b) To report on UKZN Westville students' perceptions of the quality of the physical environment when using the Wi-Fi service on campus.

c) To report on UKZN Westville students' perceptions of the interaction quality when using the Wi-Fi service on campus.

d) To investigate how user system device quality and access point configuration specifications affect outcome quality.

5. Report how outcome quality, physical environment quality and interaction quality affect students' perceived Wi-Fi service quality.

6. Identify the factors that may affect Wi-Fi outcome quality on Westville campus.

The findings will be presented in this chapter. The demographic information of the participants will be presented, followed by the results from the research questions in the students' questionnaires, and from the interviews.

4.2 Basic demographic and education information

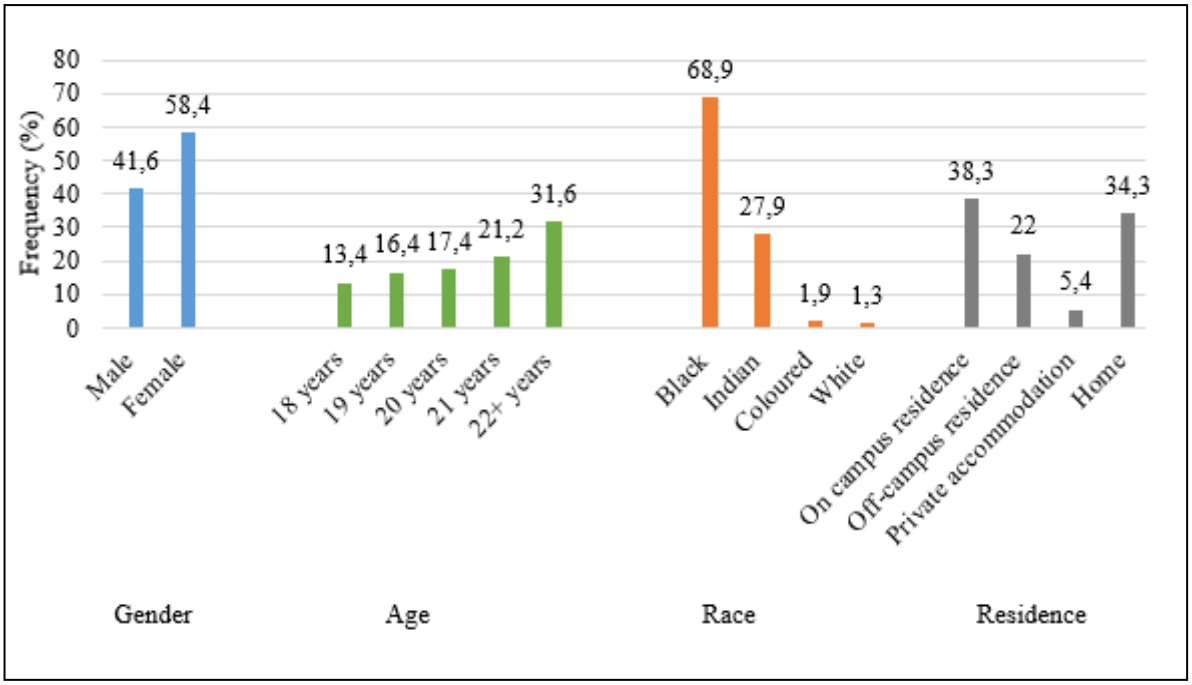

Figure 9: Students' demographic information: gender, age, race and place of residence.

A total of 373 UKZN Westville students who use Wi-Fi on campus responded to the questionnaires, resulting in a response rate of 100%. Of the respondents, 58.4% were females and 41.6% were male (see Figure 9). Most of the respondents were aged 22 and older (31.6%). The majority of the respondents were Black (68.9%), followed by Indians (27.9%). In addition, the largest group of respondents stayed in on-campus residences (38.3%). The next largest group of students stayed at home (34.3%). Few students (5.4%) lived in private accommodation (see Figure 9).

4.3 Education information

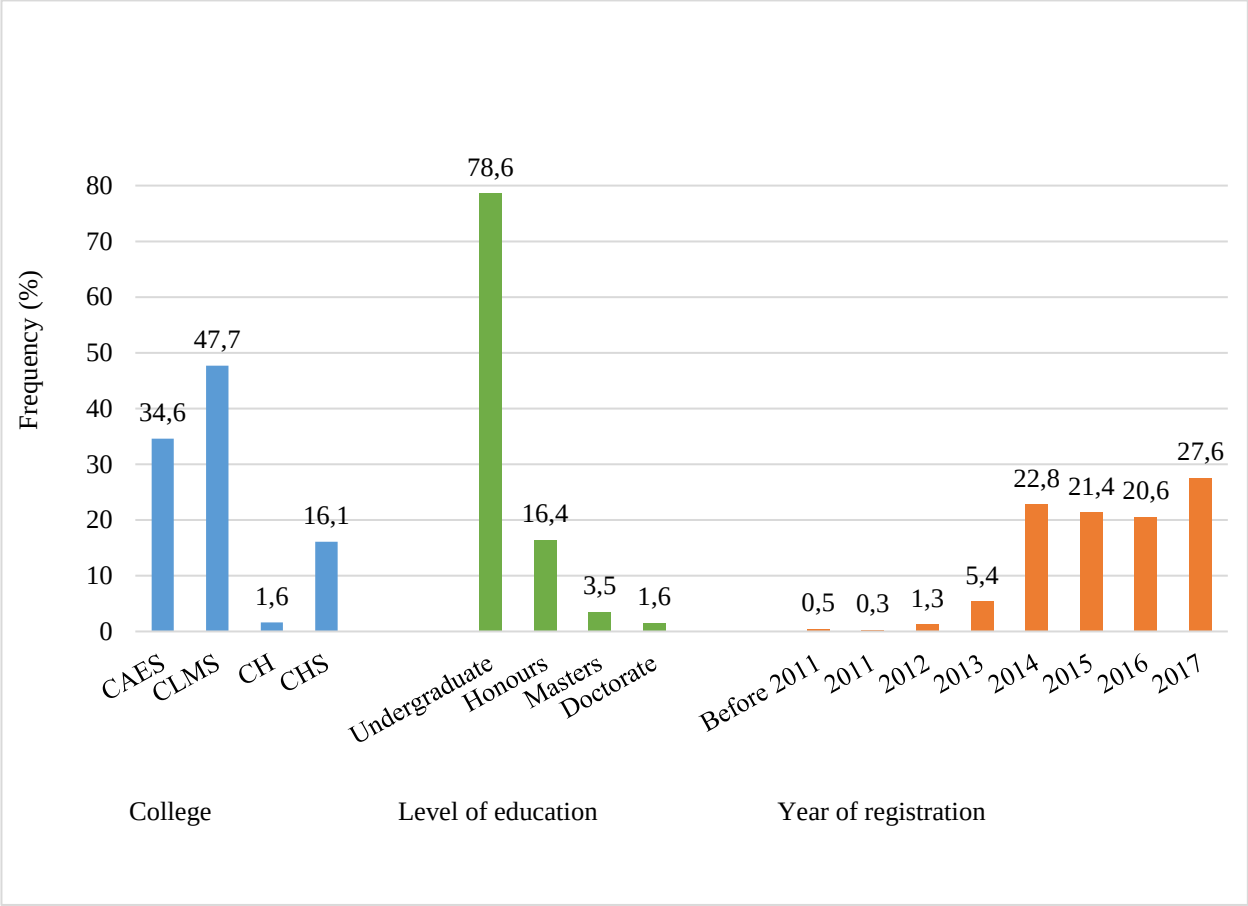

Figure 10: Students' education information.

As can be seen in Figure 10, the majority of the respondents were registered in the College of Law and Management Studies (CLMS) (47.7%), followed by the College of Agriculture, Engineering and Science (CAES) (34. 6%) and the College of Health Sciences (CHS) (16.1%). Very few (1.6%) were registered in the College of Humanities (CH). Most of the respondents

were undergraduate students (78%) and Honours students (16.4%). Nearly all the students (92.4%) first registered between 2014 and 2017.

The next section presents the results from the five research questions identified for the study. The findings are presented according to their respective research objectives.

4.4 Objective 1: Use of free Wi-Fi on campus

The aim in this section was to research students' use of Wi-Fi. This research objective was broken down into four sub-objectives. The objectives address the locations in which students prefer to use Wi-Fi; the amount of time spent using Wi-F; the devices used; and Internet resources accessed over Wi-Fi.

In order to understand the popularity of Wi-Fi use among students on the campus, the study first examined how students learnt to use Wi-Fi, and their use of the free on-campus Wi-Fi compared to using other methods to access network resources.

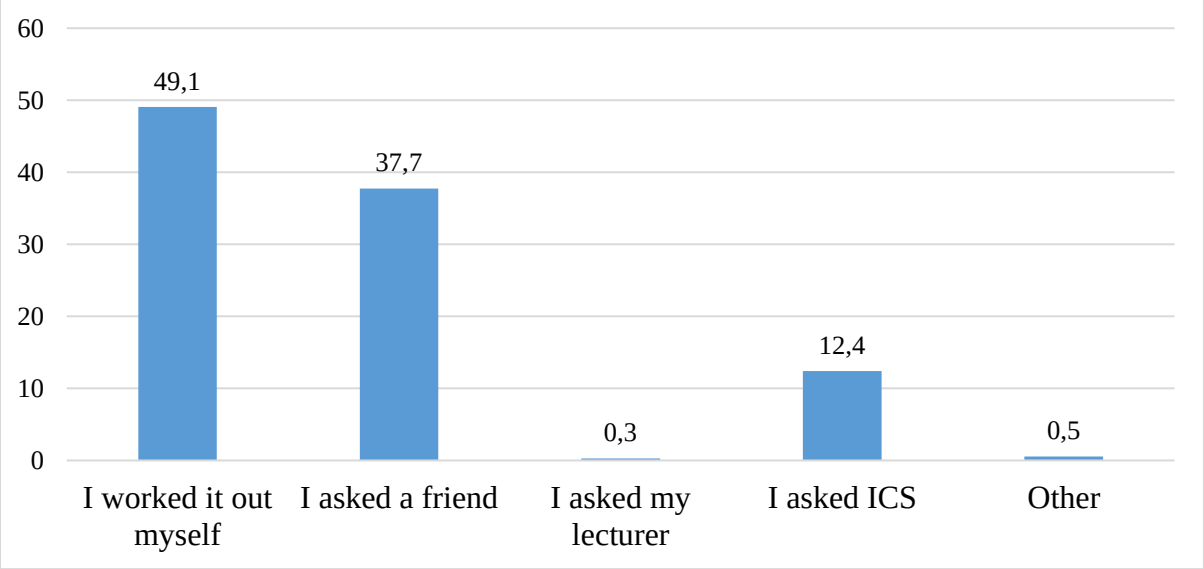

Figure 11: How students learnt how to use Wi-Fi on campus

Students were asked to indicate how they learnt to use the Wi-Fi on campus. A chi-square goodness-of-fit test was carried out to test how students learnt to use Wi-Fi on campus. A significant number of students learnt how to use the Wi-Fi on campus, either by asking a friend

(37.5%), or by working it out themselves (49.1%), χ^2 (4) = 370.070, p<.0005). The results further showed that few students asked their lecturer (0.3%) (see Figure 11).

The results were further analysed by students' residential accommodation to understand how students living in different places learnt how to use Wi-Fi. These results are described in the next section.

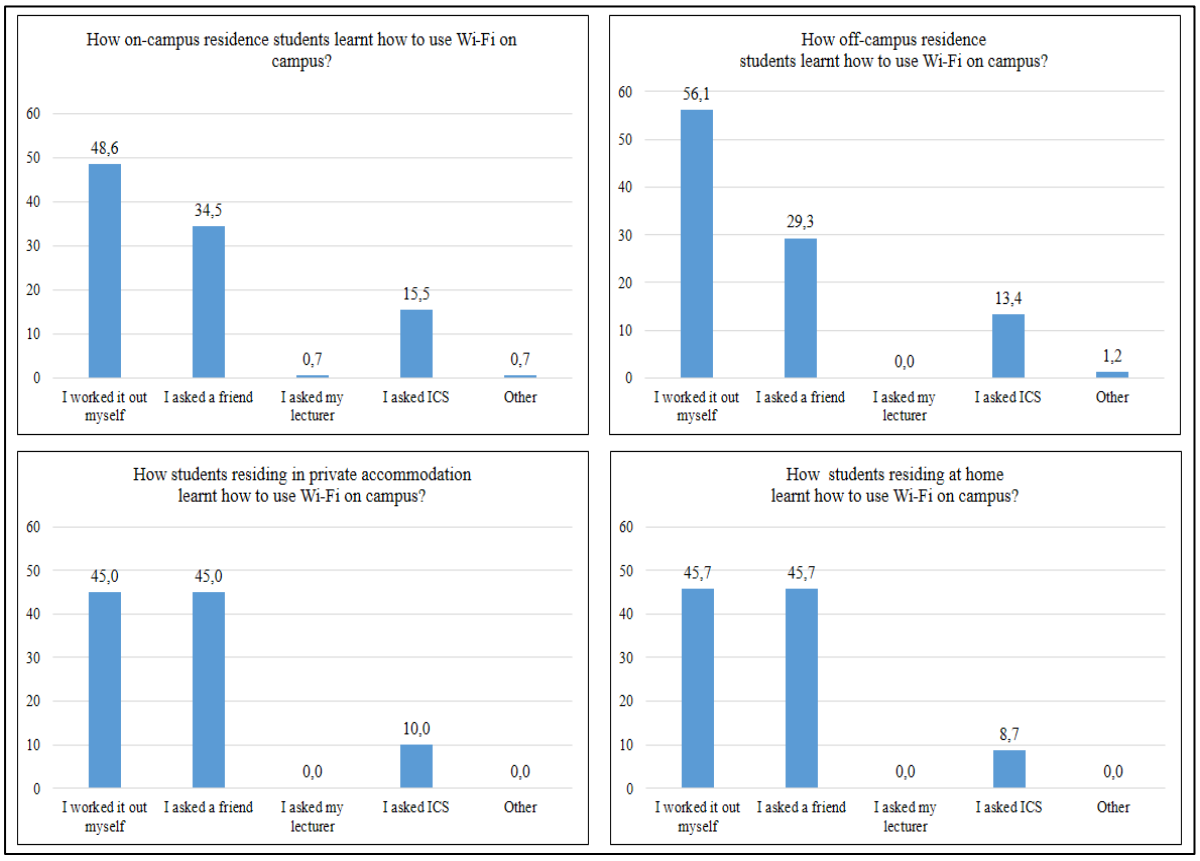

Figure 12: How students learnt to use Wi-Fi on-campus, by place of residence.

When students were asked how they learnt how to use Wi-Fi on-campus, a majority of the students residing in off-campus residences (56.1%) worked it out themselves. The only students who asked their lecturers resided in on-campus residences (0.7%) (see Figure 12).

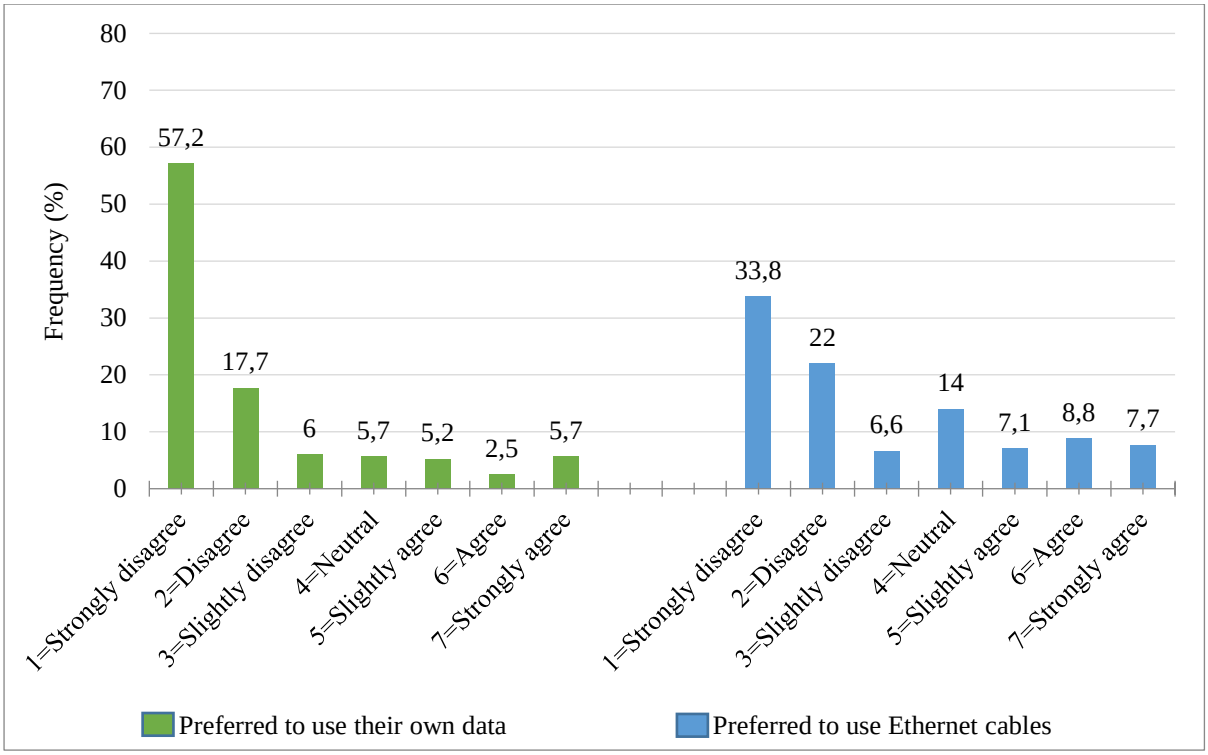

Figure 13: Students' use of their own data or Ethernet cables on campus.

When students were asked how they would access Internet resources on campus, a majority of the students disagreed that they preferred to use their own data instead of the free Wi-Fi (57.2%), while few students agreed (2.5%) or strongly agreed (5.7%). In addition, 33.8% of the students strongly disagreed that they preferred to use Ethernet cables as opposed to using their own data (see Figure 13). These results show a preference for using the free on-campus Wi-Fi.

4.4.1 Locations UKZN Westville students prefer to access Wi-Fi services on campus

The respondents were asked to indicate the locations at which they use Wi-Fi services on campus in general, and the locations where they use it the most. In addition, respondents were asked to indicate locations in which they perceive poor, and the best, Wi-Fi signal quality; and the times when they perceived this signal quality.

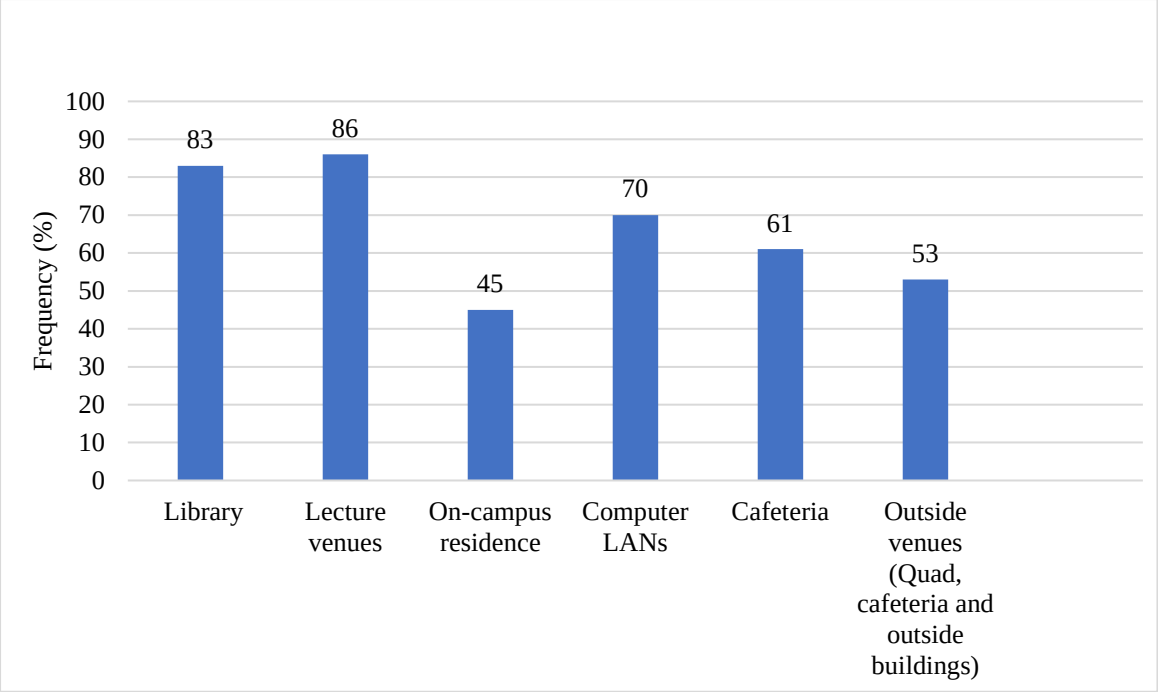

Figure 14: Locations at which students use Wi-Fi on campus.

A binomial test was conducted to determine the most-chosen Wi-Fi locations on campus. The results showed that a significant proportion of respondents used Wi-Fi in lecture venues (86%, p<.0005), the library (83%, p<.0005), computer LANs, (70%, p<.0005) and in the cafeteria (61%, p<.0005). Students also used Wi-Fi in outside venues (53%) and in on-campus residences (45%) (see Figure 14). These results are interesting in that more students use Wi-Fi in on-campus residences (45%) than actually live in on-campus residences (38.3%) (see Figure 9). Many students report that they use Wi-Fi in computer LANs (70%). However, it is unclear if they understand that the desktop computers in the LANs access the Internet via Ethernet cables.

In the questionnaire, there was ambiguity in Question 14 (Section 3 in Appendix 3), in that students could report that they used Wi-Fi in the cafeteria or in an outside venue, such as outside the cafeteria. The area intended by this 'outside venue' option is shown in Figure 3. It is unclear whether students had the same thing in mind when they responded.

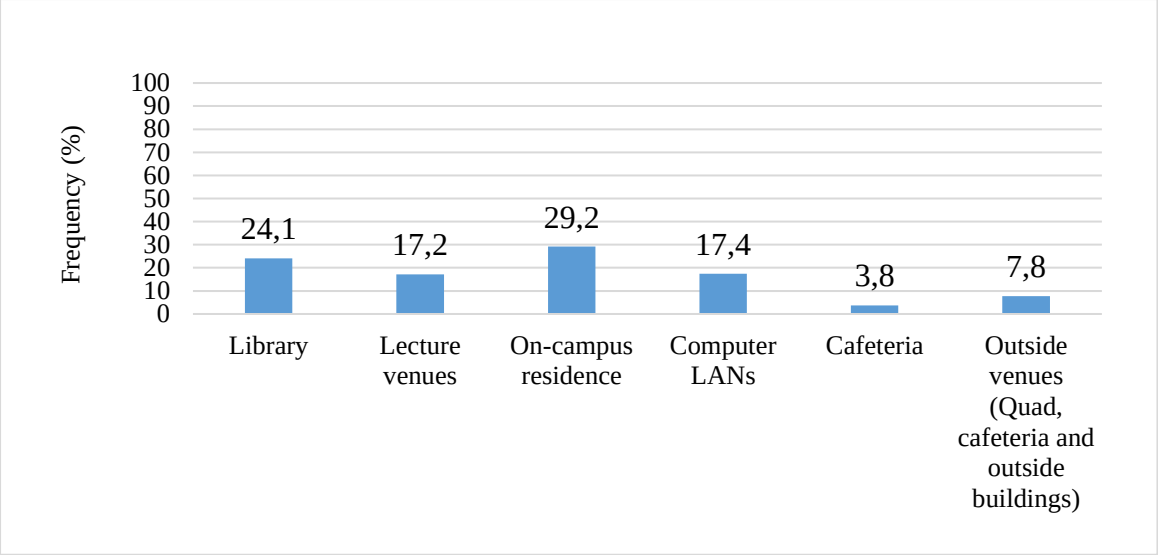

Figure 15: The most-used Wi-Fi locations on campus.

Respondents were asked to choose a single location in which they used Wi-Fi the most. The results showed that on-campus residences (29.2%), the library (24.1%), computer LANs (17.4%) and lecture venues (17.2%) were chosen significantly more than other venues (χ^2 (6) = 177.673, p<.0005) (see Figure 15). These locations were analysed further according to students' residence (see Figure 16). In the questionnaire, there was a possible ambiguity in Question 15 (Section 3 in Appendix 3), between the choice of cafeteria and an outside venue. In this case, neither category was significantly chosen.

As can be seen in Figure 16, the most-used Wi-Fi locations varied according to where the students lived during the academic term. Of the students residing in on-campus residences, 74.1% selected on-campus residences as their most-used location. In addition, although Wi-Fi was provided in on-campus residences, some on-campus residence students chose the library (7.0%), lecture venues (7.7%) and computer LANs (8.4%) as their most-used Wi-Fi locations.

The majority of the students who selected the library as their most-used Wi-Fi location resided in private accommodation (40%) and at home (36%), followed by those who live in off-campus residences (31.7%). The majority of students who live in off-campus residences selected the computer LANs (32.9%) as their most-used Wi-Fi location. It should be noted that the highest percentage of students who used Wi-Fi in computer LANs resided in private accommodation (40%). Overall, the results showed that most of the students who did not stay in on-campus residences used Wi-Fi in designated study locations like the library, lecture venues and

computer LANs. These locations are particularly designed for study purposes, as opposed to other locations like the cafeteria and other outside venues. Very few students staying in on-campus residences selected the cafeteria (0.7%) or outside venues (1.4%) as their most-used Wi-Fi locations. However, these venues were used more by students residing in private accommodation (10%), in off-campus residences (10.9%) and most by students residing at home (22.6%). This result shows that most students residing in on-campus residences prefer to use the Wi-Fi in residence, rather than in other venues. It was interesting to note that some students living in off-campus residences (1.2%) and at home (1.6%) also selected on-campus residences as their most-used Wi-Fi location.

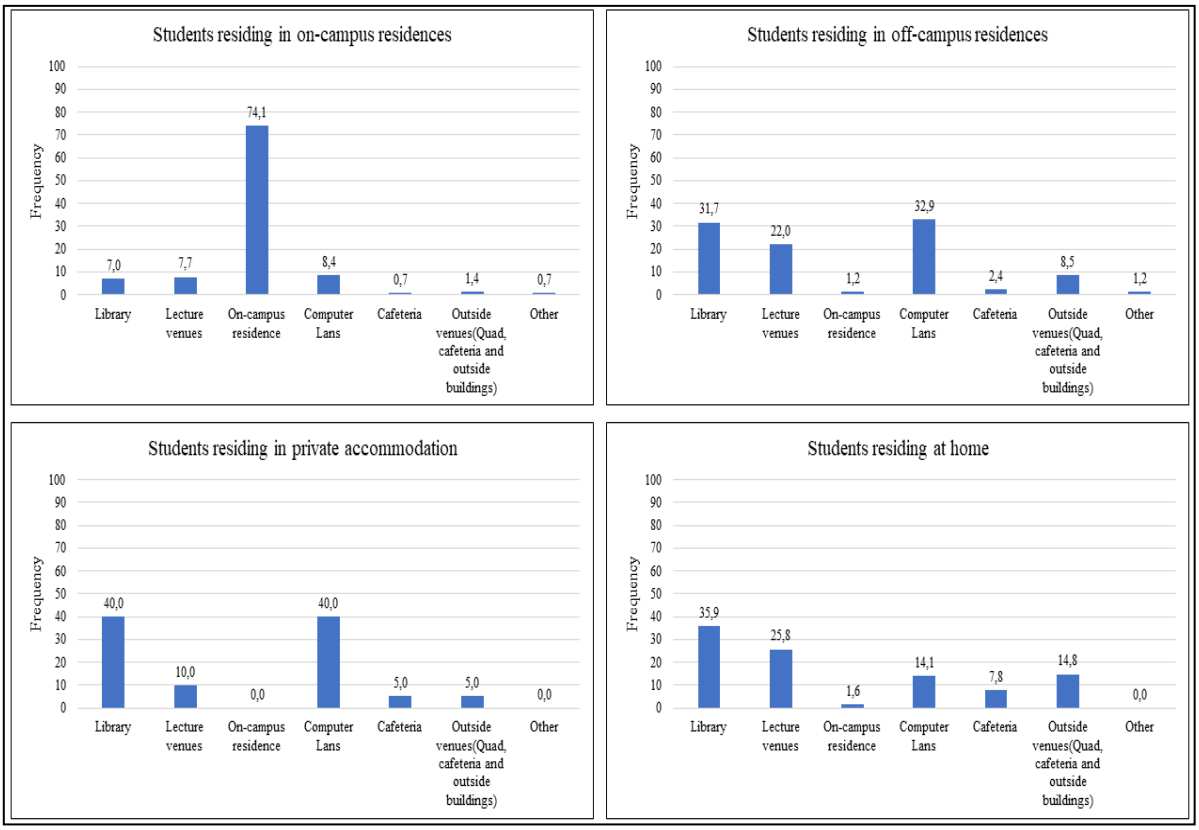

Figure 16: The most-used Wi-Fi locations on campus, by students' place of residence.

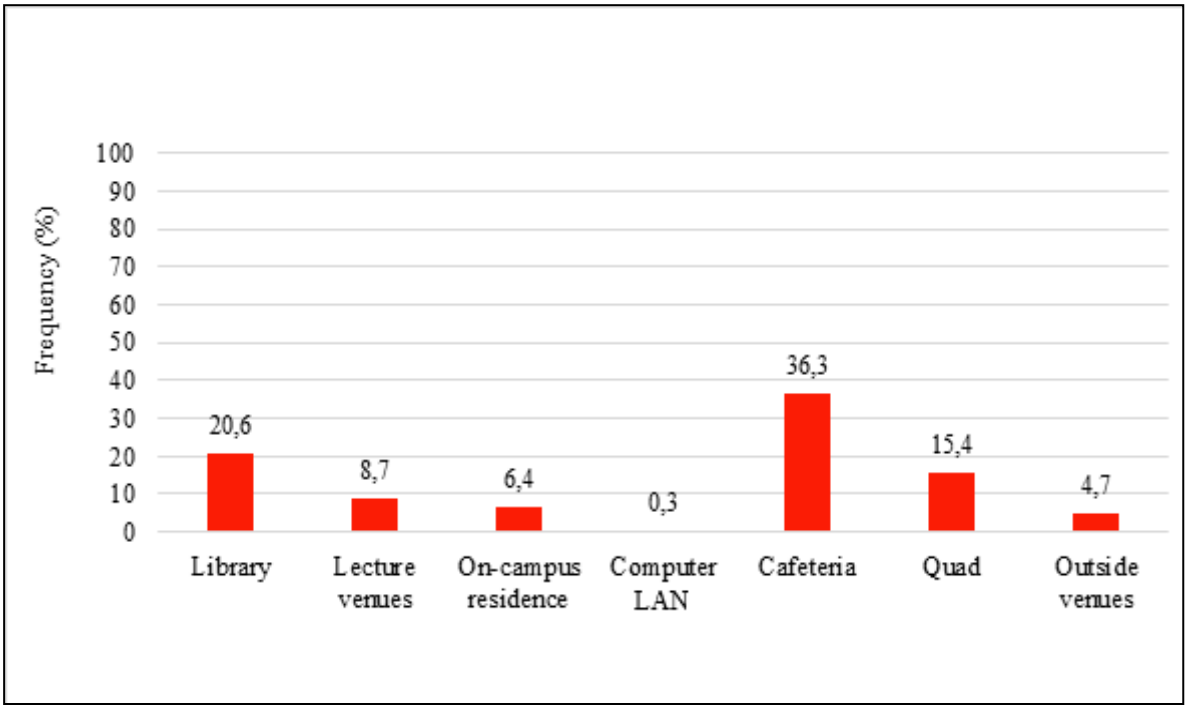

Figure 17: Locations where students experience poor Wi-Fi signal quality.

When students were asked to identify the location where they experienced poor Wi-Fi, the cafeteria (36.3%), the library (20.6%), and the Quad (15.4%) (χ^2 (18) = 1049.517, p<.0005) were indicated (see Figure 17).

It is worrying that, while the library was chosen as the second most-used Wi-Fi location (24.1%) (see Figure 15), it was identified as the location with the second poorest Wi-Fi signal (20.6%). With the exception of the library, the venues which are thought to be more conducive to learning were rated by fewer students as having poor Wi-Fi quality.

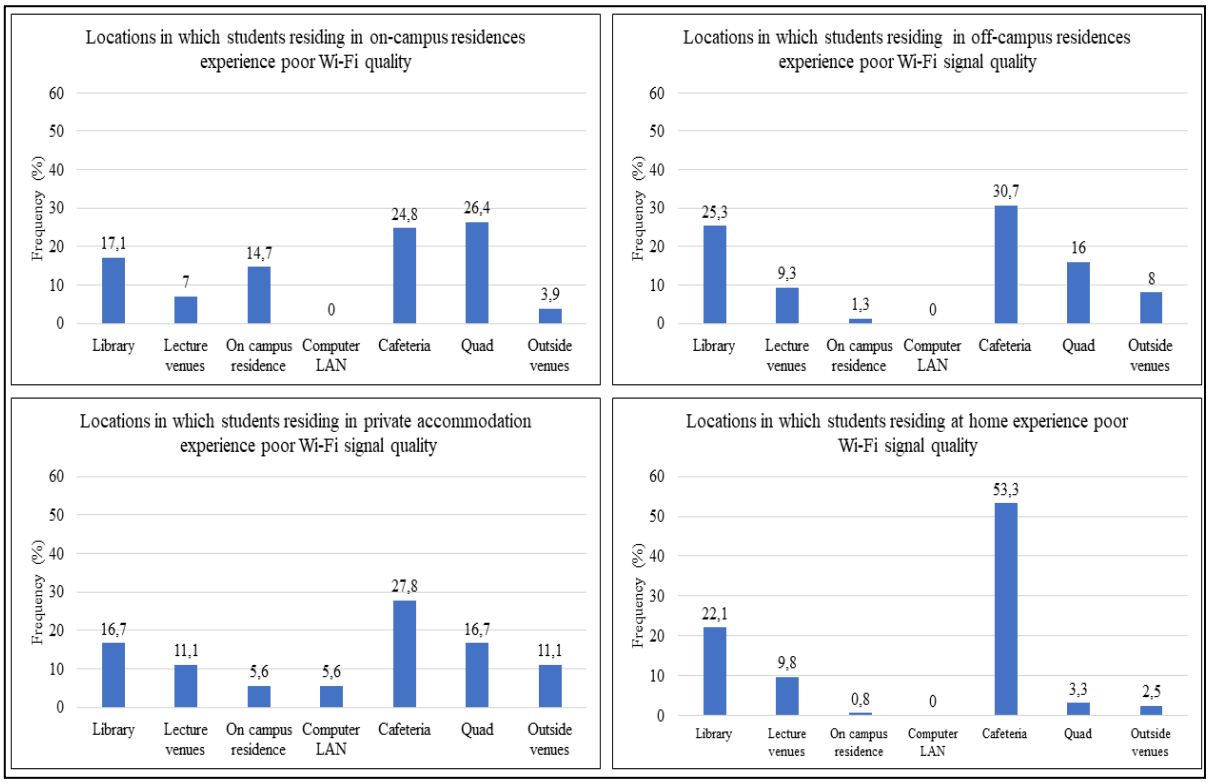

Figure 18: Locations where students experience poor Wi-Fi signal quality on campus, by place of residence.

The locations where students experience poor Wi-Fi signal on campus were analysed by student residence (see Figure 18). The majority of students who reported that they experienced poor signal quality at the cafeteria resided at home (53.3%). More students who stayed in on-campus residences experienced poor Wi-Fi quality in the library (17.1%) than in their residence (14.7%) (see Figure 18). It is important to note that the majority of students who resided in off-campus residences selected the library as the second-most-used Wi-Fi location (31.7%) and it was also selected as the location with the second poorest Wi-Fi signal quality (25.3%). In addition, students in private accommodation are the only group that reported poor Wi-Fi in the computer LANs (see Figure 18); and yet they selected the computer LANs as a most-used Wi-Fi location (40%) (see Figure 16).

Comparing the most-used locations with the locations having poorest quality Wi-Fi, 55.6% of students who selected the library as their most-used location indicated that it is a location with poor Wi-Fi quality, and 35.9% of those who selected lecture venues as their most-used location think that this is a location with poor Wi-Fi quality. Overall, only 19.6% of students think that

Wi-Fi is poor in their most-used location. This result shows that students prefer to use Wi-Fi in locations with good Wi-Fi quality and administrators should implement strategies to improve Wi-Fi quality in order to increase the use of Wi-Fi services.

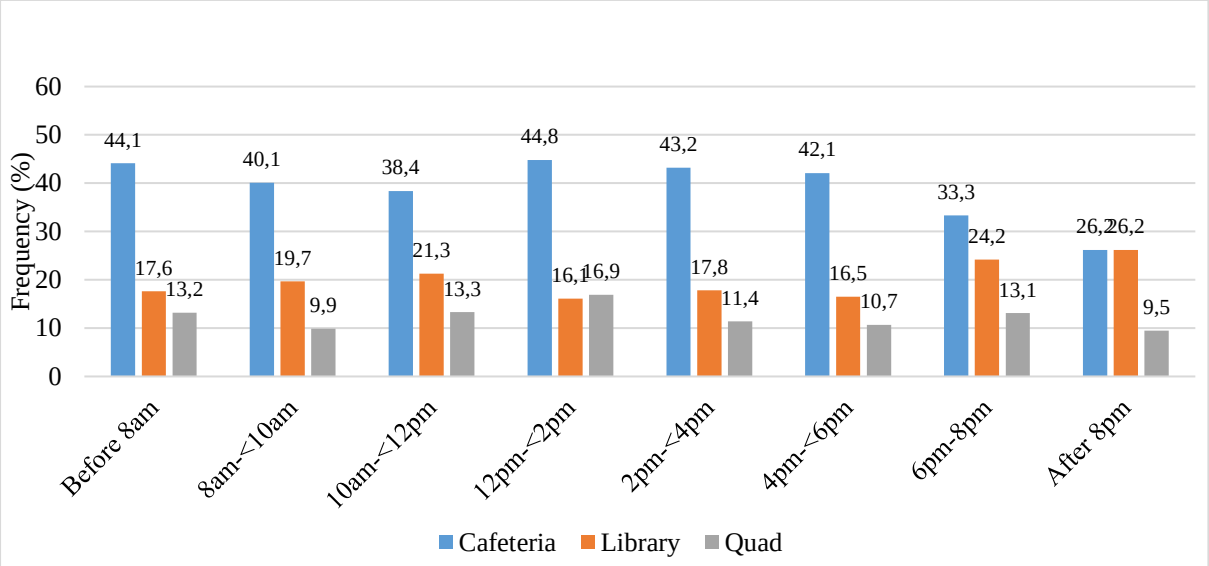

Figure 19: Times in which students experience poor Wi-Fi quality in the three poorest Wi-Fi locations.

Students were asked when they experienced poor Wi-Fi quality. The three significantly most selected locations (cafeteria, library and Quad) were analysed for these different times (see Figure 19). Poor Wi-Fi is experienced in the library after 8pm (26.2%), from 6-8pm (24.2%), and from 10am-<12pm (21.3%). Students experience poor Wi-Fi signal at the cafeteria between 12pm-<2pm (44.8%), followed by 2pm-<4pm (43.2%) and 4pm-<6pm (42.1%) (see Table 4).

Table 4 summarises the three main times when students experience the poor Wi-Fi signal quality in different locations on campus. Students experienced the worst Wi-Fi quality from 12pm-<2pm in the cafeteria and the Quad. Between 12pm-<2pm, it is lunchtime and many students gather in the cafeteria and Quad, contributing to congestion on the access points; thus worsening the Wi-Fi signal quality. In the library, it was experienced most after 8pm. It should be noted that lectures end at 5.30pm. These results imply that students using the library after 6pm cause congestion on access points and thus contribute to the poorer signal quality.

Table 4: A summary of times at which students experience poor Wi-Fi signal quality in locations on campus.

Poor Wi-Fi quality	Computer LANs	Lecture venues	On-campus residence	Library	Cafeteria	Quad
First Worst time	6pm-8pm	8am-<10am	After 8pm	After 8pm	12pm-<2pm	12pm-<2pm
Second Worst time		4pm-<6pm	6pm-8pm	6pm-8pm	Before 8am	10am-<12pm
Third Worst time		10am-<12pm and 2pm-<4pm	4pm-8pm	10am-<12pm	2pm-<4pm	Before 8am

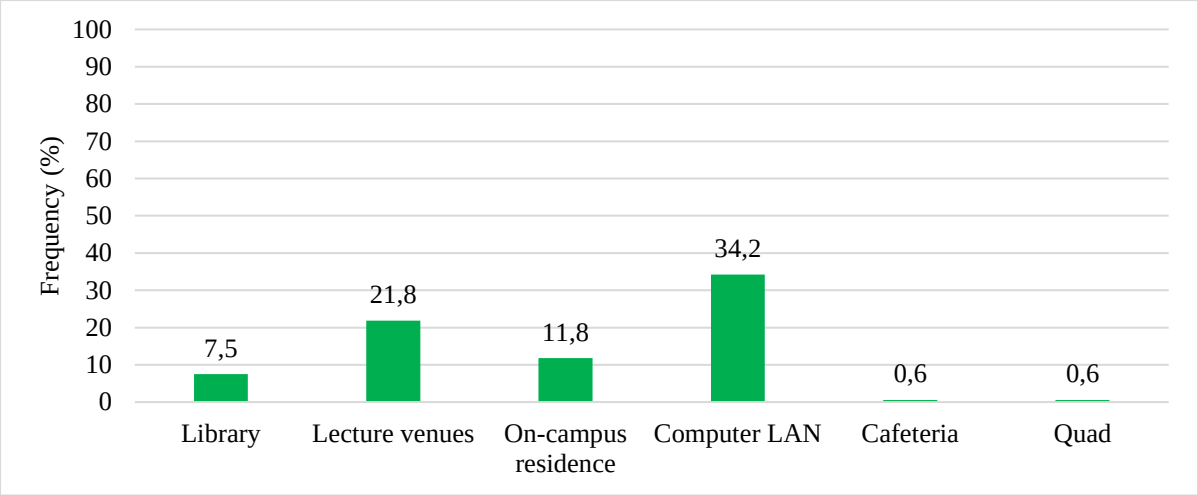

Figure 20: Locations where students experience the best Wi-Fi signal quality on campus.

The locations with the best Wi-Fi signal quality were the computer LANs (34.2%), lecture venues (21.8%) and on-campus residences (11.8%) (χ^2 (21) = 1145.218, p<.0005) (see Figure 20). It was not clear whether Westville students understood that desktop computers were accessing the Internet via Ethernet cables and not Wi-Fi. It is pleasing to note that, with the exception of the library, venues on campus which are more conducive to studying were chosen more by students as having the best Wi-Fi quality.

Results showed that 30.8% of students think that there is the best Wi-Fi quality at their most-used location. These results mean that students tend to go more regularly to places where the Wi-Fi quality is better. As can be seen in (see Figure 20), few students (7.5%) reported the best

Wi-Fi quality in the library, indicating that these students still used Wi-Fi in the library, in spite of them thinking that it has poor Wi-Fi quality.

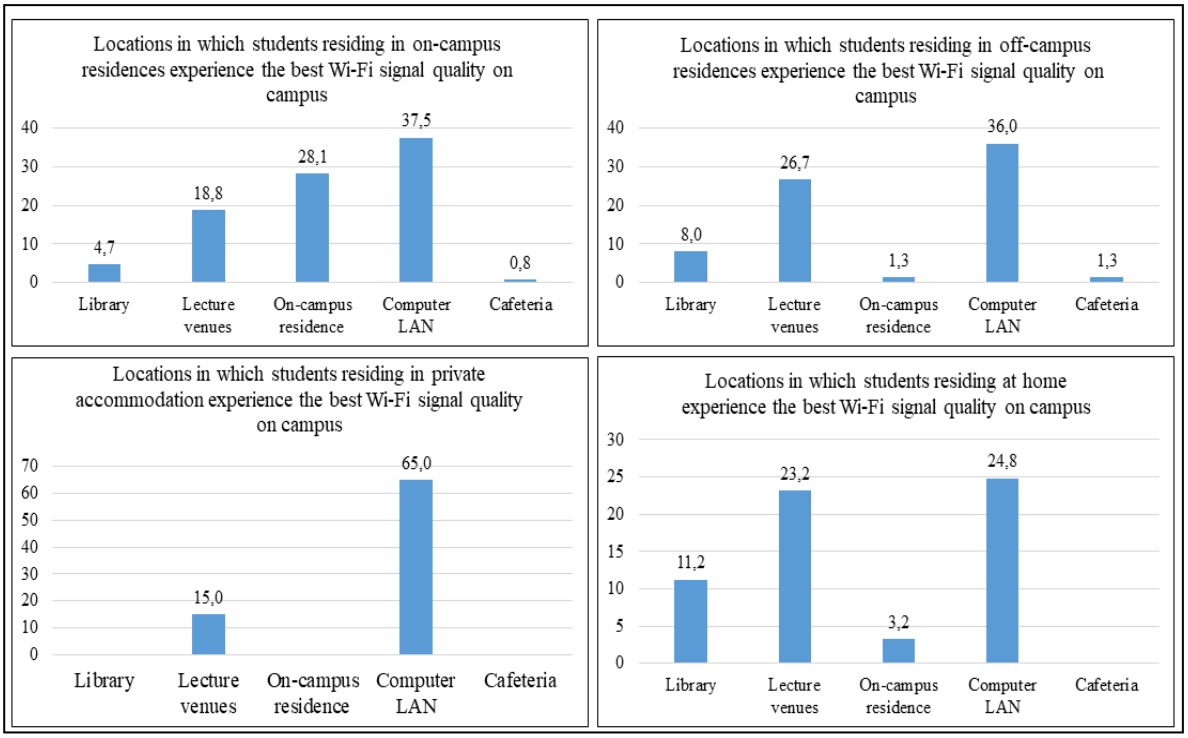

Figure 21: Locations where students experience the best Wi-Fi signal quality on campus, by place of residence.

The locations where students experienced the best Wi-Fi signal quality were analysed according to where the students lived (see Figure 21). The majority of students who resided in private accommodation reported that they experienced the best Wi-Fi signal quality at the computer LAN (65%) (see Figure 21). An interesting finding is that students who lived at home (3.2%) experienced the best Wi-Fi signal quality in on-campus residences; this percentage is much higher than the reported 0.8% of students, who live at home, who reported that they got poor Wi-Fi signal quality in on-campus residences (see Figure 18).

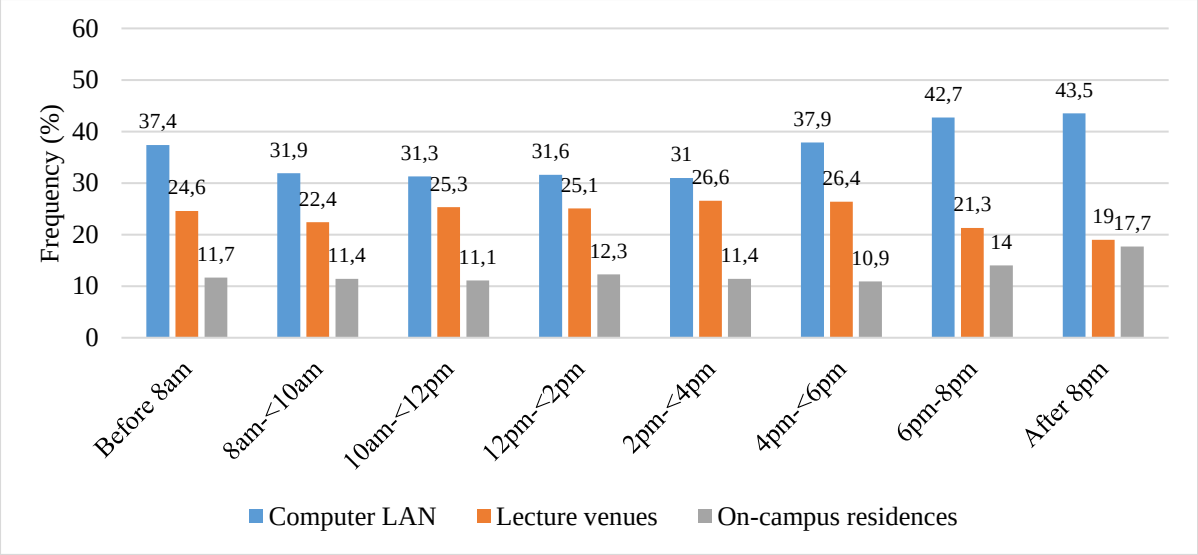

Figure 22: Times of best Wi-Fi quality in most-used on-campus locations.

Students were asked when they experienced the best Wi-Fi signals in the top three most-used Wi-Fi locations. As can be seen in Figure 22, the best Wi-Fi signal quality is experienced in the LAN (43.5%) and in on-campus residences after 8pm (17.7%). Students experienced the best Wi-Fi quality in lecture venues between 2pm and 4pm (26.6%). This may be because few lectures occur at this time and hence the lecture venues have fewer users.

Table 5: A summary of time periods when students experience the best Wi-Fi signal quality in locations on campus

Best Wi-Fi quality	**Computer LANs**	**Lecture venues**	**On-campus residence**	**Library**	**Cafeteria**	**Quad**
First best time	After 8pm	2pm-<4pm	After 8pm	8am-<10am	Before 8am	8am-<10am
Second best time	6pm-8pm	4pm-<6pm	6pm-8pm	Before 8am	8am-<10am	
Third best time	4pm-<6pm	10am-<12am	12pm-<2pm	6pm-8pm		

Table 5 shows the three time periods when students experienced the best Wi-Fi signal in different locations. Students experienced the best Wi-Fi signal quality from 8am-<10am in the library and before 8am at the cafeteria. In addition, the best time (4pm-<6pm) and second-best

time (10am-<12am) for good Wi-Fi signal quality (see Table 5) in lecture venues, was the same time that students reported the second and third worst Wi-Fi quality (see Table 5).

4.4.2 Amount of time UKZN Westville students spend accessing Wi-Fi on campus

The respondents were asked to indicate the number of hours they make use of Wi-Fi on campus per day. They were given a range of hours and they made one selection. Students were also asked to indicate the times when they use Wi-Fi the most during weekdays and weekends.

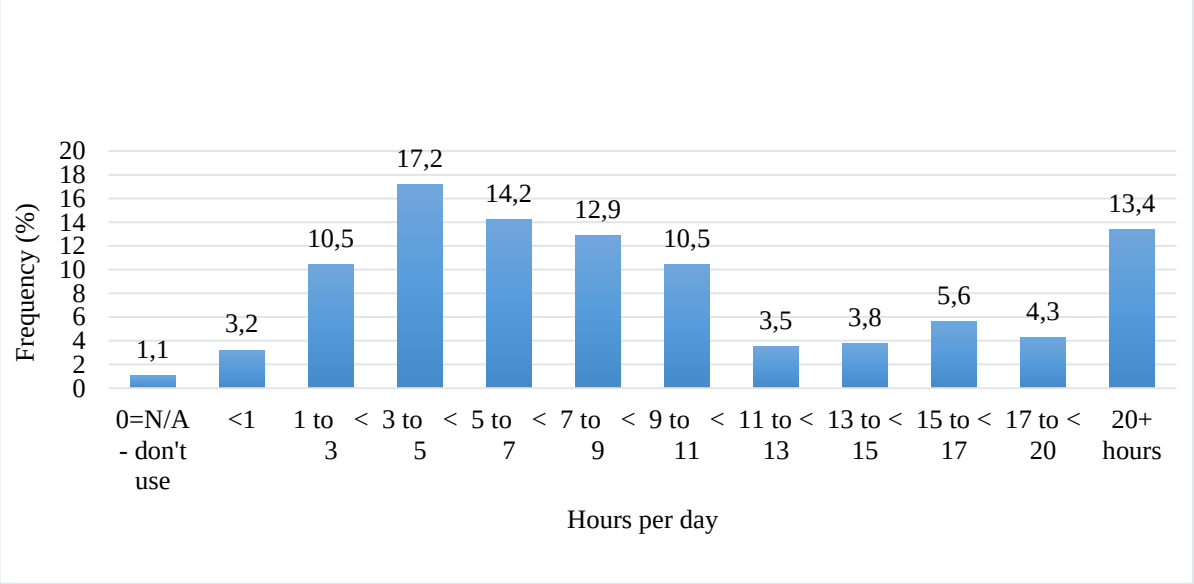

Figure 23: The number of hours, on average, that students make use of Wi-Fi on campus per day.

A significant number of students used Wi-Fi for 3 to <5 hours (17.2%); 5 to <7 hours (14.2%); and 20+ hours (13.4%), χ^2 (11) = 140.877, p<.0005 (see Figure 23). Very few students (1.1%) indicated that they did not use Wi-Fi (see Figure 23). Since the use of Wi-Fi may be affected by the locations in which the respondents reside, each of these results is analysed by the students' place of residence.

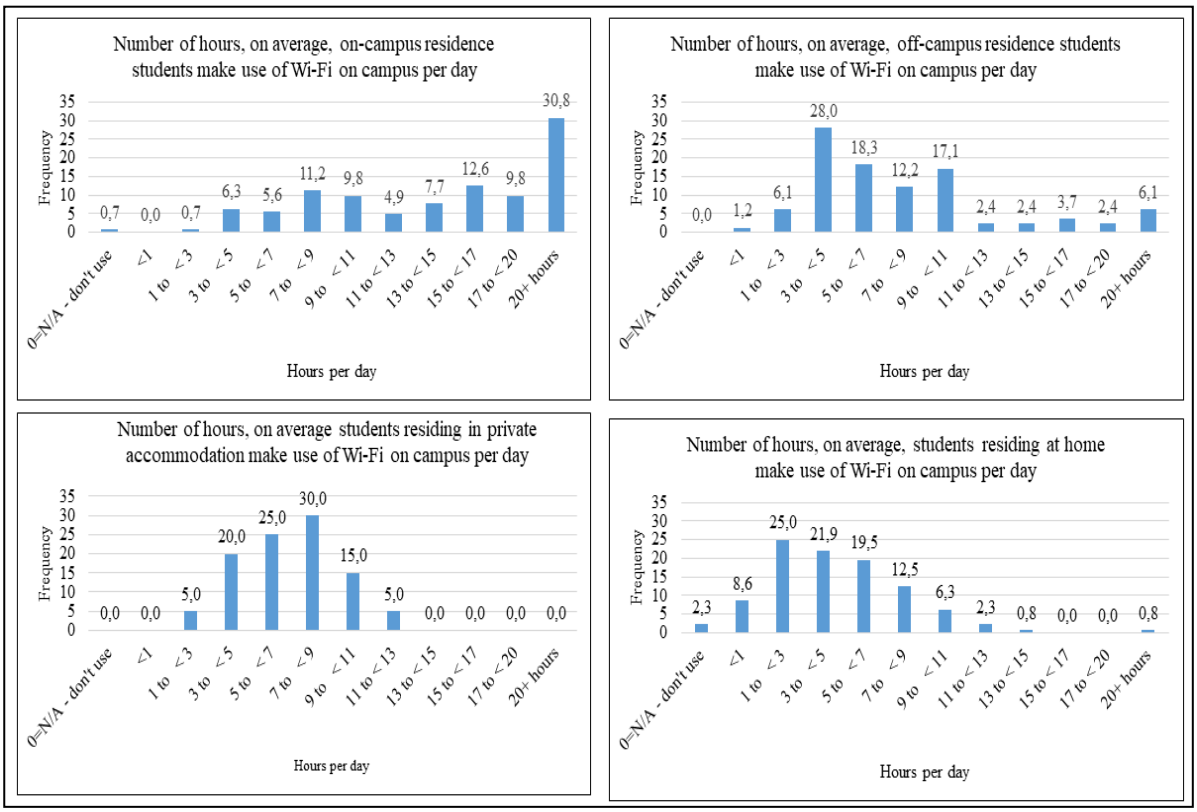

Figure 24: The number of hours, on average, that students make use of Wi-Fi on campus per day, by student place of residence.

The majority of students who used Wi-Fi for 1 to <3 hours (25%) resided at home; those who used Wi-Fi for 3 to <5 hours resided in off-campus residences (28%); and those who used Wi-Fi for 5 to <7 hours resided in private accommodation (30%) (see Figure 24). Students staying in on-campus and off-campus residences tend to use Wi-Fi for longer periods, whereas those staying in private accommodation or at home seldom use Wi-Fi after 3pm. The results showed that students who resided in on-campus residences used Wi-Fi for 20+ hours (13.4%). This could be because students staying on campus have access to on-campus Wi-Fi in their residences and they reside closer to other on-campus Wi-Fi locations. This information is useful to the ICS if they need to plan for an increase in the number of students staying in on-campus and off-campus residences.

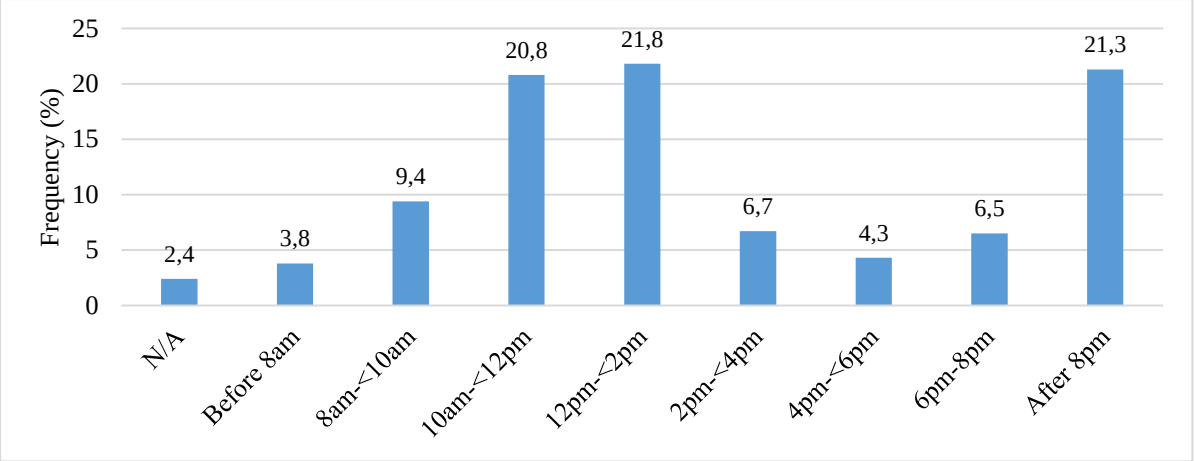

Figure 25: Times when students use Wi-Fi on campus the most, on average, during weekdays (Monday - Friday).

As shown in Figure 25, the largest groups of students used Wi-Fi between 12pm-<2pm (21.8%), after 8pm (21.3%) and between 10am-<12pm (20.8%) on weekdays.

Times of Wi-Fi use were analysed according to where students resided during the academic term. The results are shown below:

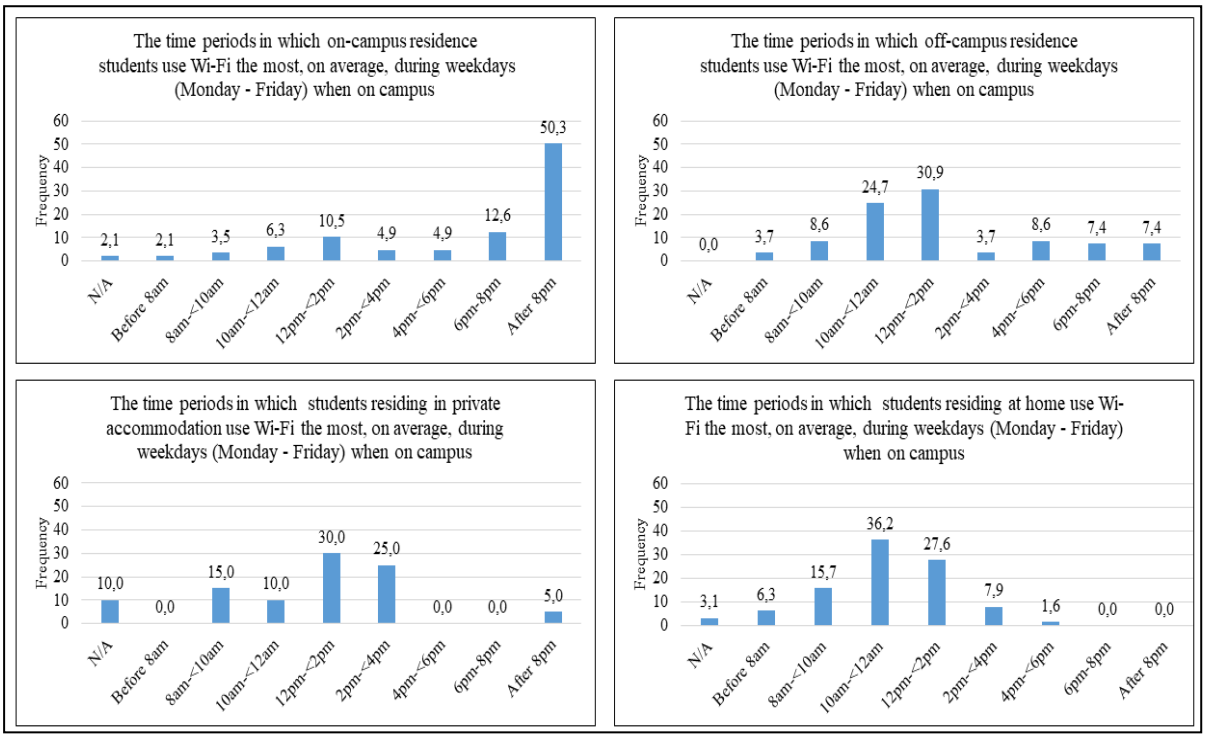

Figure 26: Times when students use Wi-Fi the most, on average, during weekdays, by place of residence.

As can be seen in Figure 26, the majority of the students who used Wi-Fi from 10am to <12pm resided at home (36.2%); and those who used Wi-Fi the most from 12pm-<2pm resided in off-campus residences (30.9%). The majority of students who used Wi-Fi after 8pm (50.3%) resided in on-campus residences. This information is useful for Wi-Fi delivery if more students are enrolled to stay in on-campus residences. In addition, if the university had more students living in other types of accommodation, they would know what sorts of usage patterns to expect. In particular, it would facilitate the distribution of access points within residences.

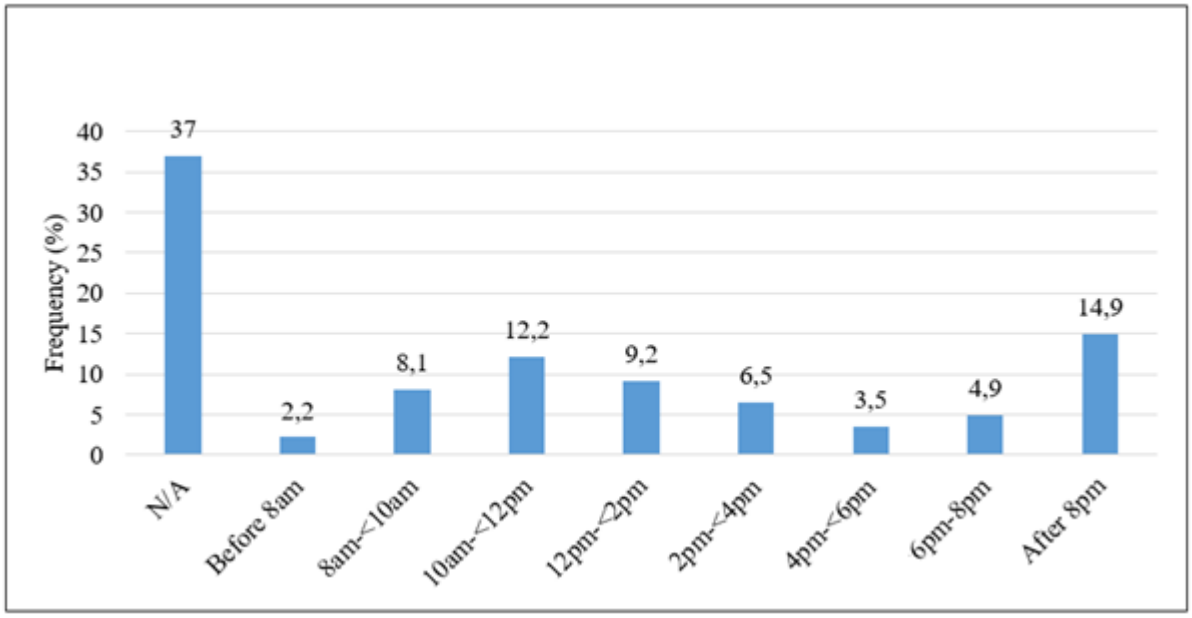

Figure 27: Times when students use Wi-Fi the most, on average, during weekends.

During the weekends, the majority of students either did not use Wi-Fi (37%); or they used Wi-Fi after 8pm (14.9%), or between 10am-<12pm (12.2%) (see Figure 27).

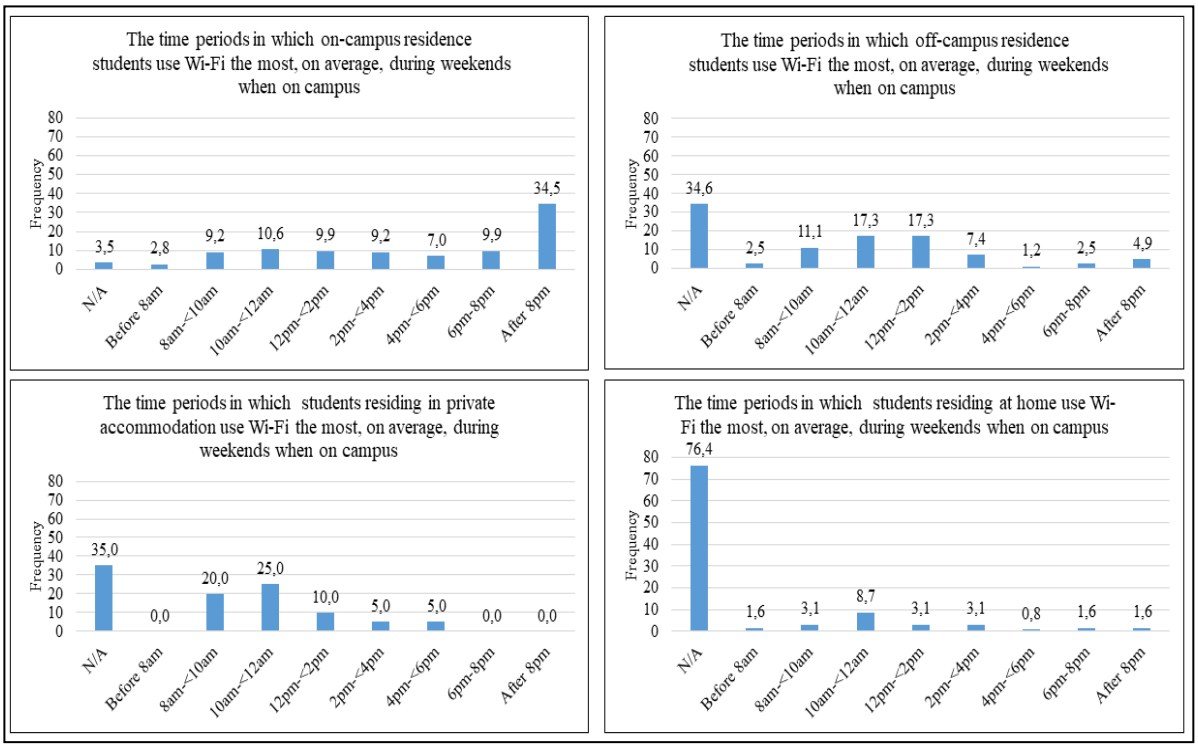

Figure 28: Times when students use Wi-Fi on campus the most, on average, during weekends, by place of residence.

The use of Wi-Fi on weekends was analysed by place of residence. The results showed that many more students do not use the Wi-Fi during the weekend, compared to during the week. Most students who used Wi-Fi between 10am-<12pm resided in private accommodation (25%) (see Figure 28). Most of the students who used Wi-Fi after 8pm (34.5%) resided in on-campus residences. The majority of the students who stayed at home did not use campus Wi-Fi on the weekends (76.4%). Further investigation may be conducted by ICS to discover the reasons for this limited use of Wi-Fi on campus by this population if they want to encourage the use of Wi-Fi on weekends.

The next section presents the Internet resources that students access when using the on-campus Wi-Fi.

4.4.3 Internet resources UKZN Westville students access when using Wi-Fi on campus

The third aspect of students' use of Wi-Fi was to discover which Internet resources students access with Wi-Fi on campus.

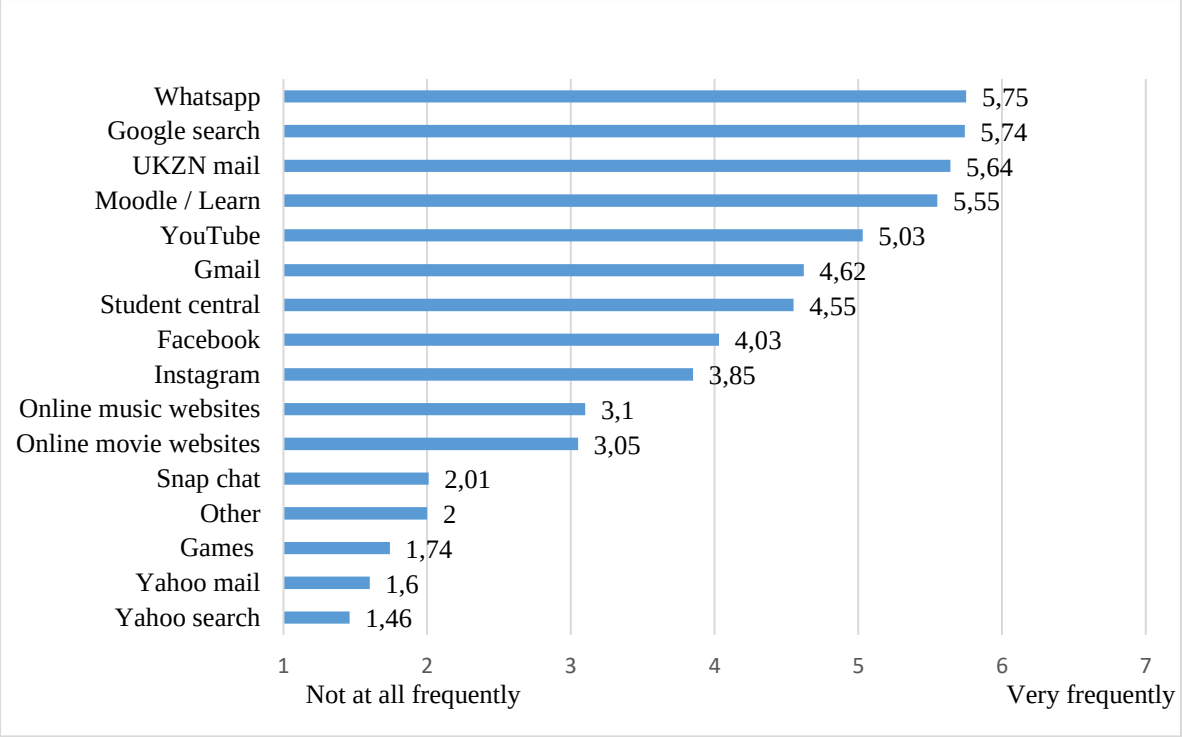

Figure 29: Frequency of accessing Internet resources when using Wi-Fi on campus.

Students use Wi-Fi to access different Internet resources when on campus. These are plotted in Figure 29, where, on a scale of one to seven, one means not at all frequently accessed and seven means very frequently accessed. The most-frequently used Internet resources over Wi-Fi were WhatsApp (5.75), Google search (5.74), UKZN Mail (5.64) and the learning management system, Moodle/Learn (5.55). The least-frequently accessed Internet resources accessed were Yahoo search (mean 1.46) and Yahoo mail (mean 1.60).

UKZN Mail and Moodle are in the top four Internet resources accessed by students using Wi-Fi, indicating that Wi-Fi is indeed being used to access dedicated educational resources on campus. Google could also be used by students to access educational information. These results show that Wi-Fi is serving its educative purpose.

When asked about which Internet resources load slowly, it was not surprising that a significant number of students indicated online movie websites (29.4%) and YouTube (20.8%). However, it was surprising that UKZN mail (13.3%) and Instagram (9.4%) were also reported to load slowly when being accessed over Wi-Fi, χ^2 (14) = 536.299, p<.0005. Regarding UKZN mail, this is a concerning finding as this is the main communication channel between the university and students.

The next section details the different Wi-Fi devices student use to access Wi-Fi services.

4.4.4 Devices UKZN Westville students use to access Wi-Fi on campus

This section describes the types of Wi-Fi devices students use to access Wi-Fi services, and their characteristics. It further presents the results that explain how the devices are used by students at their most-used Wi-Fi locations on campus.

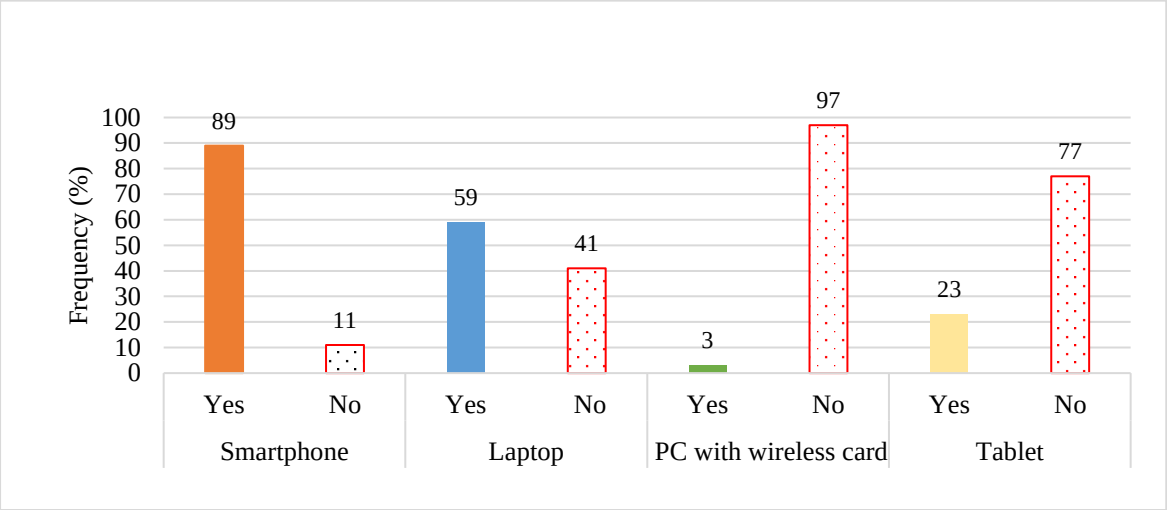

Figure 30: Devices used by students to access Wi-Fi on campus.

Students were asked which Wi-Fi devices they use to access Wi-Fi on campus in general. A binomial test showed that a significant number of students accessed Wi-Fi using a smartphone (89%, $p<.0005$) or a laptop (59%, $p<.0005$). A significant proportion did not use a PC with a wireless card to access Wi-Fi on-campus (97%, $p<.0005$) (see Figure 30). When students were asked to choose the one device they use the most to access Wi-Fi in their most-used Wi-Fi locations, a significant number of students used smartphones (66.7%) or laptops (28.2%), $\chi^2(3) = 410.731$, $p<.0005$.

A significant proportion of students connected two or more devices to campus Wi-Fi at the same time (56.8%, $p=.010$), as reported by a binomial test.

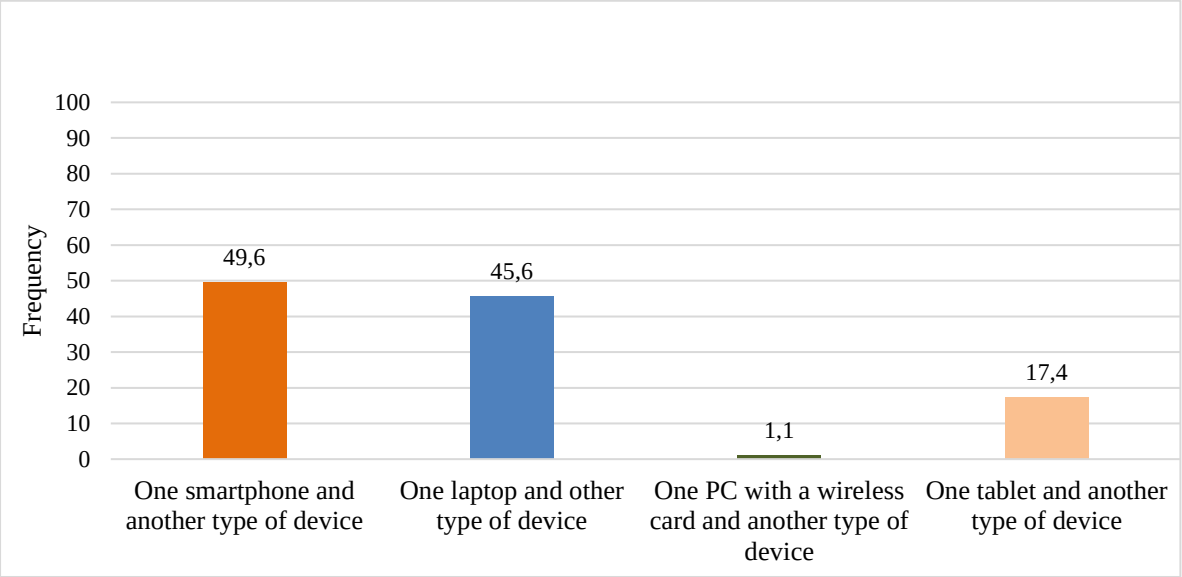

Figure 31: Different Wi-Fi devices connected at the same time when using Wi-Fi on campus.

Most of the students (49.6%) who used two different types of Wi-Fi device at the same time used one smartphone and another device type; 45.6% used one laptop and another Wi-Fi device; while 17.4% used a tablet and another Wi-Fi device type at the same time (see Figure 31).

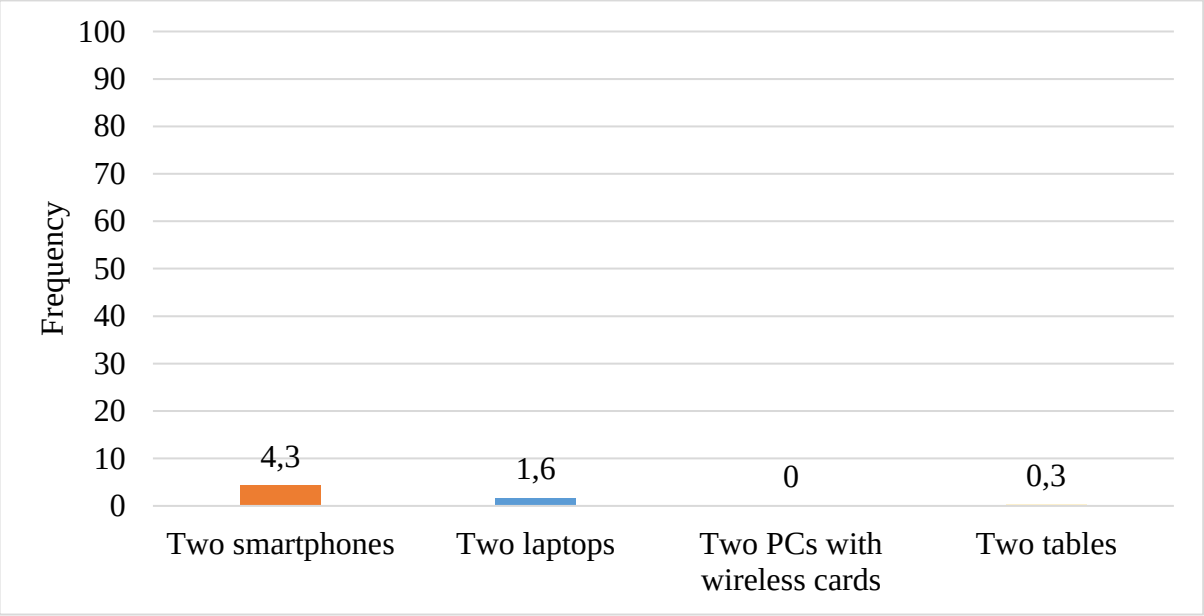

Figure 32: The same Wi-Fi devices connected at the same time when using Wi-Fi on campus.

Figure 32 shows that the majority of the students who used two devices of the same type on Wi-Fi used two smartphones (4.3%). No student connected more than two devices on Wi-Fi.

There was also a significant relationship between the most-used Wi-Fi location and the device used most to access Wi-Fi, χ^2 (18) = 49.081, p<.0005. A significant number of students used a tablet in lecture venues; a laptop in on-campus residences; and a smartphone in the cafeteria or outside venues.

Further analysis on the most-used Wi-Fi devices in the most-used Wi-Fi locations was conducted. This was to understand the device characteristics, which included the make, operating system, Wi-Fi standards, memory and speed of the Wi-Fi devices. The next part of this section presents the technical specifications of laptops and PCs with wireless cards; followed by those of smartphones and tablets.

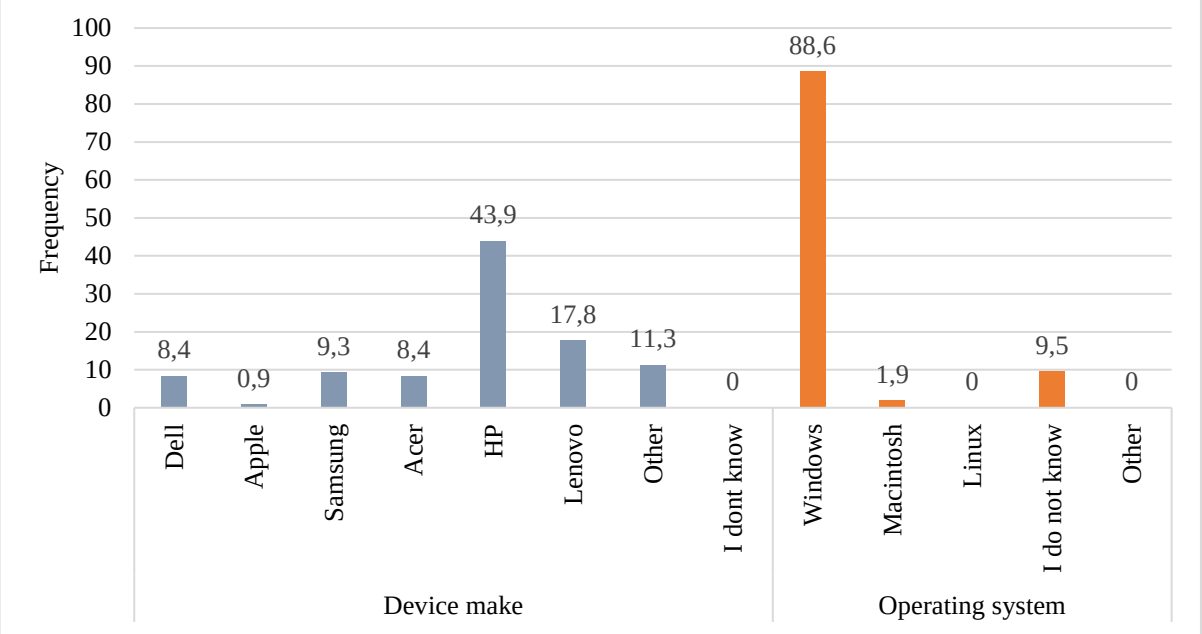

Figure 33: Makes and operating systems of laptops and PCs used in the most-used Wi-Fi locations on campus.

The makes and operating systems of the laptops and PCs used in the most-used Wi-Fi locations can be seen in Figure 33. A chi-square goodness-of-fit test was carried out to analyse the characteristics of laptops and PCs with wireless cards. The results from this analysis showed that a significant number indicated that they used HP (43.9%) or Lenovo (17.8%) laptops χ^2 (6) = 87.757, p<.0005. The operating system used most on these devices was Windows (88.6%), χ^2 (2) = 145.086, p<.0005.

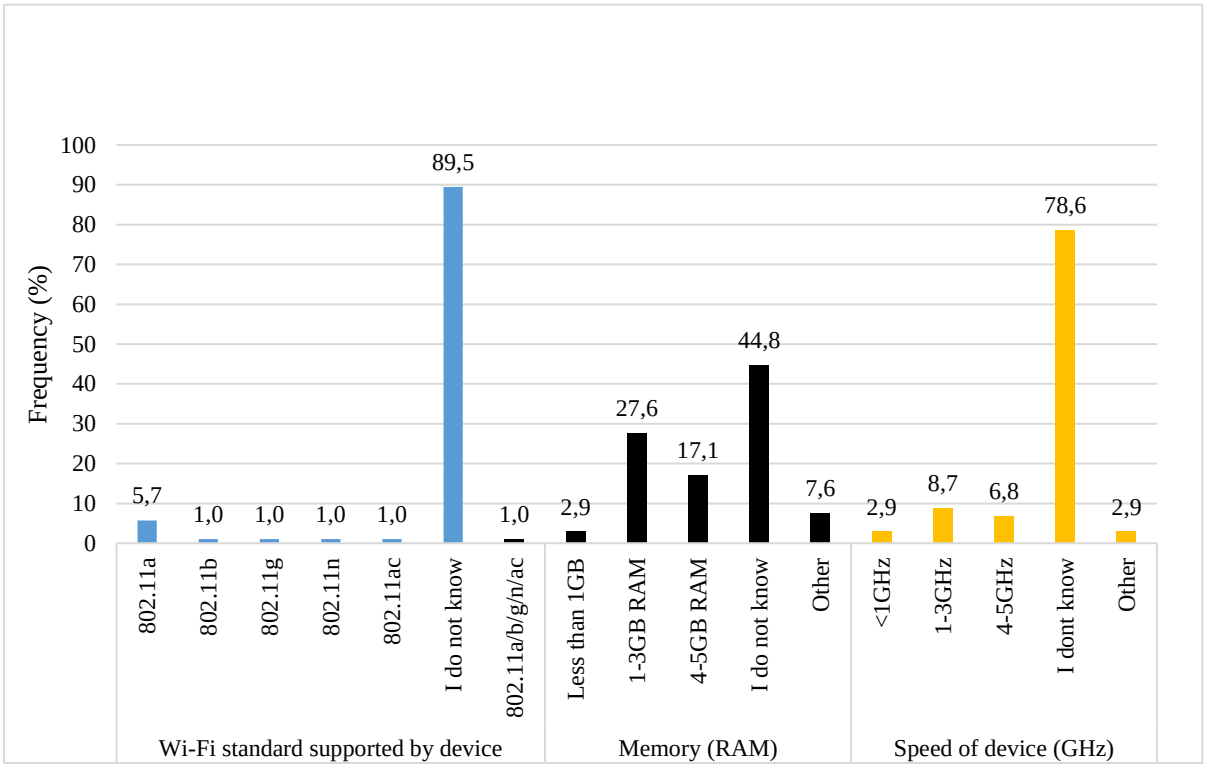

Figure 34: Wi-Fi standards, amount of memory (RAM) and speed of laptops and PCs used in the most-used Wi-Fi locations on campus.

Figure 34 shows the Wi-Fi standards, memory and speed of laptops and PCs with wireless cards used in the most-used Wi-Fi locations on campus. A significant number of students did not know the Wi-Fi standard supported by their laptops and PCs (89.5%), χ^2 (6) = 486.800, p<.0005; and a significant number had 1-3GB of RAM (27.6%,) or they did not know the amount of RAM their laptop/PC had (44.8%), χ^2 (4) = 59.143, p<.0005. A significant number of students (78.6%) indicated did not know the speed of their laptop or PC χ^2 (4) = 222.680, p<.0005.

Next, the characteristics of smartphones and tablets were analysed.

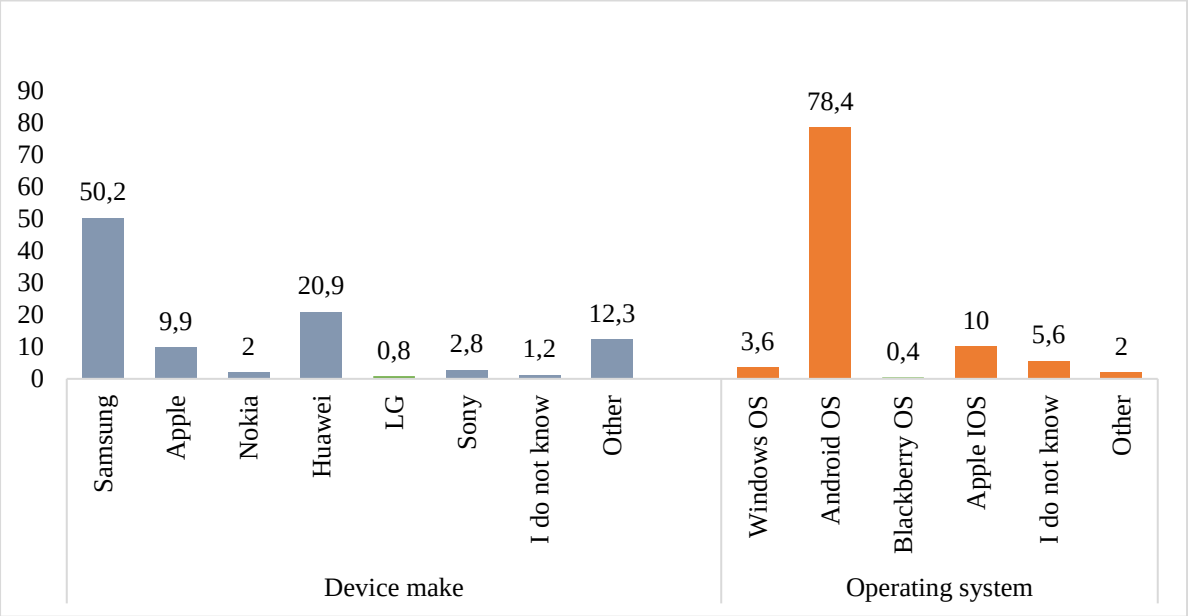

Figure 35: Makes and operating systems of smartphones and tablets used in the most-used Wi-Fi locations on campus.

The makes and operating systems of smartphones and tablets used in the most-used Wi-Fi locations can be seen in Figure 35. A significant number of students used Samsung (50.2%) or Huawei (20.9%) smartphones and tablets χ^2 (7) = 398.731, p<.0005. The operating system used most on smartphones and tablets was Android (78.4%), χ^2 (5) = 694.256, p<.0005.

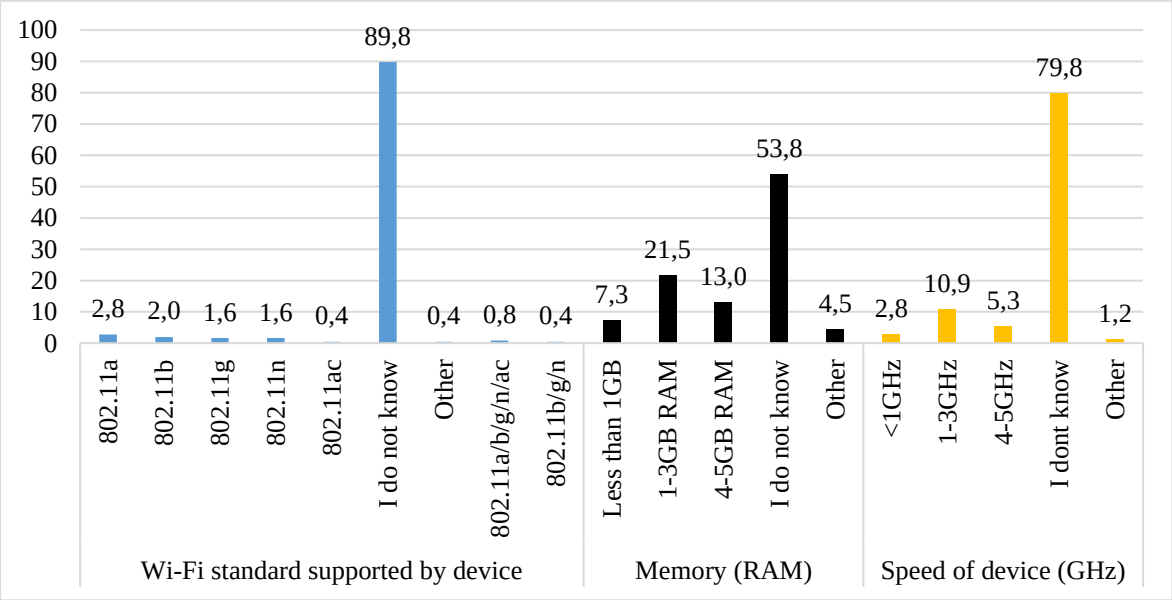

Figure 36: Wi-Fi standards, memory and speed of smartphones and tablets used in the most-used Wi-Fi locations on campus.

A significant number of the students (89.8%) did not know the Wi-Fi standard supported by their smartphones and tablets, χ^2 (8) = 1545.000, p<.0005 (see Figure 36). A significant number of students indicated that their smartphones and tablets supported 1-3GB of RAM (21.5%), or they did not know (53.8%), χ^2 (4) = 197.676, p<.0005. A significant number of students (79.8%) indicated that they did not know the speed of their smartphones and tablets, χ^2 (4) = 557.960, p<.0005 (see Figure 36).

In summary, the results showed that across all the characteristics identified in the study, students knew the most about their device's operating system and the least about the Wi-Fi standards supported by the devices being used to access Wi-Fi on campus.

4.5 Objective 2: Access point configurations and specifications provided on Westville campus

To understand the access point configurations and specifications provided on Westville campus, an ICS staff member responsible for Wi-Fi infrastructure development on UKZN Westville campus was interviewed (Participant 1).

4.5.1 Access point configuration and specification

Participant 1 could not disclose the exact location of each of the Wi-Fi access points installed on the Westville campus. He indicated that the UKZN network supports the 802.11a/b/g and n Wi-Fi standards. He added that the university adopts extreme access points. These include models 3610 (old model) (see Figure 37) and 3825 (new model) (see Figure 38).

Figure 37: Extreme access point AP3610

The extreme 3610 access points support the 802.11a/b/g/n network with six internal dual-band antennas and a maximum throughput per radio of 300Mbps / 600Mbps (Netsolutionstore, 2018).

Figure 38: Extreme access point AP3825

The AP3825 is a high-performance access point supporting the 802.11ac and 802.11abgn networks (see Figure 38). It is purposely built for high-density use in heavy-user and mission-critical environments such as healthcare facilities, universities, conference centres, arenas, and stadiums (Extremenetworks, 2018). In addition, the 2.4GHz spectrum has a maximum throughput of 450Mbps and the 5GHz spectrum has a maximum throughput of 1.3 Gigabits per second (Gbps) (Extremenetworks, 2018). The number of simultaneous devices that can connect to this access point model is 316 devices.

UKZN Westville configures access points with both the 2.4GHz and 5GHz spectrums. The ICS administrator reported that the access points automatically negotiate with the student devices to decide the best spectrum to be accessed by the device. This activity is mediated and controlled by the WLAN controller. The administrator added that if a device supports access to both the 2.4GHz and the 5GHz spectrums, the access point will provide access to the buy spectrum as this is considered better than the 2.4GHz since it provides faster data access and is less prone to interference.

Omnidirectional antennas are adopted on all access points on campus. There are no access points configured with different antenna types.

Regarding bandwidth allocation, the administrator commented that access points do not have any dedicated bandwidth allocation. He indicated that bandwidth is allocated on a switch and then it is shared by connected access points. He further added that these switches were allocated 1Gbps. Hence, the more access points connected to the switch and other devices, the less the bandwidth, as it has to be shared by all connected devices.

The WPA2 security mode is supported on the access points to authenticate students' login details. According to the administrator, the WPA2 security used is the 802.1x, which is an enterprise-wide solution. Students have to provide their student number and password before they access Wi-Fi services.

In general, three or four channels are configured on each access point. Access points automatically select the channel to use as a way of avoiding interference.

It is important to note that the participant emphasised that all the above configurations were the same on all access points installed on campus. However, for those locations in which users reported regular faults, the administrator changed the access points to support the 2.4GHz spectrum. This was because most students' devices supported access to the 2.4GHz spectrum. However, a list of access points which had been changed to 2.4GHz only was not available.

4.5.1.1 Configuration and specification of access points in locations where students experience poor Wi-Fi signal quality

Participant 1 was asked to indicate the configuration of the Wi-Fi infrastructure in locations reported by students to have poor Wi-Fi signal. The configurations are reported below.

Cafeteria: He indicated that two access points were positioned in the cafeteria to support Wi-Fi devices supporting the IEEE 802.11a, b, g and n IEEE 802.11 standards. The access points had the same configuration as all the other access points on campus. These included omni-directional antennas and WPA2 security; and they did not have any specific bandwidth allocation.

Quad: No access points were installed at the Quad area. Wi-Fi signals received by devices were from signal spillage from nearby broadcasting access points within buildings. At the time of the interview, the external use access points were still being tested.

Library: Two access points were configured on each floor in the library, one at the rear and one at front. These access points had the same configuration as all the other access points on campus. These included omni-directional antennas and WPA2 security, and they did not have any specific bandwidth allocation.

4.5.1.2 Configuration and specification of access points in locations where student experience the best Wi-Fi signal quality

Participant 1 indicated that access point configuration in locations where students perceived the best Wi-Fi signal quality (LANs, lecture venues and on-campus residence) had the same configurations as the other access points on campus. Hence, they were configured with omni-directional antennas and WPA2 security, and they did not have any specific bandwidth allocation.

4.5.1.3 Configuration and specification of access points in most used Wi-Fi location

When asked about configurations in areas where students use Wi-Fi the most, he emphasised that the configurations were the same in on-campus residences, the library and computer LANs. Hence, they were configured with omni-directional antennas and WPA2 security, and they did not have any specific bandwidth allocation.

The results in Section 4.4.4.1 showed many students say that the library has poor Wi-Fi quality, while some say it is good. It should, however, be noted that if a student is sitting far from the access point, that student will get poorer Wi-Fi quality than the student sitting close to an access point. In addition, participant 1 added that access points leave blind spots in locations as they pass through thick walls or obstructions, hence delivering weak Wi-Fi signals to users.

The study was not able to determine the number of access points in the locations with the best Wi-Fi quality. Hence, it is not clear whether there were more access points in locations with the best Wi-Fi, like the computer LAN.

The next section presents the difficulties faced by students when using Wi-Fi services on campus.

4.6 Objective 3: Difficulties UKZN Westville students face when using Wi-Fi services on campus

Students were asked to choose one location where they used Wi-Fi the most on campus in order to identify the difficulties UKZN Westville students face when using Wi-Fi services on campus. This objective was broken down into two sub-objectives. In the first sub-objective, the difficulties students experience when using Wi-Fi on campus are examined. Students' responses to the Wi-Fi difficulties they encounter on campus are discussed. In the second sub-objective, the difficulties students report to ICS are presented, as well as an evaluation of the students' familiarity with logging calls to ICS; or asking for help from people who are not part of ICS to solve Wi-Fi problems.

4.6.1 Difficulties UKZN Westville students experience when using Wi-Fi services on campus

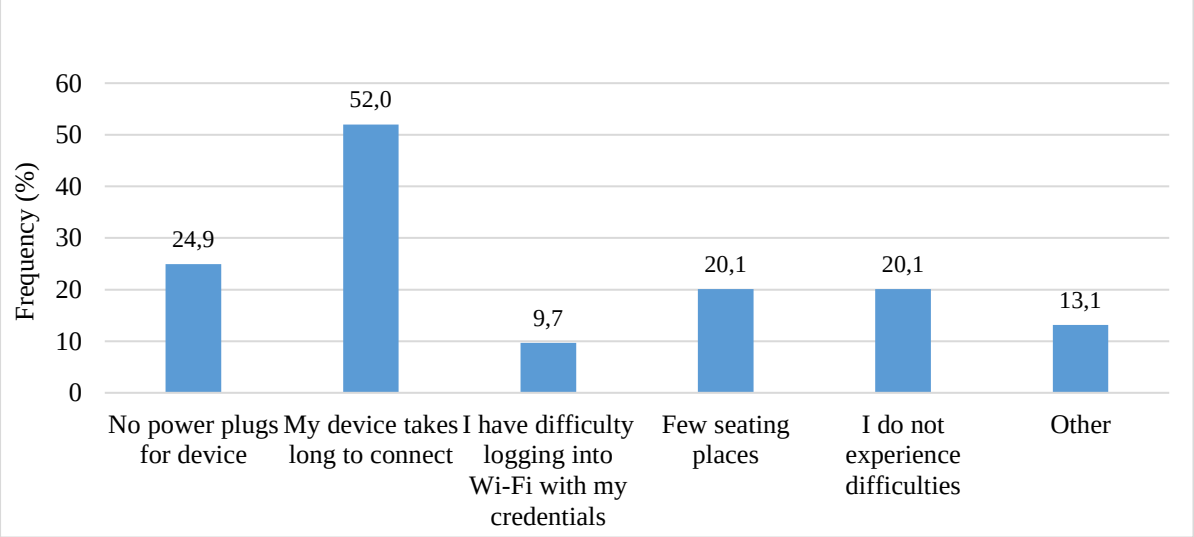

Figure 39: Difficulties experienced by students when using Wi-Fi.

Students were asked to choose one or more options regarding the difficulties faced when using Wi-Fi on campus. The majority of the students indicated that their devices took long to connect to Wi-Fi (52%); there were no power plugs (24.9%); there were few seating places (20.1%); they faced difficulty logging in with their credentials (9.7%); and 13.1% faced other problems (see Figure 39). Other problems included issues such as signals dropping, weak Wi-Fi signals,

and Wi-Fi locations being closed. It was interesting to note that 20.1% of students did not experience any difficulties.

The next section presents the difficulties experienced by students in their most-used Wi-Fi locations.

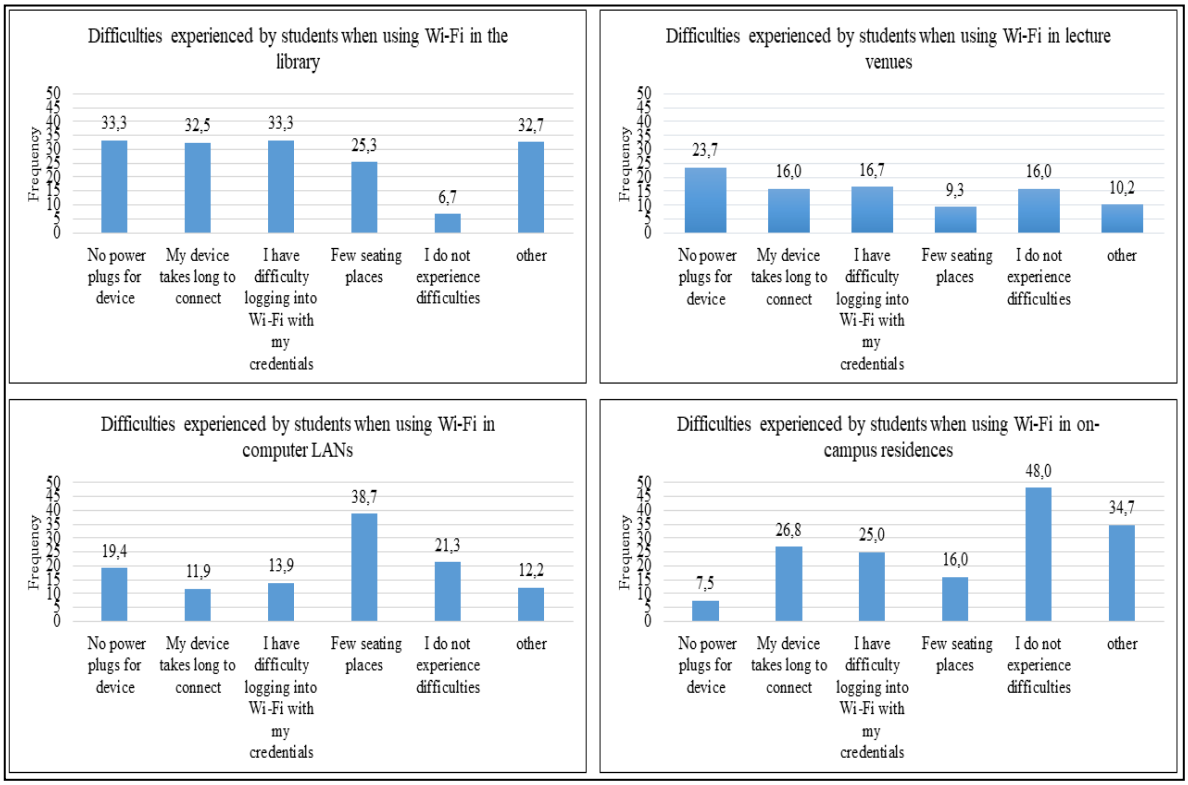

Figure 40: Difficulties experienced by students when using Wi-Fi in the library, lecture venues, computer LANs and on-campus residences.

Figure 40 shows an analysis of the Wi-Fi difficulties students face in locations which are thought to be conducive to studying. Of the students who indicated that their devices take long to connect to Wi-Fi, 32.5% experienced this difficulty in the library, followed by on-campus residences (26.8%). The majority of the students who experienced difficulties in the LANs, complained of too few seating places (38.7%). Students experienced difficulty logging into Wi-Fi with credentials (33.3%) and having no power plugs for devices in the library (33.3%) more than in any other location (see Figure 40). The library had consistently more difficulties reported for the first three items, (no plugs, takes long to connect, and logging in); which means that this is a location where useful improvements can be made.

Students reported that they did not face any difficulties when using Wi-Fi in on-campus residences (48%), computer LANs (21.3%) and lecture venues (16%). As one of the most-used locations, and a designated study area, these difficulties need attention.

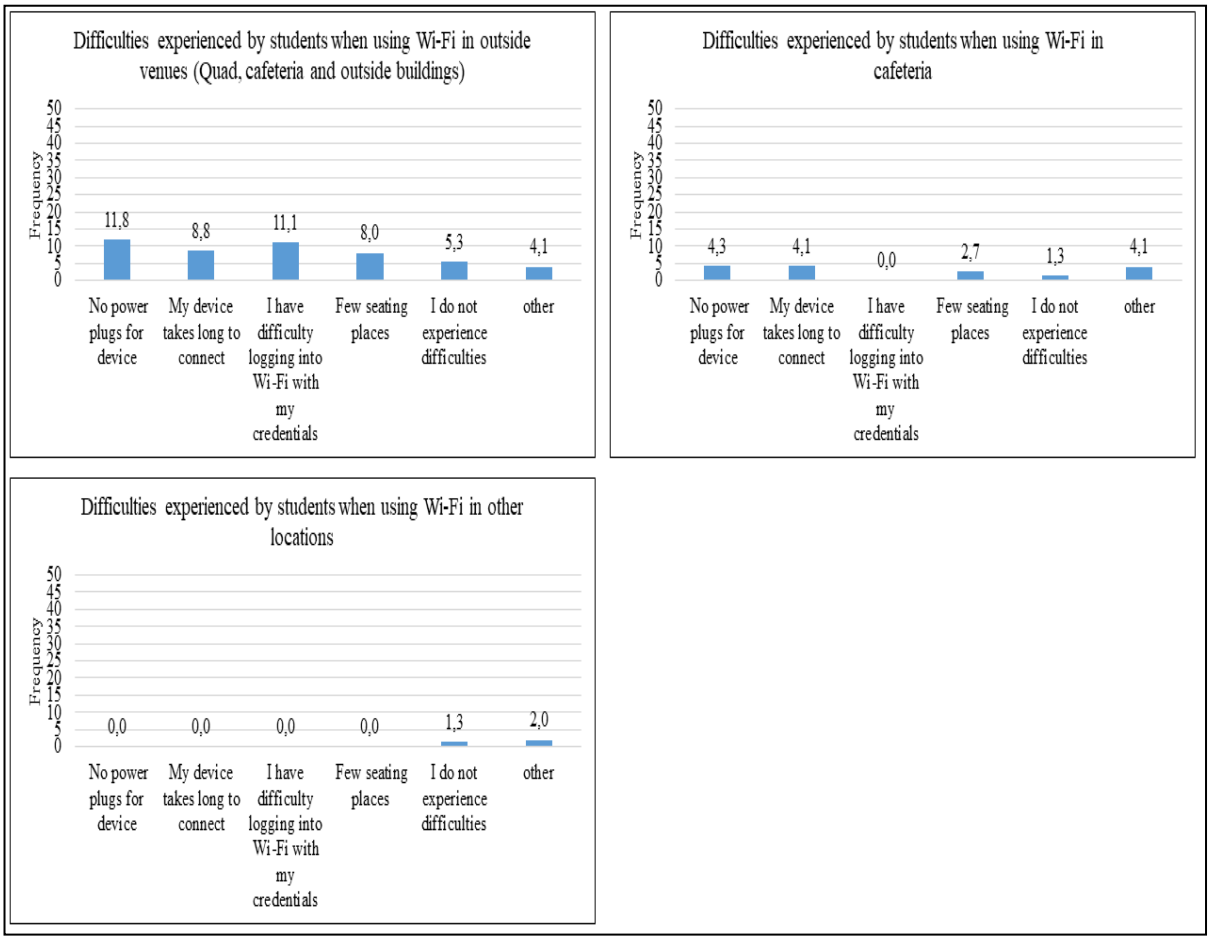

Figure 41: Difficulties experienced by students when using Wi-Fi in outside venues, the cafeteria and other locations.

It was interesting to note that students did not experience any of the difficulties listed in the study in other locations on campus (Makabane shopping centre, school pitches and outside the LANs) (see Figure 41). However, they reported experiencing other problems, such as the Wi-Fi signal disconnecting, and weak connections. A lack of power points (11.8%) was reported as the main difficulty in outside venues, followed by difficulty logging in with credentials (11.1%) (see Figure 41).

The next section presents the difficulties faced by students, according to their place of residence.

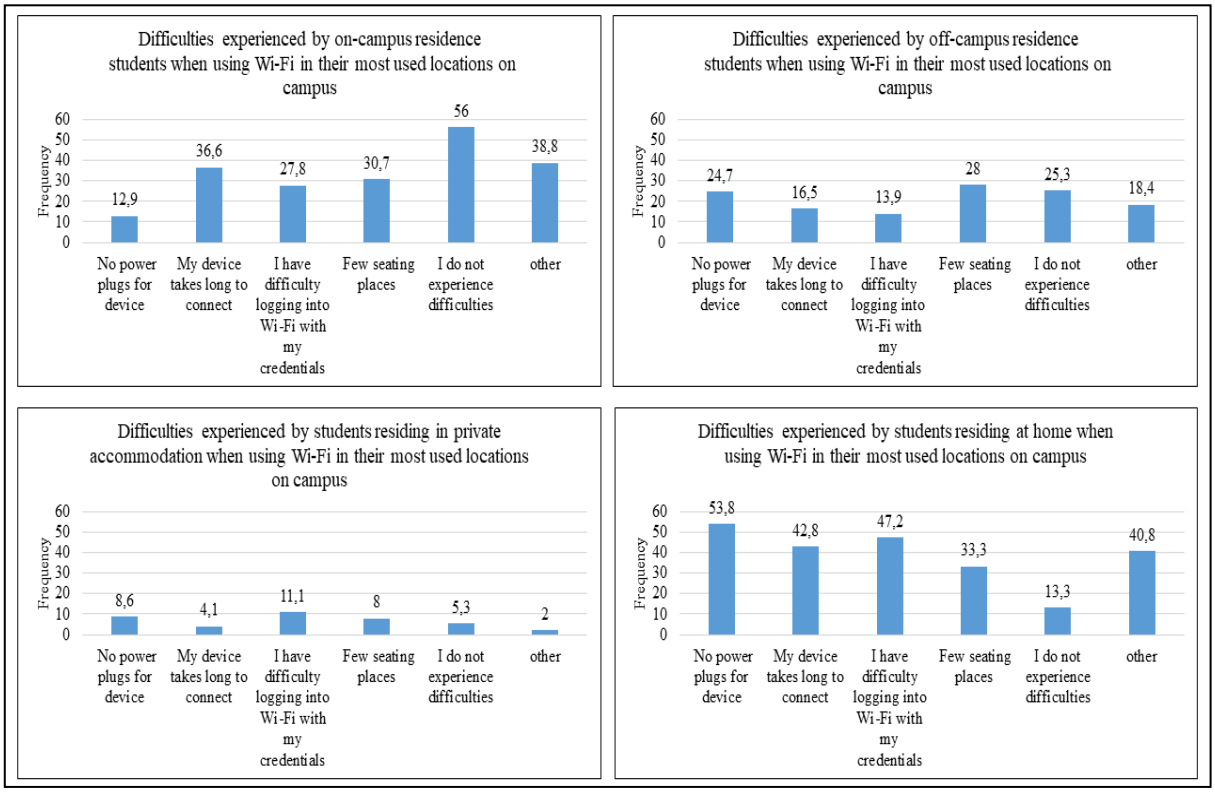

Figure 42: Difficulties experienced by students when using Wi-Fi in their most-used locations on campus, according to their place of residence

As can be seen in Figure 42, the majority of the students who resided at home faced the difficulty of no power plugs for devices (53.8%). The students who encountered this problem the least stayed in private accommodation (8.6%). Most of the students who had difficulty logging into Wi-Fi with credentials resided at home (47.2%).

A Chi-square test of independence was carried out to see whether a significant relationship exists between no power plugs and students' place of residence. The results showed that there was a significant relationship between residing on- or off-campus and not having power plugs for the device, χ^2 (1) = 33.903, p<.0005. Significantly, more of those students staying on campus indicated they did not face the difficulty of having no power plugs for devices, while a significant number of those off campus (private accommodation, home, off-campus residences) indicated they faced the problem of having no power plugs for devices.

There was a significant relationship between residing on- or off-campus and not experiencing difficulties, χ^2 (1) = 12.388, p<.0005. The students residing at home experienced the greatest number of difficulties, followed by those living in on-campus residences. However, it is

pleasing to see that many students (56%) living in on-campus residences experienced no difficulties at all.

Further analysis was conducted to understand what students do when they face problems using Wi-Fi on campus. The results are reported in the next section.

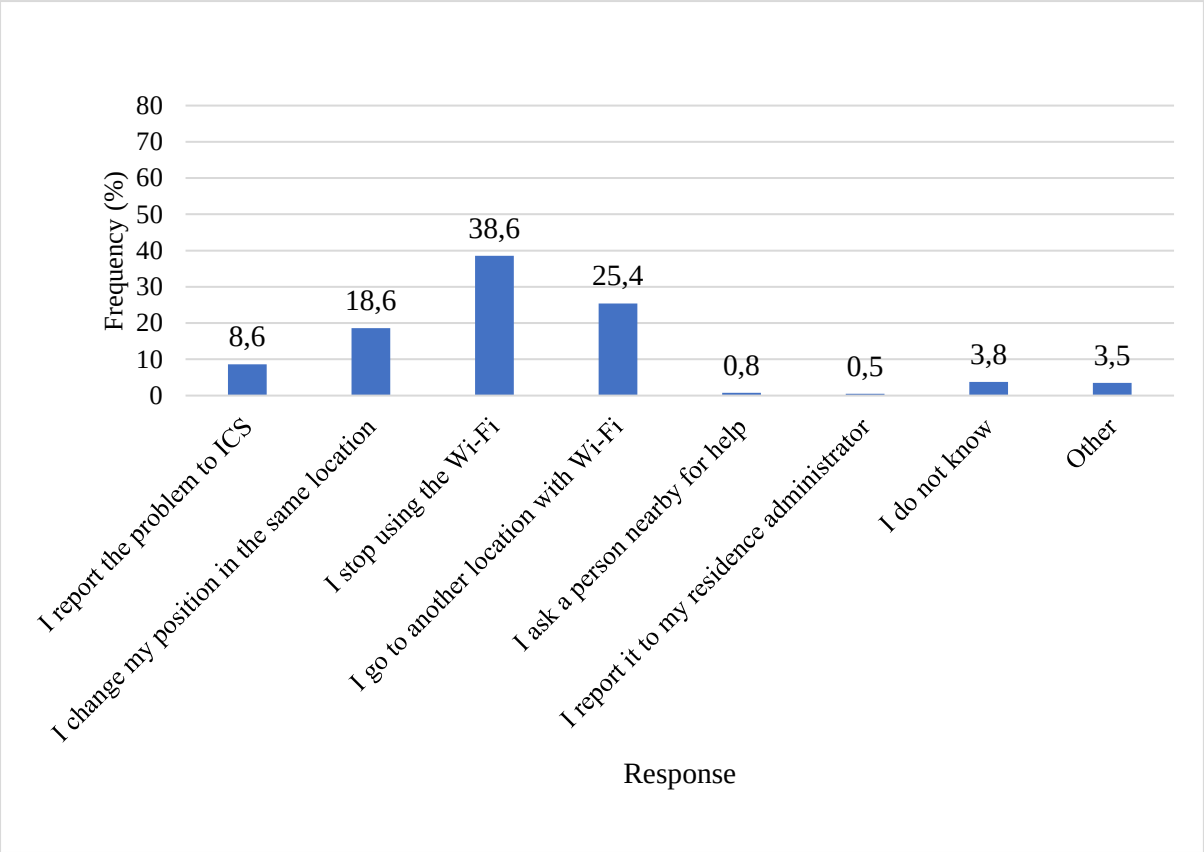

Figure 43: What students do when they face difficulties using Wi-Fi on campus

As can be seen in Figure 43, when students faced difficulties using Wi-Fi on campus, 38.6% stop using Wi-Fi, 25.4% go to another location, or they change their position in the same location (18.6%). Relatively few report their problem to ICS (8.6%) or to their residence administrator (0.5%), or ask a person nearby for help (0.8%).

These results show that students may have chosen to solve their Wi-Fi problems themselves, instead of seeking for help from other institutional administrators like the ICS, possibly because the majority learnt how to use Wi-Fi by themselves (see Figure 11).

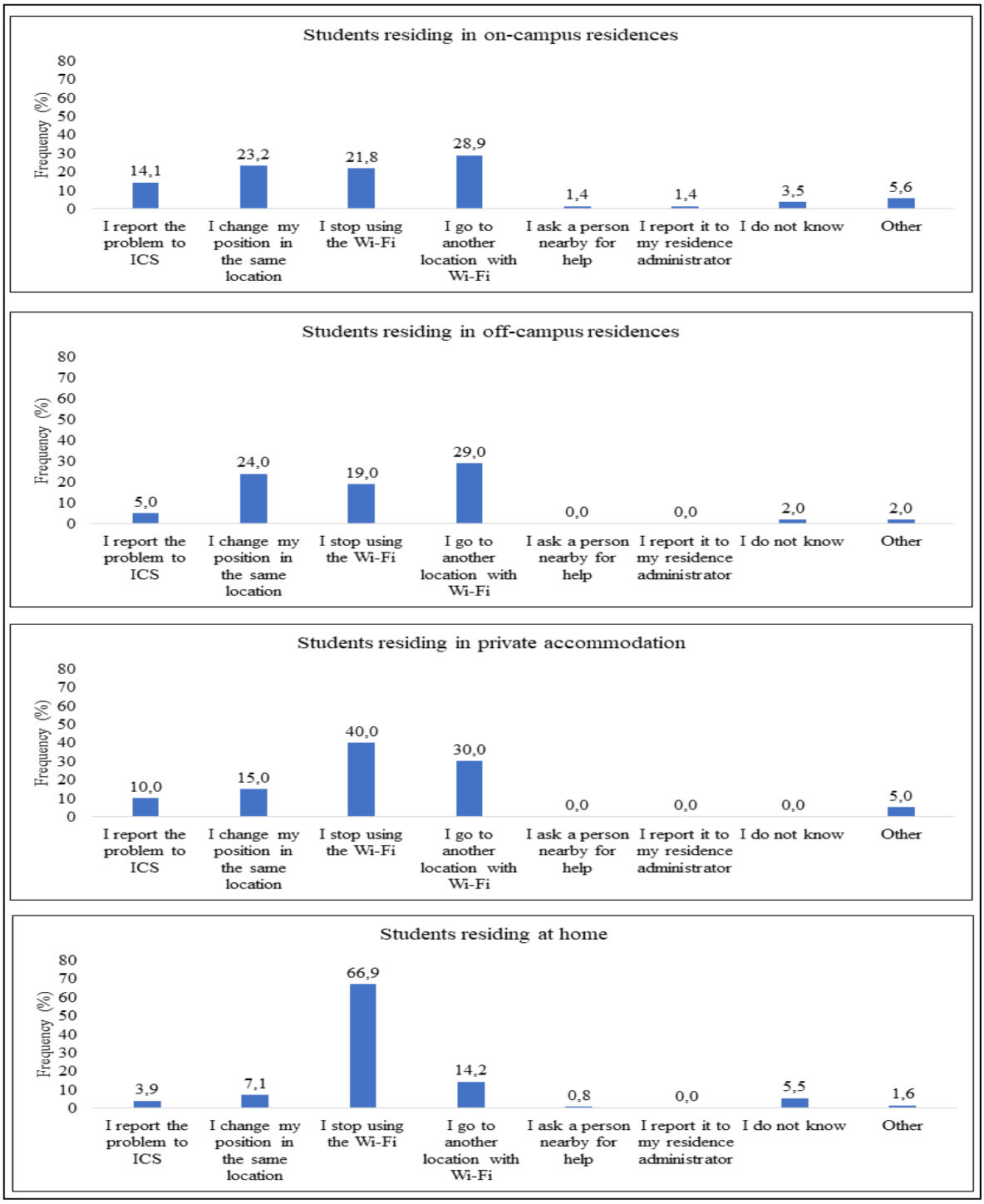

Figure 44: What students do when they face difficulties using Wi-Fi on campus, according to their place of residence

There is a significant relationship between residing on- or off-campus, and what students normally do when they experience a difficulty using Wi-Fi on campus, χ^2 (1) = 35649, p<.0005. Significantly more of those residing on campus indicated that they report the problem to ICS, change their position in the same location, report it to their residence administrator, or 'other';

while a significant number of those off-campus indicated they stop using the Wi-Fi. As can be seen in Figure 44, the majority of the students who stay in on-campus (28.9%) and off-campus residences (29%) go to other locations when faced with a difficulty using Wi-Fi on campus. However, the majority of students residing at home (66.9%) and in private accommodation (40%) stop using it.

4.6.2 Difficulties UKZN Westville students report to ICS about the use of Wi-Fi services on campus

To find out the difficulties students report to ICS, two ICS staff members were interviewed. Participant 1 was responsible for Wi-Fi infrastructure provision. Participant 2 was responsible for student support. (See the interview schedule in Appendix 4.)

Participant 2 indicated that it was difficult to estimate the correct statistics for difficulties reported by students, as more than one student could go into the call centre to log the same difficulty experienced at the same location. He added, *"Upon investigation to ascertain whether it is a student device or whether it is an actual access point problem, in most cases, you find that it is a student device."* He also added that when students went into the ICS call centre to report Wi-Fi connection difficulties with their devices, the devices connected at the call centre. However when they went back to the original location, they failed to connect to the Wi-Fi.

When asked whether there was infrastructure available to report Wi-Fi connection difficulties, he said that all ICS-owned computer LANs have telephones with which students can phone extension 4000 and select the student option to call ICS. Alternatively, they can send an email to ICS student support. He added that in case of emergency, or at night, or on holidays, students can call Risk Management Services (RMS); then RMS can contact someone who is on standby from ICS student support.

When they were asked what problems are reported about Wi-Fi infrastructure, what became evident was that most of the difficulties reported by students were related to device connectivity and most of the problems were experienced by students in their on-campus residences. He thought that difficulties reported were due to lack of coverage in some locations in the on-campus residences, due to too few access points and disconnected power switches at the access

points. However, the results showed that on-campus residence students faced fewer difficulties than other students (see Figure 42).

When asked about locations where students report the best Wi-Fi quality, he said that students may experience the best Wi-Fi in the computer LANs. This response was similar to what students reported in the study, as can be seen in Figure 20. However, he also noted that students may get the best Wi-Fi quality in any location if they are close to access points. He further indicated that students faced technical difficulties regarding the technical configurations of their devices, and login difficulties. This response was similar to what students reported in the study, as can be seen in Figure 39.

In addition to technical difficulties experienced by students, Participant 1 (in charge of Wi-Fi infrastructure provision) said that student Wi-Fi devices would not connect to Wi-Fi because their devices were automatically set with the default configuration to switch off their Wi-Fi card to save power for the device. He added that this was a default configuration which could be changed by users. However, most users did not deselect this configuration on their devices.

When Participant 2 was asked to indicate the top three locations where students report Wi-Fi related difficulties, he responded that the on-campus residences, followed by the library and other areas around the university, were the locations with the highest number of reported problems. He emphasised that the on-campus residences were the main locations where students reported Wi-Fi difficulties; and occasionally in other areas. He elaborated on the reasons why these difficulties may occur in the residences by saying, "*You find that sometimes students disconnect the power from the switches."* He indicated that the difficulties in the library could be because of too many connections caused by students using multiple devices. Regarding this perception, the results showed that students' devices took long to connect and students experienced difficulty logging onto Wi-Fi, which could be a result of congestion on the access points (see Figure 40).

Participant 2 added that no problems are reported in the lecture venues and computer LANs. However, there were occasional complaints of poor Wi-Fi connectivity in common areas. He added that students reported the lack of Wi-Fi coverage in on-campus residences. He also indicated that because of security, some devices do not connect to Wi-Fi. He elaborated on device connection problems, saying that student devices are able to see the access point but are

unable to connect because student have changed their login passwords, or the devices have technical problems.

There was a strong feeling that, by teaching students how to solve connection difficulties through hands-on training, students could resolve their difficulties themselves, reducing the number of difficulties reported to ICS. Participant 2 indicated that in 2015, when they carried out ICS hands-on training for house committees and volunteers in on-campus residences, they received fewer calls about network problems. He said that network problems decreased because when many students reported a particular problem they investigated it further to find a solution. He said that, *"Training was given to house coms and volunteers because you find that there are people who say, 'teach us'.* He added that, *"Going forward our plan is to have training videos".* The main reason why he recommended using videos was that students were reluctant to read prepared documents about configuring devices. However, he hopes that students may be more inclined to view training videos, given the popularity of accessing YouTube videos. Furthermore, he said that he had meetings with the student leadership every year to tell them about ICS services. However, he expressed concern that there was delayed reporting of Wi-Fi difficulties from the SRC, and they report the problem months after it has occurred.

While students face difficulties using Wi-Fi, there is lack of prompt reporting from students, with the majority deciding to stop using Wi-Fi services. Most of the difficulties experienced in the library affect students who do not stay on-campus.

On-campus residence students faced fewer difficulties using Wi-Fi (see Figure 42). However, since only 15.5% of on-campus residential students report the difficulties (see Figure 44), this shows that the training given to these students by ICS paid off. More training needs to be provided to students with other residential arrangements, so that more student problems can be addressed.

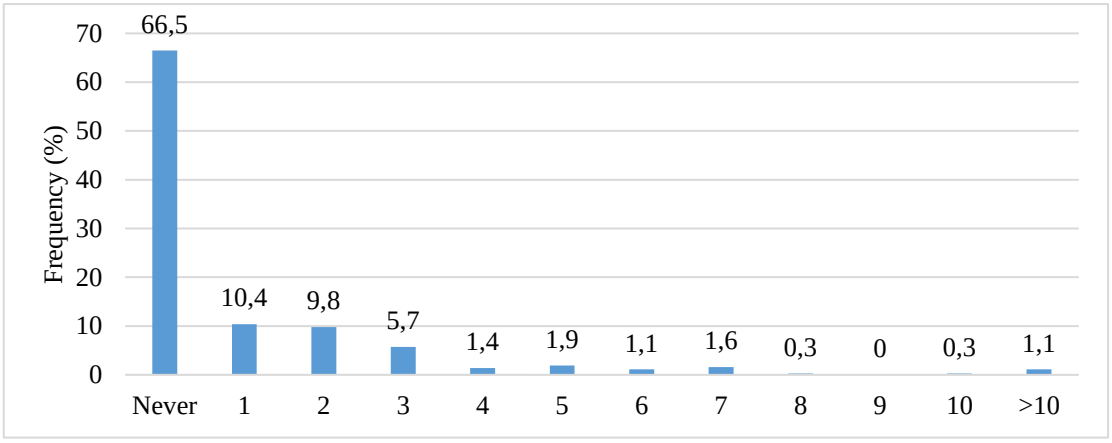

Figure 45: The number of time students asked ICS for help with Wi-Fi difficulties.

As can be seen in Figure 45, 66.5% of students have never asked ICS for help with difficulties; and very few students asked for help.

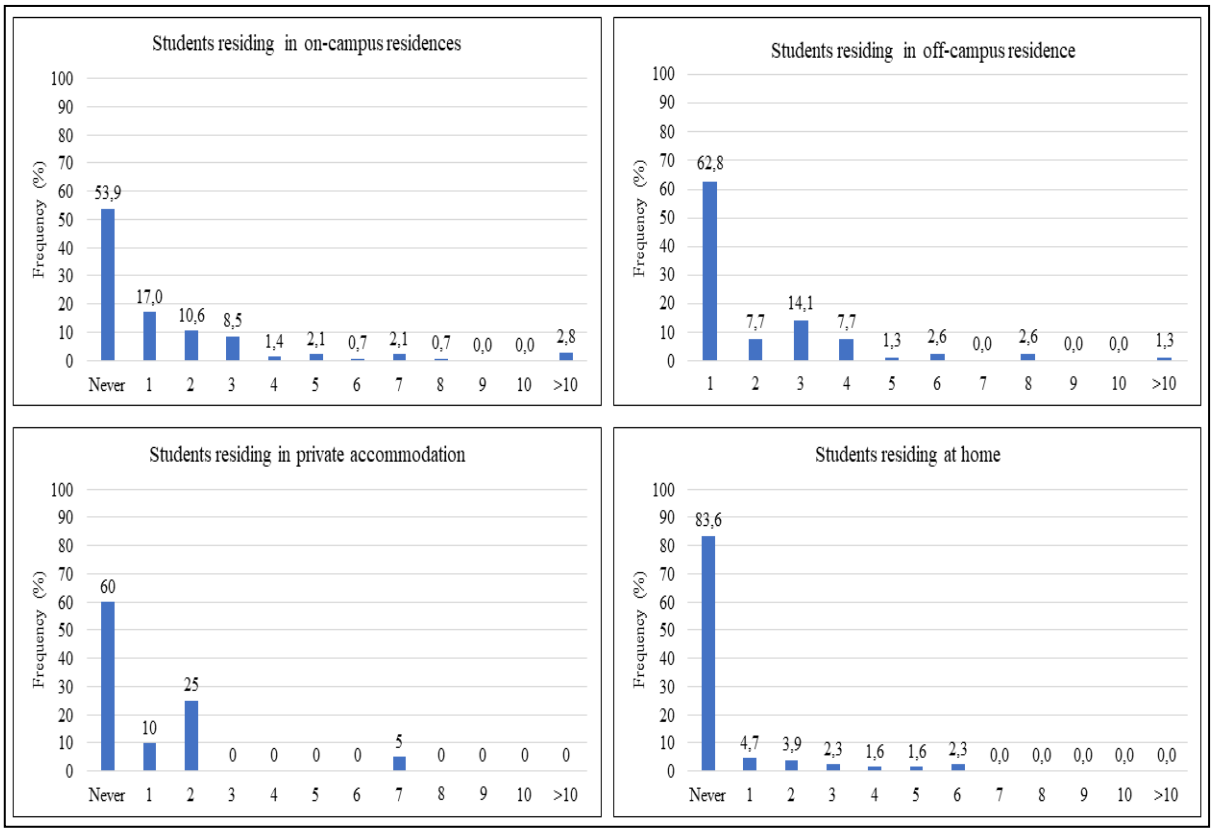

Figure 46: The number of occasions students have asked ICS for help with Wi-Fi difficulties in the last seven months, according to their place of residence.

Of the students living at home, 83.6% never asked ICS for help; with 60% in private accommodation; and 62.8% in off-campus residences (see Figure 46). All the students who

asked ICS for help with Wi-Fi difficulties on more than 10 occasions resided in on-campus residences (2.8%) and off-campus residences (1.3%) (see Figure 46).

Figure 44 shows that the highest percentage of students who stopped using Wi-Fi when encountering a difficulty resided at home (66.9%); whereas only 3.9% of those residing at home reported their difficulties to ICS. This confirms the results shown in

Figure 46, that 83.6% of those living at home have never asked ICS for help.

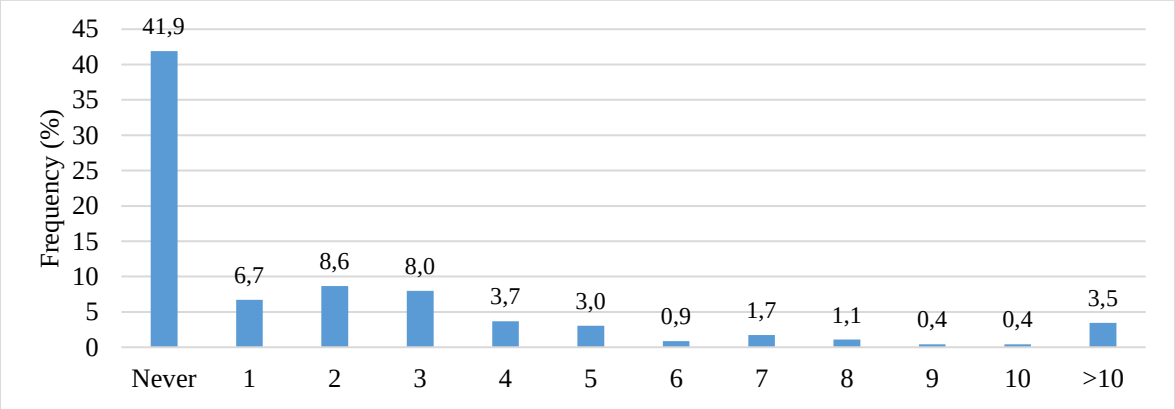

Figure 47: The number of times students have asked someone who is not part of ICS for help with difficulties when using Wi-Fi in the last seven months.

Of the students, 41.9% have never asked someone who is not part of ICS for help with difficulties when using Wi-Fi in the last seven months (see Figure 47). Students were less reluctant to ask someone who was not part of ICS for help with difficulties. These results also confirm the fact that the majority of the students learnt how to use Wi-Fi by asking someone else instead of ICS (see Figure 11).

Further analysis was undertaken to understand these results by their place of residence. These are discussed in the next section.

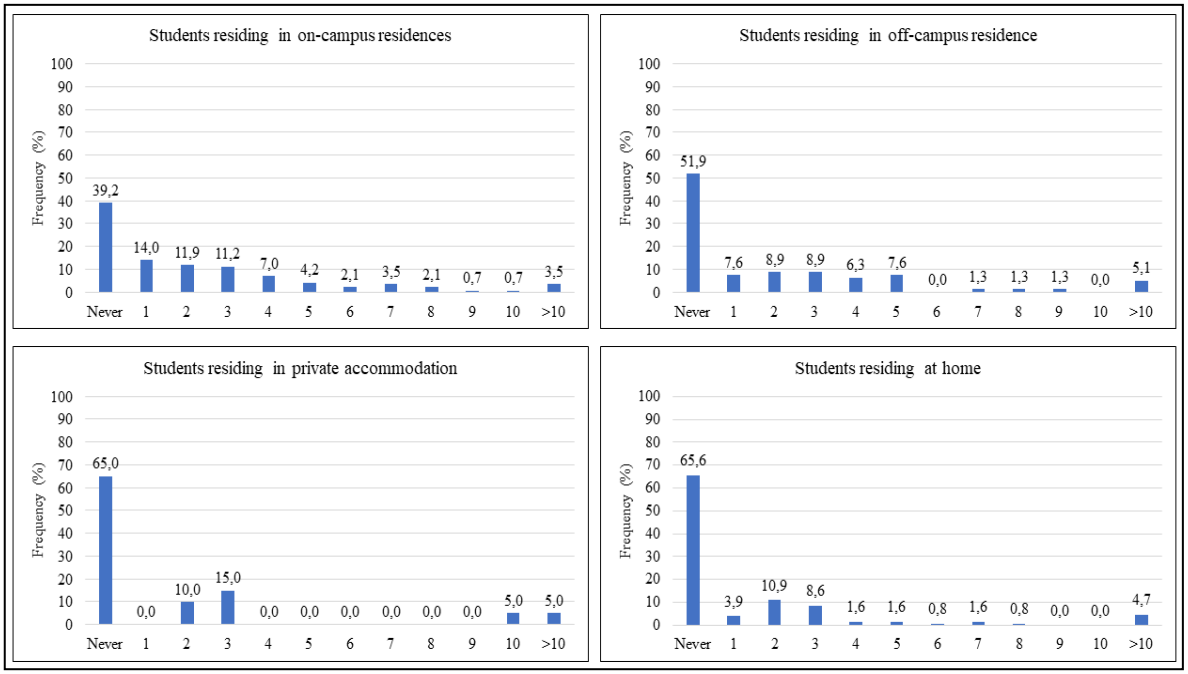

Figure 48: The number of times students have asked someone who is not part of ICS for help with difficulties when using Wi-Fi in the last seven months, by their place of residence.

As can be seen in Figure 48, most of the students who have never asked someone who is not part of ICS for help with difficulties when using Wi-Fi in the last seven months resided at home (65.6%), followed by students in private accommodation (65%). Most of the students who asked someone who is not part of ICS for help with difficulties on more than 10 occasions resided in off-campus residences (5.1%) followed by those residing in private accommodation (5.0%).

An analysis using an independent samples t-test was carried out to assess significant differences between the occasions students ask ICS for help, or someone who is not part of ICS, according to whether they live on- or off-campus. Results show that the average number of occasions ICS is asked for help by on-campus students (1.36 times) is significantly greater than for off-campus students (home, private accommodation and off-campus residences) (0.73 times), t (219.881) =2.844, p=.005. The average number of occasions an on-campus residence student asks someone who is not part of ICS for help with difficulties when using Wi-Fi (2.26 times) is significantly greater than for off-campus students (1.63 times), t (368) =2.061, p=.040.

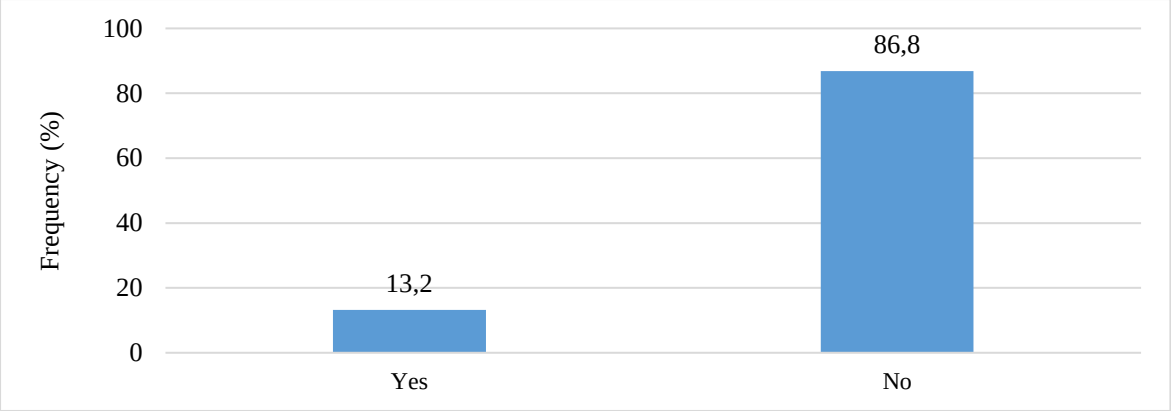

Figure 49: Students' awareness of how to log call to ICS about difficulties.

As can be seen in Figure 49, 86.8% of students did not know how to log a call to ICS about Wi-Fi difficulties.

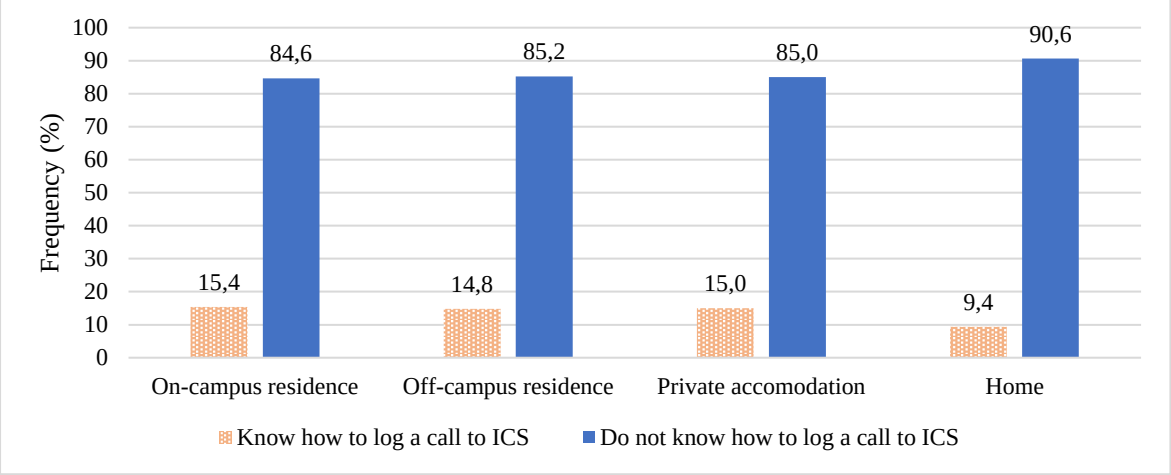

Figure 50: Whether students know how to log an ICS call about Wi-Fi difficulties, by their residence.

Slightly more students in on-campus residences knew how to log a call to ICS (15.4%) than students residing anywhere else. Students staying at home (90.6%) knew the least about logging a call with ICS (see Figure 50).

From the interview with Participant 2, it is clear that students who resided in on-campus residences had received training on the use of Wi-Fi. This could be a reason why they managed to log more calls to ICS to report Wi-Fi difficulties.

4.7 Objective 4: UKZN Westville students' perceptions of the quality of Wi-Fi service on campus

To investigate students' perceptions of service quality, the research adopted three primary constructs (independent variables) believed to affect the perceived service quality (dependent variable) (see Figure 51). This was described in Section 2.7. The three independent variables were outcome quality, physical environment quality and interaction quality. In the questionnaire (Appendix 3), Question 30, students rated the extent to which they disagreed or agreed with questions seeking to understand their perceptions of quality of service, and the three variables affecting perceived service quality.

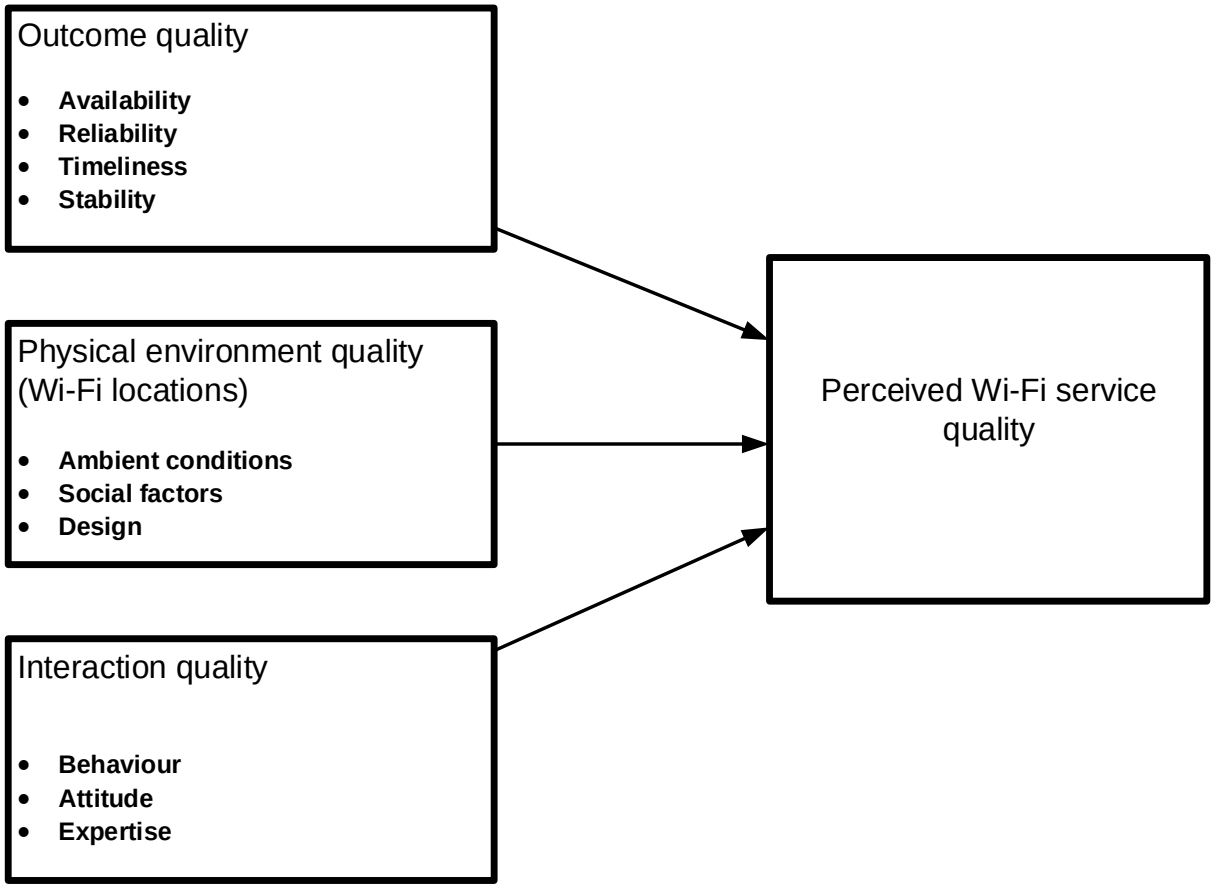

Figure 51: The effect of outcome quality, physical environment quality and interaction quality on perceived Wi-Fi service quality

Outcome quality was assessed by including questions to evaluate students' perceptions of the Wi-Fi availability (OQ1-OQ3), reliability (OQ4-OQ6), timeliness (OQ7-OQ9) and stability (OQ10-OQ12).

Physical environment quality was assessed through questions to evaluate the students' perceptions of the ambient conditions (PEQ1-PEQ3), the perceived social conditions (PEQ4-PEQ6), and the physical design of the Wi-Fi locations (PEQ7-PEQ9).

Interaction quality was assessed through questions to understand the students' perceptions of the behaviour (IQ1-IQ3), attitude (IQ4-IQ6) and expertise of ICS, and how this affects perceived Wi-Fi service quality (IQ7-IQ9).

The investigation into perceptions of service quality involved questions to understand, overall, how satisfied the students were with Wi-Fi services on campus. Relationships between the variables are explored in Section 4.8, under Objective 5.

4.7.1 UKZN Westville students' perceptions of the outcome quality when using the Wi-Fi service on campus at their most-used location.

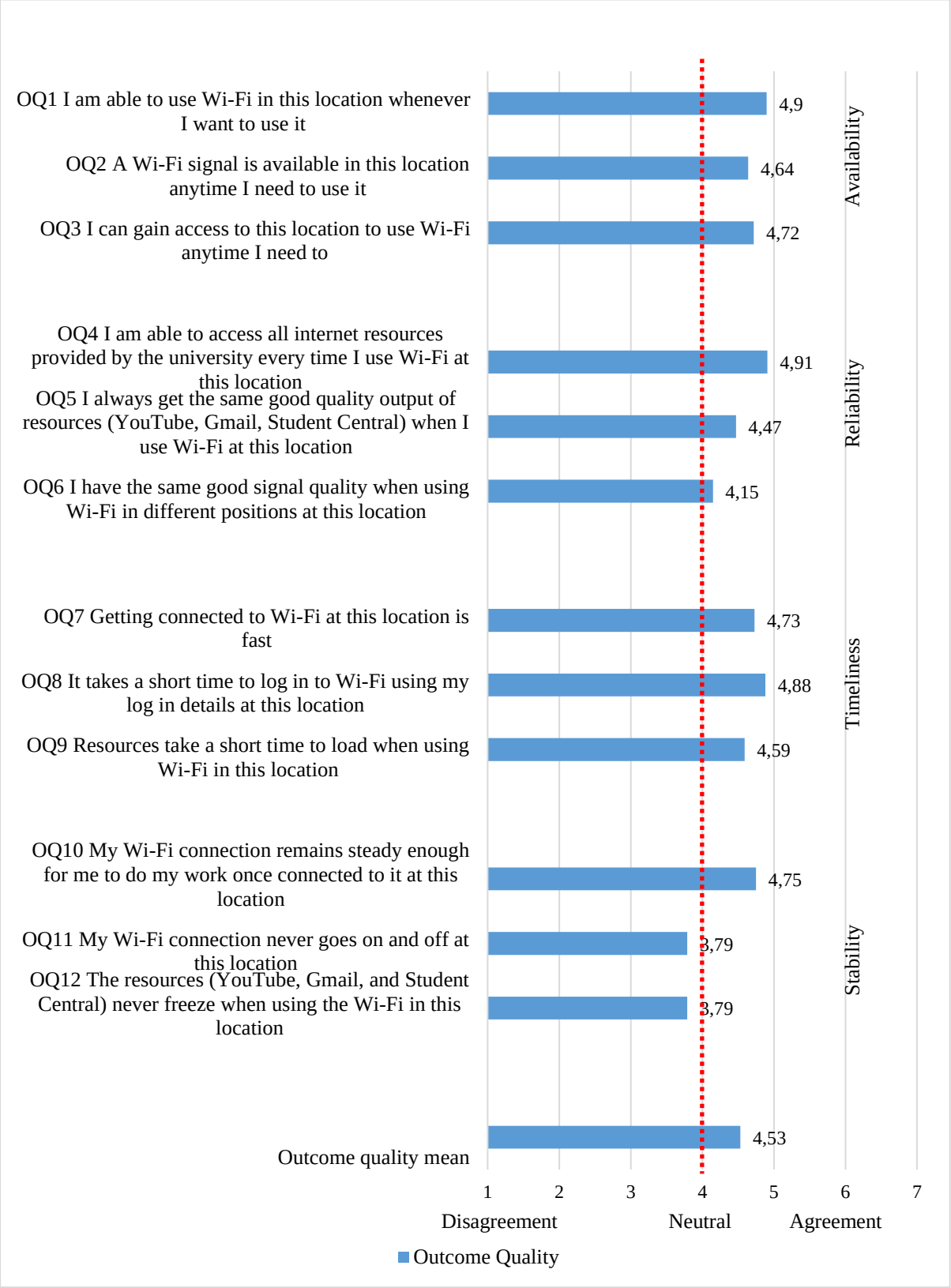

Figure 52: Students' perceptions of the outcome quality when using the Wi-Fi service on campus at their most-used location.

The first independent variable sought to understand students' perceptions of outcome quality at their most-used location. The sub-constructs were the availability, reliability, timeliness and stability of Wi-Fi services in most-used locations. Each sub-construct had questions to allow students to rate the extent to which they agreed or disagreed (see Figure 52).

Figure 52 shows students' perceptions of the outcome quality when using the Wi-Fi service on campus at their most-used locations. A one-sample t-test was applied to test for significant agreement/disagreement with students' perceptions of outcome quality in different Wi-Fi locations. Regarding availability, there was significant agreement for all three questions, i.e. that students are able to use Wi-Fi in locations whenever they want to use it (OQ1) (M=4.90, SD=1.979), t (372) = 8.818, p=<.0005; a Wi-Fi signal is available at these locations any time they need to use it (OQ2) (M=4.64, SD=2.016), t (372) = 6.112, p=<.0005; and students can gain access to the locations to use Wi-Fi any time they need to (OQ3) (M=4.72, SD=1.983), t (372) =7.051, p=<.0005.

Similarly, with reliability, there was a significant agreement for all three questions, i.e., that: students are able to access all Internet resources provided by the university every time they use Wi-Fi at locations (OQ4) (M=4.91, SD=1.874), t (372) =9.395, p=<.0005; that students always get the same good quality output of resources (YouTube, Gmail, Student Central) when they use Wi-Fi at the locations (OQ5) (M=4.47, SD=1.988), t (372) =4.557, p=<.0005; and that students have the same good signal quality when using Wi-Fi in different positions at the locations (OQ6) (M=4.15, SD=2.001), t (372) =1.425, p=<0.155.

Regarding timeliness, there is significant agreement that getting connected to Wi-Fi at the locations is fast (OQ7) (M=4.73, SD=1.959), t (372) =7.189, p=<.0005; it takes a short time to login to Wi-Fi using login details in Wi-Fi locations (OQ8) (M=4.88, SD=1.840), t (371) =9.185, p=<.0005; and resources take a short time to download when using Wi-Fi in this location (OQ9) (M=4.59, SD=1.855), t (372) =6.140, p=<.0005.

Results showed that there is a significant agreement regarding stability, that students' Wi-Fi connections remains steady enough for them to do their work once connected to Wi-Fi (OQ10) (M=4.75, SD=1.908), t (371) =7.607, p=<.0005. However, the students disagree significantly that their Wi-Fi connections never go on and off at Wi-Fi locations (OQ11) (M=3.79, SD=2.033), t (372) = -2.038, p=.042; and that the resources (YouTube, Gmail, and Student

Central) never freeze when using the Wi-Fi at Wi-Fi locations (OQ12) (M=3.79, SD=2.058), t (372) -2.013, p=.045. This indicates that students had problems with unstable Wi-Fi connections which made resources freeze or terminate.

The results showed that there were notable problems with the stability of Wi-Fi services, due to Wi-Fi connections going off (mean = 3.79) and Internet resources freezing (mean =3.79). The majority of the students were able to access all Internet resources provided by the university every time they use Wi-Fi, with a mean of 4.91.

The average mean score for outcome quality was 4.53 out of 7 which, while it is above the neutral value of 4, still offers room for improvement.

The next section discusses Westville students' perceptions of the physical environment quality when using the Wi-Fi on campus at their most-used locations.

4.7.2 UKZN Westville students' perceptions of the physical environment quality when using the Wi-Fi on campus at their most-used location.

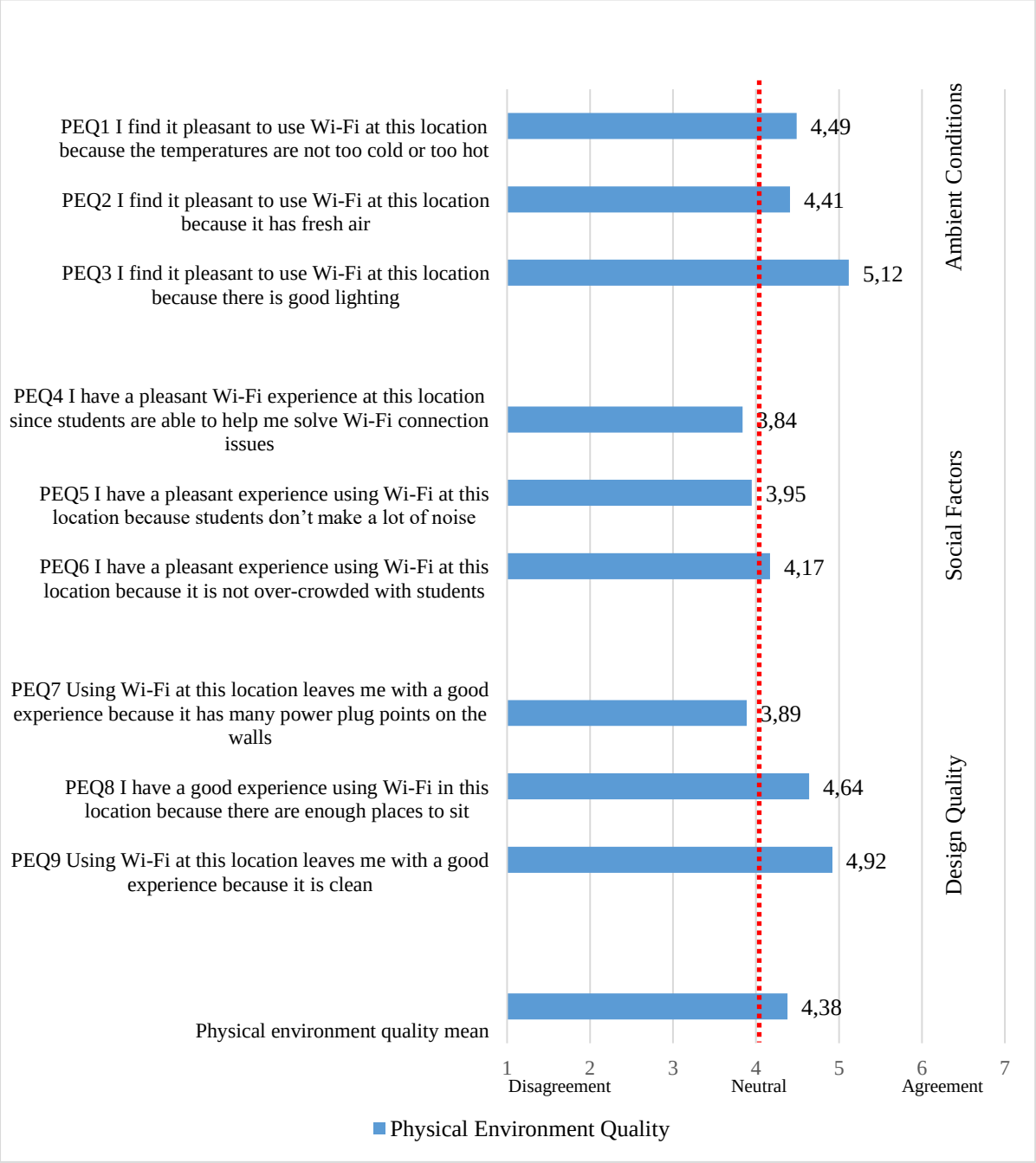

Figure 53: Students' perceptions of the physical environment quality when using the Wi-Fi service on campus at their most-used location.

Students were asked for their perceptions of the second independent variable to understand their perceptions of physical environment quality in their most-used locations. The variables included questions to allow students to rate the extent to which they agree or disagree (see Figure 53). A one-sample t-test was applied to test for significant agreement/disagreement

between students' perceptions of physical environment quality at different Wi-Fi locations. The sub-constructs were the ambient conditions, social factors and the design quality.

Regarding the ambient conditions, there is significant agreement that students find it pleasant to use Wi-Fi in locations where the temperature is not too cold or too hot (PEQ1) (M=4.49, SD=1.883), t (372) = 5.004, p=<.0005; and students find it pleasant to use Wi-Fi in locations where they have fresh air (PEQ2) (M=4.41, SD=1.839), t (372) = 4.335, p=<.0005. There is also significant agreement that students find it pleasant to use Wi-Fi in locations because there is good lighting (PEQ3) (M=5.12, SD=1.608), t (372) = 13.489, p=<.0005.

There was no significant agreement that students had a pleasant Wi-Fi experience at locations because of social factors, such as other students helping to solve their Wi-Fi connection issues (PEQ4); students not making a lot of noise (PEQ5); or because of no over-crowding with students (PEQ6).

There was no significant agreement that the design of the environment at the Wi-Fi locations left students with a good experience, because of many power plug points on the walls (PEQ7). However, there is significant agreement that students enjoy using Wi-Fi at their most-used location because there are enough places to sit (PEQ8) (M=4.64, SD=1.829), t (370) = 6.757, p=<.0005; and because they are clean (PEQ9) (M=4.92, SD=2.614), t (371) = 6.822, p=<.0005.

In summary, the results show that there is stronger agreement on ambient conditions, with an average mean of 4.67, than on any other physical environment quality variable identified in the study. However, this mean was lower that of outcome quality (4.75). Students have responded that available power plug points and enough seating places improve their perception of the Wi-Fi locations. This should be noted, given that the same factors were identified as difficulties that students faced in their most used Wi-Fi locations (see Figure 39).

4.7.3 UKZN Westville students' perceptions of the interaction quality when using the Wi-Fi service on campus at their most-used location.

Figure 54: Students' perceptions of the interaction quality when using the Wi-Fi service on campus at their most-used location.

The third independent variable was chosen to assess students' perceptions of interaction quality (see Figure 55). The results showed that there was no significant agreement on the items for the behaviour of ICS. Regarding attitude, there is a significant agreement that students can count on the ICS employees at UKZN Westville being friendly when interacting with them about Wi-Fi issues and needs in Wi-Fi locations (IQ4) (M=4.22, SD=1.434), t (372) = 2.924, p=.004); that the attitude of UKZN Westville ICS employees demonstrates their willingness to help students with Wi-Fi needs in Wi-Fi locations (IQ5) (M=4.32, SD=1.435), t (372) = 4.367, p<.0005); and that UKZN Westville ICS employees show enthusiasm when helping students with Wi-Fi problems in Wi-Fi locations (IQ6) (M=4.28, SD=1.408), t (372) = 3.826, p<.0005).

There is a significant agreement that students can count on UKZN Westville ICS employee expertise when addressing issues of Wi-Fi services in Wi-Fi locations (IQ7) (M=4.41, SD=1.401), t (372) = 5.654, p<.0005); when students ask UKZN Westville ICS employees to help them with Wi-Fi issues, they solve their problems quickly (IQ8) (M=4.39, SD=1.400), t (372) = 5.401, p<.0005); and UKZN Westville ICS employees are very professional when addressing the students' Wi-Fi needs at the Wi-Fi locations (IQ9) (M=4.42, SD=1.464), t (372) = 5.589, p<.0005).

There was a significant agreement on the expertise (M=4.4) and attitude (M=4.27) that ICS administrators reflect while providing Wi-Fi services on campus. However, it is important to note that most students don't know how to log a call to ICS (Figure 49). The results also showed that interaction quality was the lowest of all the independent variables (M=4.25).

4.7.4 UKZN Westville students' perceptions of the service quality when using the Wi-Fi service on campus at their most-used location.

The study identified a dependent variable to evaluate the overall perception of the service quality at students' most-used locations. Five items were identified (SQ1-SQ5). The results are given below.

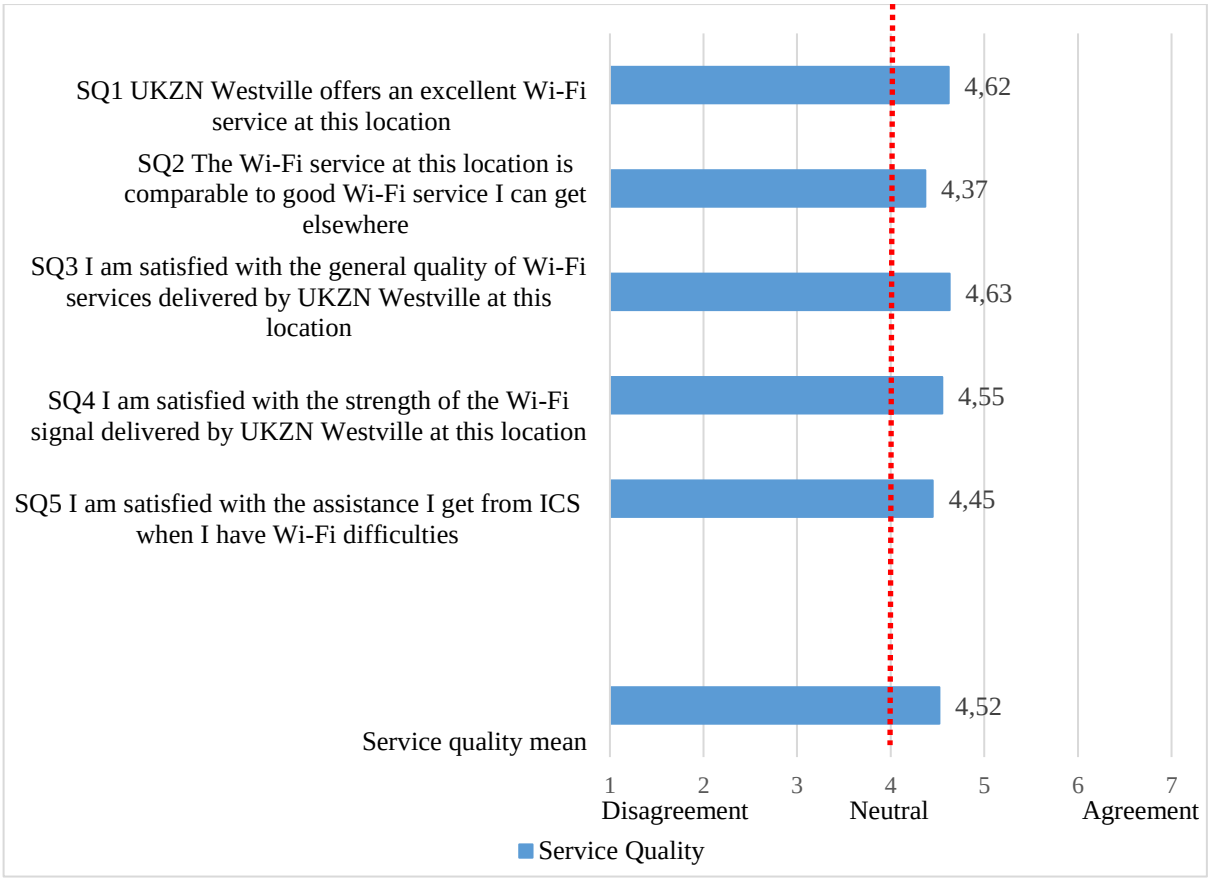

Figure 55: Students' perceptions of the service quality when using the Wi-Fi service on campus at their most-used locations.

A one-sample t-test was applied to test for significant agreement/disagreement with students' perceptions of service quality (the dependent variable) at the participants' most-used locations (see Figure 55). There is significant agreement that UKZN Westville offers an excellent Wi-Fi service in Wi-Fi locations (SQ1) (M=4.62, SD=1.776), t (371) = 6.716, p<.0005; the Wi-Fi service at these locations is comparable to good Wi-Fi service students can get elsewhere (SQ2) (M=4.37, SD=1.871), t (371) = 3.797, p<.0005; students are satisfied with the general quality of Wi-Fi services delivered by UKZN Westville in Wi-Fi locations (SQ3) (M=4.63, SD=1.833), t (372) = 6.612, p<.0005; students are satisfied with the strength of the Wi-Fi signal delivered by UKZN Westville in Wi-Fi locations (SQ4) (M=4.55, SD=1.900), t (372) = 5.615, p<.0005; and students are satisfied with the assistance they get from ICS when they have Wi-Fi difficulties (SQ5) (M=4.45, SD=1.510), t (371) = 5.734, p<.0005.

In summary, it was interesting to find that there was significant agreement on all the items identified to understand students' perceptions of quality (M=4.52). Given that this mean was

on a scale of 7, this shows that there is still room for improvement in the Wi-Fi services on campus.

4.7.5 How user system device quality and access point configuration specifications affect outcome quality

This section looks at how user device quality and technical access point configuration could affect students' perceptions of outcome quality, see Figure 56, below.

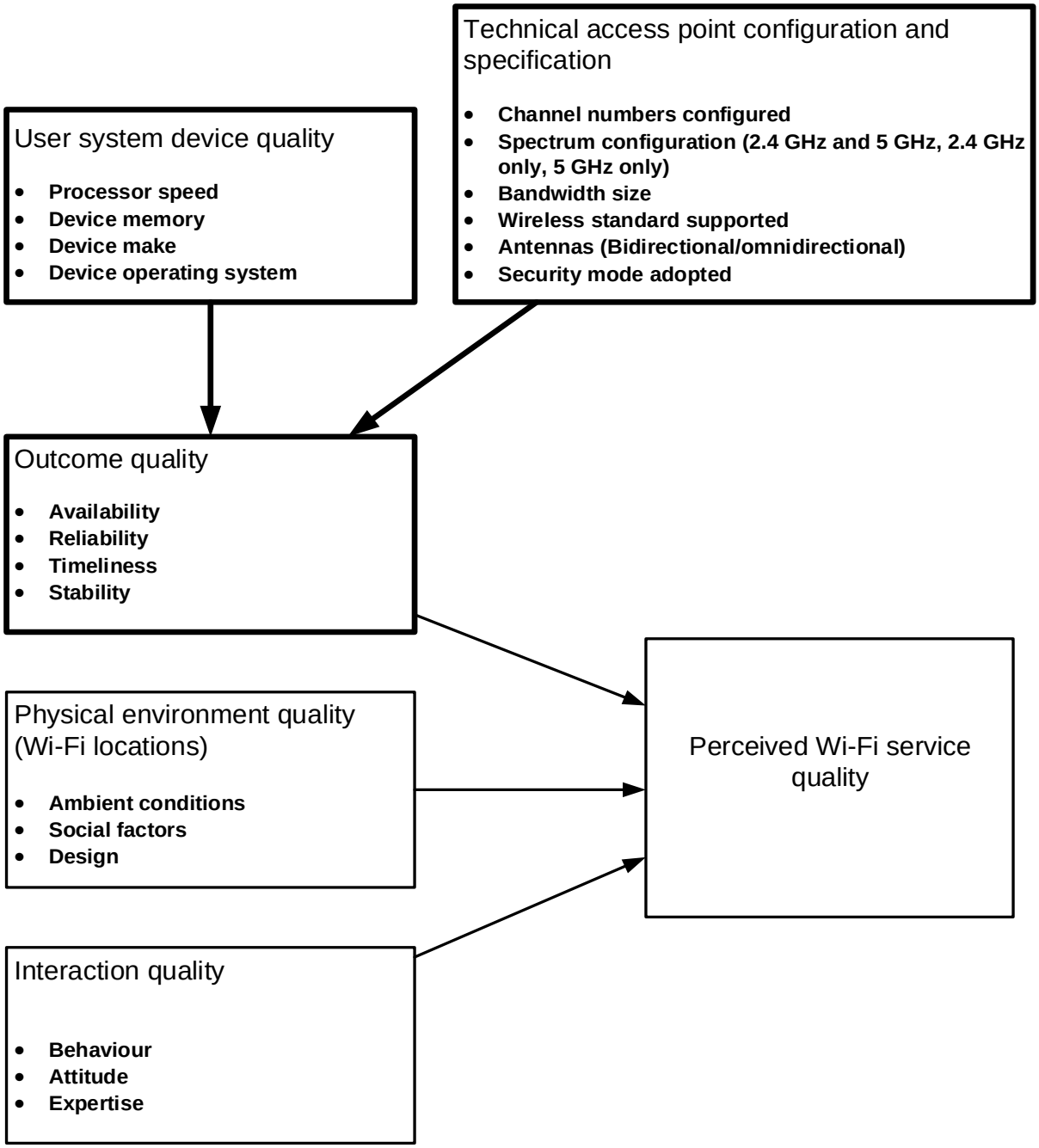

Figure 56: The effect of system device quality and access point configuration on outcome quality

The conceptual framework (see Figure 56) proposed that user devices and access point configurations may affect the outcome quality of Wi-Fi services. The characteristics of user devices were discussed in Section 4.4.4, and access point configurations in Section 4.5.1.

An Anova test was used to see if the average outcome quality is significant across the specifications of the devices used. The results show that there was no significant difference in outcome quality across the make, operating system, Wi-Fi standard, speed and memory of laptops and PCs with wireless cards. A relationship between system device quality and outcome quality was not found. However, it is important to note that students did not know the characteristics of their devices, so more research needs to be carried out to provide a full inventory of student device characteristics.

Reports from the ICS interview (see Section 4.5.1) were analysed to see if access point configuration may affect outcome quality. Results showed that the configuration of the 5GHz spectrum on access points was reported as a factor in connectivity problems, as most student devices would only access the 2.4GHz spectrum. As a solution, in areas where there were reports of constant connection faults, this configuration was changed to the 2.4GHz spectrum. Hence, the choice of spectrums configured affects the outcome quality.

Furthermore, the access point automatically selects which spectrum to allow the device to use, depending on what the device can support. Hence, some students will be accessing the access point on the 5GHz spectrum while others use the congested 2.4GHz spectrum. This in turn gives those students with devices accessing the 5GHz spectrum better Wi-Fi services.

In addition, the choice of security mode adopted requires students to authenticate themselves before accessing resources. This configuration affects the time taken to access Wi-Fi resources, especially when students forget their password.

The next section discusses the results from factor analysis and the Bartlett's test of the independent variables (factor 1, factor 2 and factor 3) and the dependent variable (factor 4). It also presents the adjustment made to create the final proposed model to understand perception of the quality of Wi-Fi services. Factor analysis was undertaken to understand how well the items under each sub-construct measured that sub-construct.

4.8 Objective 5: How outcome quality (OQ), physical environment quality (PEQ) and interaction quality (IQ) affect students' perceived Wi-Fi service quality (SQ).

The mean values for the independent variables (outcome quality (OQ), physical environment quality (PEQ) and interaction quality (IQ)) and the dependent variable (service quality (SQ)) were given in Section 4.7. This section will determine whether there is a relationship between the OQ, PEQ and IQ constructs and the students' perceived Wi-Fi service quality (SQ) (see Figure 57).

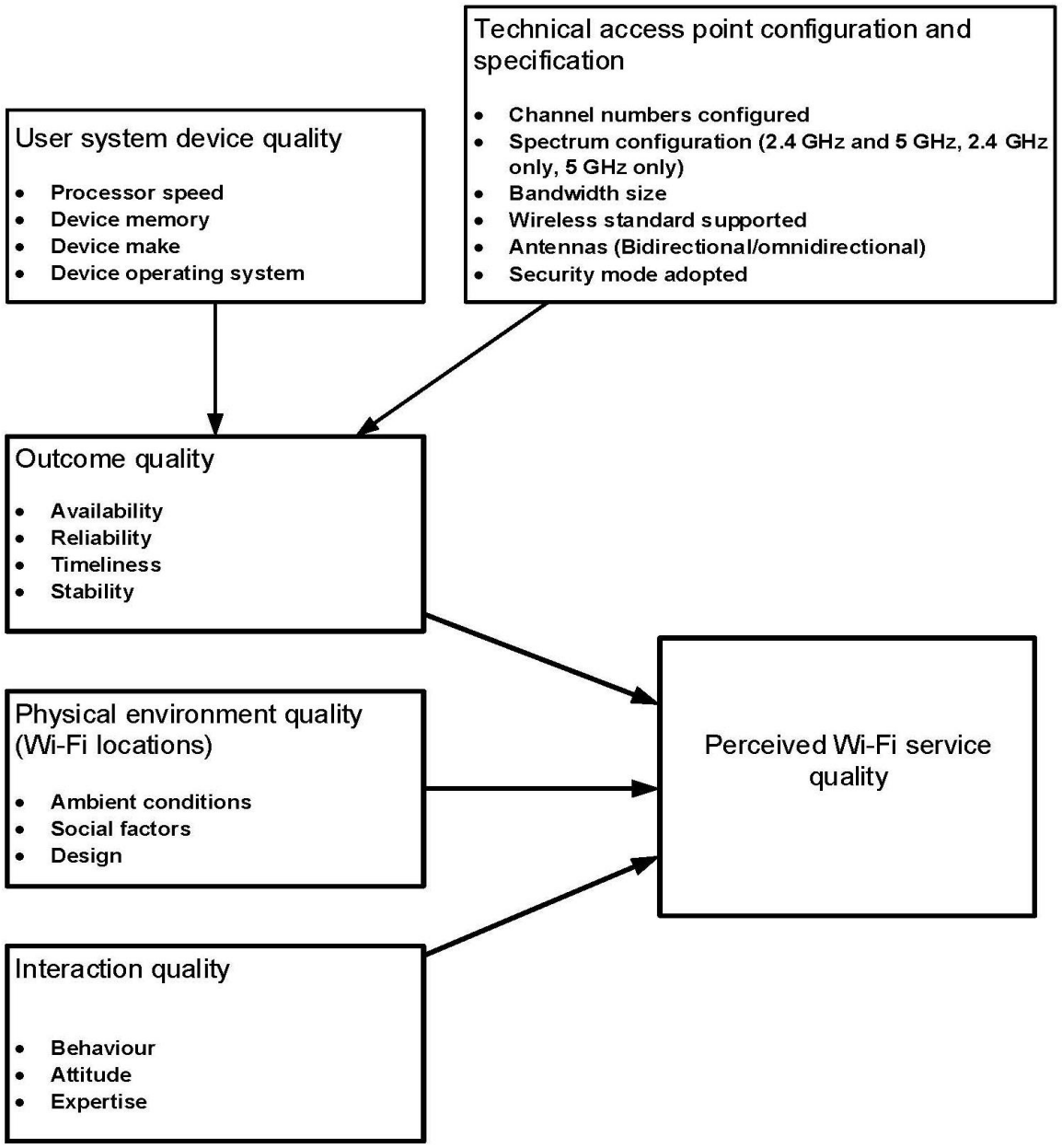

Figure 57: Relationship between the independent variables (Outcome quality, Physical environment quality and Interaction quality) and the dependent variable (Service quality).

In order to show the validity and suitability of the responses collected regarding students' perceptions of Wi-Fi service quality, principal axis factoring was carried out. Principal axis factoring in SPSS was applied to all 35 items that were chosen to understand perceptions of Wi-Fi service quality. The study adopted the Kaiser-Meyer-Olkin (KMO) measurement of sampling adequacy to reliably extract factors from the data. Principal axis factoring was chosen as a suitable extraction technique for this data because the aim was to identify latent variables and to see how well the items under each sub-construct measured that sub-construct.

The analysis extracted four factors (see Table 6) and adopted the promax rotation method to obtain easily interpretable results. The results showed that the scales of physical environment quality and service quality had good reliability. However, two items were dropped from the physical environment construct because they did not measure the physical environment dimension reliably. The first item dropped was from the social conditions sub-construct (PEQ9) ("I have a pleasant Wi-Fi experience at this location since students are able to help me solve Wi-Fi connection issues"). The other item to be dropped from the model was from the physical environment design sub-construct (PEQ4) ("Using Wi-Fi at this location leaves me with a good experience because it is clean"). The item (SQ5) ("I am satisfied with the assistance I get from ICS when I have Wi-Fi difficulties") loaded onto factor 2 with all the other interaction quality items (see Table 6).

Cronbach's alpha was applied to the four factors to test the reliability of the items in measuring each of the factors (sub-constructs) (see Table 6).

Table 6: Results of factor analysis, including Cronbach's alpha of outcome quality, physical environment quality, interaction quality and perceived service quality.

Factor	Item numbers	Cronbach alpha	Factor name
Factor 1	OQ1-OQ12	0.937	Outcome quality
Factor 2	PEQ1-PEQ3 and PEQ5-PEQ8	0.857	Physical environment quality
Factor 3	IQ1-IQ9 and SQ5	0.945	Interaction quality
Factor 4	SQ1-SQ4	0.915	Perceived service quality

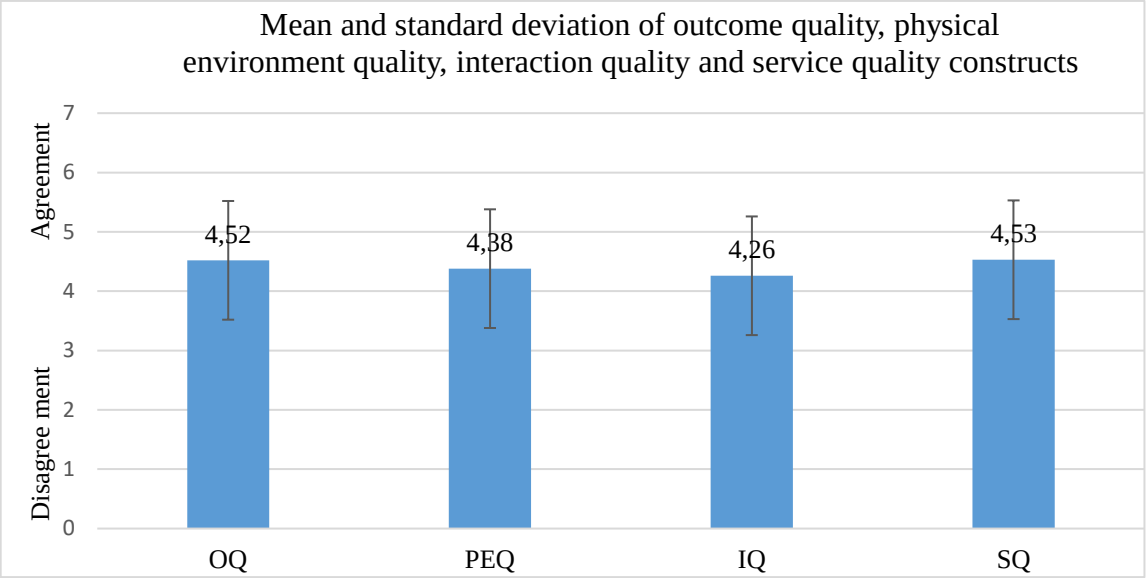

Figure 58: Mean and standard deviation of outcome quality, physical environment quality, interaction quality and service quality constructs.

A one sample t-test was applied to test if the average agreement score is significantly different from a neutral score of 4 (see Figure 58). There is significant agreement for outcome quality (M=4.5251, SD=1.51064), t (372) =19.499, p<.0005; physical environment quality (M=4.3829, SD=1.37458), t (372) =19.430, p<.0005; interaction quality (M=4.2686, SD=1.19778), t (372) =20.456, p<.0005; and service quality (M=4.5380, SD=1.65157), t (372) =17.985, p<.0005. In addition, the Bartlett's test was adopted to identify whether the correlations between the items are not too low. A significant result (p<.0005) indicates that these correlations are not too low. The results showed that 62.05% of the variation in the data is explained by the four factors, i.e. the three independent variables (factor 1, factor 2, factor 3) and the dependent variable (factor 4) (perceived service quality) .

All items developed in the questionnaire to measure various aspects of the constructs were found to be valid, except for two items in the physical environment quality section (PEQ4 and PEQ9). Future studies should replace these items with other items.

Factor 1 (Outcome quality)

Regarding outcome quality, three factors were extracted. The results from the Bartlett's test showed that KMO = .921, Bartlett's p<.0005 and the variance extracted was =- 75.37%. This was taken to be marvellous (Statisticshowto.datasciencecentral, 2018).

The outcome quality sub-construct **Wi-Fi availability** remained as it was with the following items from the original model:

1. OQ1, OQ2 and OQ3, all from the availability sub-construct

A new outcome quality sub-construct was created from the reliability, timeliness and stability sub-constructs. This new sub-construct was named **Wi-Fi efficiency** and included the following items from the original model:

1. OQ5, OQ6 from the reliability sub-construct
2. OQ7, OQ8 and OQ9 from the timeliness sub-construct
3. OQ10 from the stability sub-construct

A revised outcome quality sub-construct, **Wi-Fi stability** included the following items from the original model:

1. OQ11 and OQ12, both from the stability sub-construct

Factor 2 (Physical environment quality)

Regarding physical environment quality, three factors were extracted. The results from the Bartlett's test showed that KMO = .820, Bartlett's p<.0005 and the variance extracted was =-77.60%. This was taken to be meritorious (Statisticshowto.datasciencecentral, 2018).

The sub-construct, **ambient conditions,** remained as it was and included the following items from the original model:

1. PEQ1, PEQ2, PEQ3 from the physical environment quality sub-construct.

The revised sub-construct, **physical environment design,** included the following items from the original model:

1. PEQ7 and PEQ8 from the physical environment quality sub-construct.

The revised sub-construct, **social factors,** included the following items from the original model:

1. PEQ6 and PEQ5 from the physical environment quality sub-construct.

Factor 3 (Interaction quality)

Regarding interaction quality, three factors were extracted. The results from the Bartlett's test showed that KMO = .938, Bartlett's p<.0005 and the variance extracted was =- 80.53%. This was taken to be marvellous (Statisticshowto.datasciencecentral, 2018).

The interaction quality sub-construct, **behaviour,** included all the following items from the original mode:

1. IQ2, IQ3, IQ1 from the behaviour sub-construct.

The revised interaction quality sub-construct, **attitude,** included the following items from the original model:

1. IQ4, IQ5 and IQ6 from the attitude sub-construct.

The revised interaction quality sub-construct, **expertise**, included the following items from the original model:

1. IQ7, IQ8 and IQ9 from the expertise sub-construct.
2. SQ5 from perceived service quality.

Factor 4, the dependent variable (Service quality)

Regarding service quality, the results from the Bartlett's test showed that KMO = .821, Bartlett's p<.0005 and the variance extracted was =- 80.01%. This was taken to be meritorious (Statisticshowto.datasciencecentral, 2018).

The revised dependent variable, **Service quality**, included the following items from the original model:

1. SQ1, SQ2, SQ3 and SQ4 from service quality

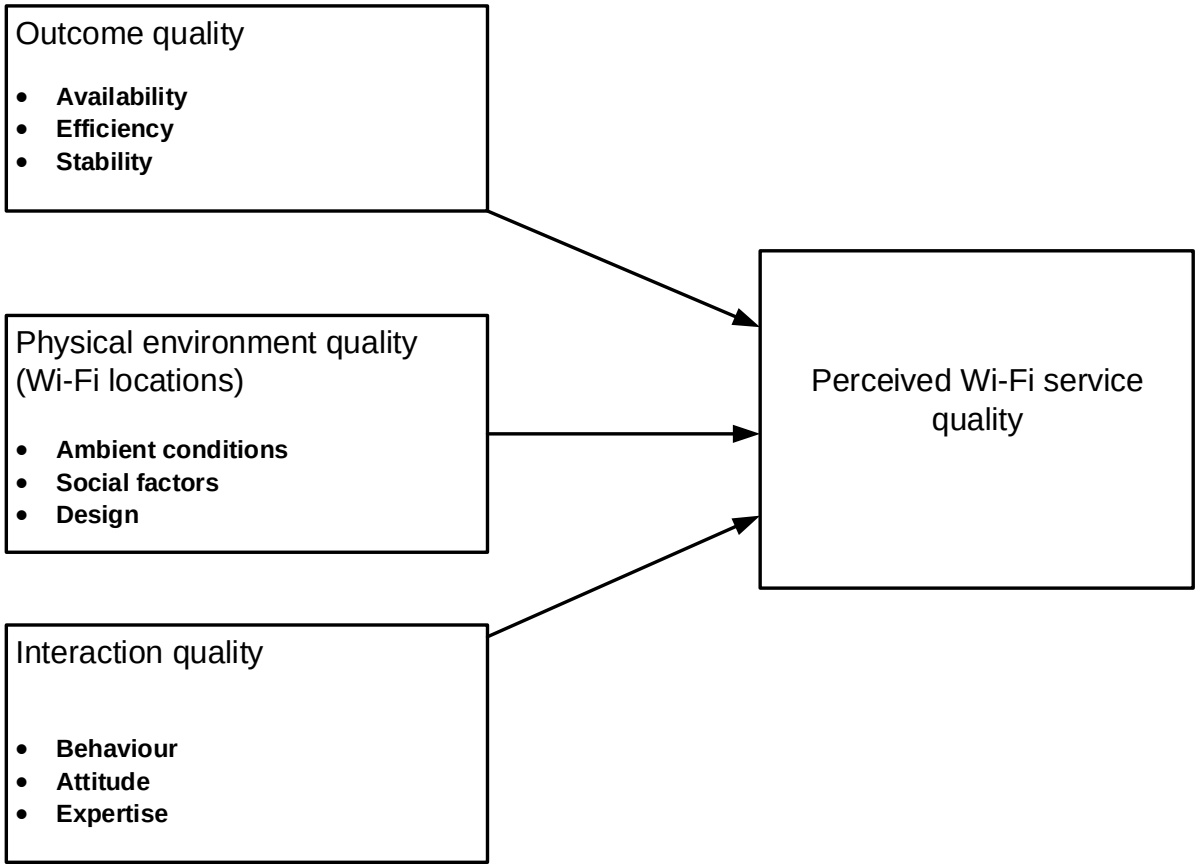

Figure 59: Revised conceptual model to understand user perception of Wi-Fi services

Figure 59 shows the new, revised conceptual model to understand user perceptions of Wi-Fi quality. The model suggest that the revised outcome quality, physical environment and interaction quality sub-constructs affect users' perceptions of Wi-Fi service quality.

4.8.1 Regression analysis

Using a multiple linear regression analysis, the construct measures were used to assess the effects of the sub-constructs on perceived service quality.

The first test was to see if the sub-constructs of outcome quality influenced perceived service quality. The dependent variable in this test was service quality and the independent variables were the sub-constructs of outcome quality. The sub-constructs for outcome quality account for 51.8% (R^2 = .518) of the variance of service quality, F (3, 369) = 132.173, p<.0005. Wi-Fi efficiency (β=.514, p<.0005) and Wi-Fi availability (β=.194, p=.000) are both significant predictors of service quality, whereas Wi-Fi stability (β=.074, p=.082) was not.

Similarly, for physical environment quality, a regression test was undertaken to investigate if the sub-constructs of physical environment quality influenced perceived service quality. The sub-constructs for physical environment quality account for 22.7% (R^2 = .227) of the variance of service quality, F (3, 369) = 36.030, p<.0005. Ambient conditions (β=.237, p<.0005) and physical environment design (β=.209, p=<.0005) are both significant predictors of service, However, social factors (β=.080, p=<.086) are not a significant predictor of service quality.

The third regression test was to determine if the sub-constructs of interaction quality influenced perceived service quality. The sub-constructs for interaction quality account for 29.1% (R^2 = .291) of the variance of service quality, F (3.369) = 50.564, p<.0005. Behaviour (β=.333, p<.0005), and expertise (β=.527, p=<.0005) are both significant predictors of service quality. However, attitude is not a significant predictor of service quality.

A regression analysis of the effect of the constructs as a whole on perceived Wi-Fi service quality was then conducted. The dependent variable was service quality and the independent variables were outcome quality, physical environment quality and interaction quality. In this model, the constructs account for 59.5% (R^2 = .595) of the variance of service quality, F (3, 369) = 180.527, p<.0005. Outcome quality (OQ) (β=.667, p<.0005), and interaction quality (IQ) (β=.402, p=<.0005) are both significant predictors of service quality. However, physical environment quality (PEQ) (β=.0.03, p=<.0.537) is not a significant predictor of service quality.

It was not surprising that outcome quality contributed the most to students' perceptions of Wi-Fi quality. This is because the outcome quality sub-constructs involve the actual use of Wi-Fi resources, whereas the other two constructs could be considered to play a supporting role.

In order to discover if the linear regression could be improved, the regression model was tested on the most-used locations, the locations which have poor Wi-Fi quality and the locations with the best Wi-Fi quality. The next sub-section shows the linear regression analysis of each of the most-used Wi-Fi locations.

4.8.1.1 Linear regression analysis of the constructs of each the most-used Wi-Fi locations

A linear regression analysis was performed on the most-used locations: the library, the lecture venues and the computer LANs, to see if the linear regression could be improved. Table 7 summarises the results for these locations. All relationships that were significant at the 1% level are denoted by **. All significant co-efficients are shown in bold type.

In the additive model for the library, the constructs account for 61.5% (R^2 = .615) of the variance of service quality (F (3, 86) = 45.816, p<.0005). Outcome quality, physical environment quality and interaction quality are all significant predictors of service quality in the library.

Regarding the lecture venues, in the additive model, the constructs account for 62.8% (R^2 = .628) of the variance of service quality in the lecture venues F (3, 60) = 33.746, p<.0005. Outcome quality and interaction quality are both significant predictors of service quality. However, physical environment quality (PEQ) is not a significant predictor of service quality (see Table 7).

In the additive model for the computer LANs, the constructs account for 37.0% (R^2 = .370) of the variance of service quality F (3, 61) = 11.938, p<.0005. Outcome quality and physical environment quality are both significant predictors of service quality in the computer LANs. However, interaction quality (IQ) is not a significant predictor of service quality (see Table 7).

Table 7: Linear regression analysis of the most-used Wi-Fi locations.

OQ, PEQ, IQ → SQ								**Constant**	**R^2**	**Significance**
General model	SQ =	**0.667**	x OQ	+ 0.30	x PEQ	**+ 0.402**	x IQ	- 0.327	59.5%	**
OQ, PEQ, IQ → SQ								**Constant**	**R^2**	**Significance**
Library	SQ =	**0.579**	x OQ	+ **0.291**	x PEQ	**+ 0.332**	x IQ	**- 0.981**	61.5%	**
Computer LANs	SQ =	**0.625**	x OQ	**- 0.214**	x PEQ	+ 0.121	x IQ	**+ 2.409**	37.0%	**
Lecture venues	SQ =	**0.454**	x OQ	+ 0.219	x PEQ	**+ 0.461**	x IQ	- 0.373	62.8%	**

The model explains user perceptions of Wi-Fi service quality well in lecture venues and in the library. However, the model is not effective in explaining user perceptions of Wi-Fi quality in computer LANs.

4.8.1.2 Linear regression analysis on the locations in which students experience poor Wi-Fi signals on campus.

The study analysed the significant locations in which student experience poor Wi-Fi signals on campus to see if the regression relationship could be improved. The locations included the library, the cafeteria, and the quad (see Figure 16). Table 8 summarises the results for these locations. All relationships that were significant at the 1% level are denoted by **. All significant co-efficients are shown in bold type.

In the additive model for the library, the constructs account for 63.4% (R^2 = .634) of the variance of service quality F (3, 67) = 38.750, p<.0005. Outcome quality and interaction quality are both significant predictors of service quality in the library. However, physical environment quality (PEQ) is not a significant predictor of service quality (see Table 8).

In the additive model for the cafeteria, the constructs account for 62.5% (R^2 = .625) of the variance of service quality F (3, 121) = 67.198, p<.0005. Outcome quality and interaction quality are both significant predictors of service quality in the cafeteria. However, physical environment quality (PEQ) is not a significant predictor of service quality (see Table 8).

Table 8: Linear regression analysis of the constructs as a whole in locations in which students experience poor Wi-Fi signal quality on campus.

OQ, PEQ, IQ → SQ								**Constant**	**R^2**	**Significance**
General model	SQ =	**0.667**	x OQ	+ 0.30	x PEQ	**+ 0.402**	x IQ	- 0.327	59.5%	**
OQ, PEQ, IQ → SQ								**Constant**	**R^2**	**Significance**
Library	SQ =	**0.576**	x OQ	+0.154	x PEQ	**+ 0.482**	x IQ	-0.821	63.4%	**
Cafeteria	SQ =	**0.713**	x OQ	+0.015	x PEQ	**+ 0.385**	x IQ	-0.491	62.5%	**
Quad	SQ =	**0.954**	x OQ	-0.202	x PEQ	**+ 0.374**	x IQ	-0.312	55.3%	**

In the additive model for the Quad, the constructs account for 55.3% (R^2 = .553) of the variance of service quality F (3, 49) = 20.175, p<.0005. Outcome quality and interaction quality are both significant predictors of service quality in the Quad. Once again, physical environment quality (PEQ) is not a significant predictor of service quality (see Table 8).

In summary, the results showed that outcome quality and interaction quality were significant predictors of Wi-Fi quality in the library, the cafeteria and the Quad. These results are similar to the ones for the most-used Wi-Fi locations (see Table 7).

It is important to note that for the library and cafeteria, the model predicts service quality better than the general additive model.

4.8.1.3 Linear regression analysis on the locations where students experience the best Wi-Fi signals on campus

Locations which were significantly identified as having the best Wi-Fi quality on campus were then investigated to see if the regression relationship could be improved. These included the lecture venues, on-campus residences and the computer LANs (see Figure 20). Table 9 summarises the results for these locations. All relationships which were significant at the 1% level were denoted by **. All significant co-efficients are shown in bold type.

In the additive model for the lecture venues, the constructs account for 69.7% (R^2 = .697) of the variance of service quality in the lecture venues F (3, 72) = 55.242, p<.0005. Outcome quality and interaction quality are both significant predictors of service quality in the lecture venues. However, physical environment quality (PEQ) is not a significant predictor of service quality (see Table 9).

In the additive model for the on-campus residences, the constructs account for 68.1% (R^2 = .681) of the variance of service quality F (3, 37) = 26.307, p<.0005. Outcome quality was a significant predictor of service quality in the on-campus residences. However, both physical environment quality (PEQ) and interaction quality (IQ) are not significant predictors of service quality (see Table 9).

In the additive model for the computer LANs, the constructs account for 53.7% (R^2 = .537) of the variance of service quality in the computer LANs F (3, 115) = 44.484, p<.0005. Outcome

quality and interaction quality are both significant predictors of service quality in the computer LANs. However, physical environment quality (PEQ) is not a significant predictor of service quality (see Table 9).

Table 9: Linear regression analysis of the locations where students experience the best Wi-Fi signals on campus.

OQ, PEQ, IQ → SQ								**Constant**	**R^2**	**Significance**
General model	SQ =	**0.667**	x OQ	+ 0.30	x PEQ	**+ 0.402**	x IQ	- 0.327	59.5%	**
OQ, PEQ, IQ → SQ								**Constant**	**R^2**	**Significance**
Computer LANs	SQ =	**0.763**	x OQ	-0.035	x PEQ	**+ 0.250**	x IQ	+ 0.262	53.7%	**
Lecture venues	SQ =	**0.786**	x OQ	+0.37	x PEQ	**+ 0.424**	x IQ	**- 1.006**	69.7%	**
On-campus residence	SQ =	**0.741**	x OQ	+ 0.104	x PEQ	+ 0.235	x IQ	- 0.235	68.1%	**

The results showed that outcome quality was a significant predictor of perception of Wi-Fi quality in all three identified locations. In the lecture venues and on-campus residences, the model predicts service quality better than the general additive model.

4.8.1.4 Conclusion

In conclusion, the additive model is better at predicting users' perception of the quality of Wi-Fi services. The model for the library, as the most-used location, was the only model where all the variables were significant. This conceptual framework could be used by ICS when investigating particular locations. For instance, it is recommended that it can be used in the library since this location is both a most-used location and has the poorest Wi-Fi quality. It is surprising that PEQ is often not significant in these models, yet students reported some factors like a lack of Wi-Fi plug points as a difficulty (see Figure 39).

4.9 Objective 6: Factors which affect Wi-Fi outcome quality on Westville campus

To ascertain which factors affect Wi-Fi outcome quality on Westville campus, results from other sections were reviewed and are summarised below.

The results showed that some locations did not have access points. For example, Participant 1 argued that there few access points in on-campus residences (see section 4.6.2). This limits the coverage of Wi-Fi signals. Those areas where the signals do not reach will have poor delivery of Wi-Fi services.

The use and configuration of access points may affect Wi-Fi outcome quality. For instance, students reported that they connect more than one device at a time to one access point. This increases the congestion on the access points and could be a reason why there is poor Wi-Fi quality on the library (see discussion in Section 4.6.2). In addition, the study identified that student devices access different spectrums which are configured on the access point (see Section 4.5.1.2). Some locations are configured with both 5GHz and 2.4GHz, while others have only 2.4GHz configured. This may lead those students using 2.4GHz having poor Wi-Fi outcome quality, as the 2.4GHz spectrum is more congested.

Furthermore, by not adopting bi-directional antennas at access points (see Section 4.5.1), users will not be able to get strong signals in one particular direction, especially at corners. Poor Wi-Fi quality could be caused by access point disconnections due to access point powers being switched off; for example, in the on-campus residences. This affects Wi-Fi availability (see discussion in section 4.6.2).

The proximity of the user device to access points was indicated as a factor which may affect the perceived Wi-Fi service quality in different locations on campus (see discussion in Section 4.6.2).

Students reported that they had to change positions in order to solve Wi-Fi connection difficulties. Hence, the availability of Wi-Fi signal at different points in a location (see discussion in Section 4.7.1, OQ 6) has been identified as a factor which may affect Wi-Fi outcome quality.

Lack of knowledge about the Wi-Fi standard supported by student devices may affect the Wi-Fi outcome quality (see the discussion in Section 4.4.4). Students may purchase devices which support standards with slow data delivery (see the discussion in Section 2.3.4.1).

The lack of power plugs for students' devices may affect Wi-Fi outcome quality. For instance, in the library and lecture venues, the lack of power plugs was identified as a difficulty that students face while using Wi-Fi (see discussion Section 4.6.2). It is important to note that without the facility to power-up their devices, students will access Wi-Fi services for only the duration of their battery power, so will be cut off from access to Wi-Fi services when the battery it depleted.

4.10 Conclusion

This chapter has presented how Westville campus students use the on-campus Wi-Fi, and their opinions of the Wi-Fi quality. It has shown how and when students use Wi-Fi on campus and shows how students with different residential arrangements use the on-campus Wi-Fi in different patterns. This would be very useful in the installation and monitoring of Wi-Fi infrastructure in the university. The study has identified the most-used locations, as well as those with the poorest and best Wi-Fi quality. Of particular concern is the library, which was a most-used location for many students; yet it had poor Wi-Fi quality.

The study also identified difficulties students face when using Wi-Fi, and what they do about these difficulties. In spite of the many ICS initiatives for students to log calls to report difficulties, very few students had ever logged a call. It is pleasing to see that the training given to on-campus residence students by ICS has paid off, in that these students log the most calls.

The model developed for the study predicted the service quality with 59.5% accuracy. It may be used to measure and improve the quality of services in specific locations which were indicated by students. The next chapter discusses these results.

5 DISCUSSION OF RESULTS

Chapter Four presented the results using both descriptive and inferential statistics and data from the interviews with the ICS administrators. The primary objective of this chapter is to present a detailed discussion of these results. Empirical evidence from the literature helped to provide further insights and explanations into the research findings obtained from the study. A concluding summary to highlight the study findings is provided at the end of this chapter

Students provided demographic information about their gender, level of degree, race, the college in which they are registered, place of residence and the year of registration for their degree. A total of 373 students participated in the study. This gave a 100% response rate, which means that the results represent UKZN students' opinions on Westville campus.

While Local Area Networks (LANs) are the most widely adopted networks, the student preference for using Wi-Fi over any other method to access Internet resources on the university network was pronounced. Also, students may have been more inclined to use the free Wi-Fi instead of data, since they would not incur the cost of purchasing airtime for data bundles.

5.1 Objective 1: How students use Wi-Fi on campus

5.1.1 Locations UKZN Westville students prefer to access Wi-Fi services on campus

This study showed the locations at which students prefer to access Wi-Fi services on campus. In addition, it reported on students' perceptions of the quality of the Wi-Fi service and their experiences when using it in these locations (see Section 4.4.1).

In general, students used Wi-Fi in many locations on campus (see Figure 14). This study found that a significant number of students used Wi-Fi in the lecture venues (86%), the library (83%), the computer LANs (70) and the cafeteria (61%). These results have a number of similarities with Gururaj et al. (2016) and Han (2008), whose findings show that there is high preference for accessing Wi-Fi in the library. However, in the computer LANs, it was not clear whether Westville students understood that the desktop computers were accessing the Internet via Ethernet cables, and not Wi-Fi.

The analyses from this study provided insight into usage patterns that were different, depending on where the students resided during term.

A closer look at Wi-Fi use in the different locations showed that many students who stayed in off-campus residences, at home and in private accommodation preferred to use the library to access Wi-Fi resources. This could have been because all registered students have 24/7 access to the library, while some locations, such as lecture venues, have closing times. In addition, the LANs and on-campus residences have access control and are limited to students who are authorised to enter those locations.

This study has identified where students use Wi-Fi the most, where they find poor and the best Wi-Fi signal quality, and the times they use the Wi-Fi, depending on where the students live. This is a useful contribution to understanding the students' usage. The results can help students know where to go to avoid poor signals or get a better signal. It could also help ICS to improve the signal at different times of the day. ICS departments in other universities could carry out this kind of analysis to understand their usage patterns over time.

The results showed that on-campus residences were the most-used Wi-Fi location on campus (see Figure 15). This finding is similar to the finding by Singson (2011), who found that 66% of the students preferred to access Wi-Fi in their hostels. An interesting finding was that not only on-campus residence students selected the on-campus residences as their most used Wi-Fi location: 2% of the students from off-campus residences and 2% living at home chose on-campus residences as their most-used on-campus Wi-Fi locations (see Figure 16).

The analysis by type of accommodation is useful for others doing similar studies. It helps ICS to plan for Wi-Fi needs, based on the numbers of students in each of the different residence categories.

Interviews were carried out to ascertain the Wi-Fi infrastructure at different locations. It was reported by ICS's Participant 2 (responsible for student support) that the poor Wi-Fi in the library may have been due to multiple device connections from a single student. In addition, the library is accessed by students from all residence categories, who may or may not connect more than one device to Wi-Fi. Possible obstructions, like books in the library and other sources

of interference (e.g. security cameras), could also cause poor Wi-Fi-quality (Held, 2003; Kotz & Essien, 2005; Soyinka, 2010). Finally, since they were only two access points per floor in the library, students would experience poor Wi-Fi signal quality if they access Wi-Fi far from an access point.

Poor Wi-Fi quality at the Quad can be explained by the lack of access points configured for outside use. When students use their Wi-Fi devices in the Quad they access signals which are broadcast from access points in the nearby buildings. This ability for access points to transmit signals outside the building for student use is in agreement with Kotz and Essien (2005), who found that the interior Internet access points installed on campus covered inside the buildings and most of the outside environment around the university. Because the Wi-Fi signals from these access points have to travel through walls and other obstructions to reach outside the buildings, their strength weakens.

The majority of the students who indicated a location as their most-used Wi-Fi location also indicated it as a location with the best Wi-Fi quality. This showed that students tend to go more to locations where the Wi-Fi quality is better. However, an important finding is that while students generally did not access Wi-Fi most in areas where they experienced poor Wi-Fi signal quality, this was not the case for Wi-Fi use in the library. The library ranked second as the location in which students experience poor Wi-Fi signal quality. However, students still preferred to use Wi-Fi services in this location and selected it as the second-most-used Wi-Fi location on campus (see Figure 15).

Students indicated locations which had the best Wi-Fi quality (see Figure 20). These locations included the computer LANs, lecture venues, and on-campus residences.

ICS could investigate the factors which may contribute to this and apply the results to other locations which were perceived to have poor Wi-Fi services.

5.1.2 Amount of time UKZN Westville students spend accessing Wi-Fi on campus

This study sought to understand how many hours students use Wi-Fi on campus per day. Most students used Wi-Fi for 3 to <5 (17.2%) hours, for 5 to <7 (14.2%) hours and 20+ hours per day (13.4%) (see Figure 23). This finding is similar to that from Han (2008) study in New

Zealand, which identified that the most participants used WLANs for half a day (4-5 hours) and all day. However, it contradicts the finding by Gururaj et al. (2016) in India, that 35.8% of students used Wi-Fi for 1-2 hours and only 2.5% of the users used the Wi-Fi service for 3-4 hours per day, with only 6.7% of those respondents saying that they used it for 4-5 hours.

This study investigated whether students used Wi-Fi resources differently, based on their residence type during the academic term. Results showed that students who stayed in on-campus residences used Wi-Fi for longer periods each day, than students who stayed in other sorts of accommodation during the academic term.

The times when students used Wi-Fi on weekdays and weekends were different, depending on where they lived during the academic term. Regarding Wi-Fi usage during week days, Han (2008) identified that Wi-Fi use was highest between 9:00 and 10:00, followed by noon. The findings in this study, however, contradict that finding: the majority of Westville students used Wi-Fi between 12pm and 2pm (21.8%); and after 8pm (21.3%) (see Figure 25).

This study has analysed the times when students use Wi-Fi, according to their residence; and these different groups of students have very different usage patterns. Regarding Wi-Fi usage during weekends, most students who did not stay in on-campus residences never used Wi-Fi on campus over the weekends. However, it is interesting to note that some students living at home and in private accommodation used Wi-Fi on campus until after 8pm. Students who resided on campus preferred to use Wi-Fi after 8pm (34.8%) (see Figure 28).

It can be concluded that on-campus residence students have better access to Wi-Fi on campus and hence they use it the most and for longer. Thus, the ease with which students access on-campus Wi-Fi locations positively influences the duration of Wi-Fi usage. Other studies have not analysed Wi-Fi use by university students according to their place of residence. To encourage the use of Wi-Fi services, the university could do things that would make it easy for students to come to the university, especially on weekends when students have more free time. This would include strategies like providing additional busses and having longer access to Wi-Fi locations, like lecture venues, by extending the opening times.

5.1.3 Internet resources UKZN Westville students access when using Wi-Fi on campus

Students used Wi-Fi to access various Internet resources; however, the frequency varied across different resources. The top four most frequently accessed resources included university-owned educative resources, UKZN mail and the learning management system, Moodle/Learn. Students use UKZN mail to communicate via email with lecturers, the school administration and other mail users. These results show that the 'bring your own device policy' which has been implemented is being supported by the installed infrastructure (Vithal, 2015).

WhatsApp, an instant messaging application, was the most frequently used Wi-Fi resource among the students. The resources which involved video streaming and graphics (online movies, YouTube and Instagram) loaded slowly over Wi-Fi. This is to be expected as these resources use a lot of bandwidth. A concerning finding in the study was that UKZN mail was the third slowest-loading resource over Wi-Fi. ICS should investigate whether this is a result of the Wi-Fi devices used or the infrastructure used to handle the emailing service.

5.1.4 Devices used by UKZN Westville students to access Wi-Fi on campus

The respondents indicated that the devices they used to access Wi-Fi on campus were laptops, smartphones and tablets. Very few students (3%) used PCs with wireless cards (see Figure 30). Students use smartphones to access Wi-Fi services on campus more than any other device (87.7%). The high rate of smartphone use is in agreement with studies that were carried out by (Gururaj et al., 2016) and (Chu & Lin, 2006). The reason for this use of smartphones instead of laptops may be because the smartphones are less expensive than any other Wi-Fi devices. The results, however, contradict the study by Singson (2011) that showed that the majority of the students preferred to use laptops to access Wi-Fi. The study by Chu and Lin (2006) indicated that, while most students intended to purchase laptops, they were prevented by the high cost. Hence, nearly 95% of the students owned cellular devices.

Significant results showed that students used a tablet in lecture venues; a laptop in on-campus residences; and a smartphone in the cafeteria or outside venues. The reason for this may have been that different devices have various advantages when used on Wi-Fi in different locations. For example, Shi et al. (2016) comment that users are more likely to carry smartphones most of the time because they are more portable than other stationary or less-portable devices. It is

possible that the participants used smartphones and tablets because they offered more flexibility of use.

The study found evidence that nearly half the students use more than one device at the same time on Wi-Fi (see Figure 31), but no one used more than three devices at once. While this allows for flexibility, the use of multiple devices can cause congestion as there is increased competition on the access point. ICS can implement more access points in the most-used Wi-Fi locations, especially in the library

The study further investigated the characteristics of Wi-Fi devices that students use over Wi-Fi. Students knew most about the operating system, followed by the make of their device. The over-whelming use of the Windows and Android operating systems reflects the use of these operating systems globally (Netmarketshare, 2017).

The study also investigated the Wi-Fi standard adopted on Wi-Fi devices used by students on campus. What was evident in this study is that while the service provider (i.e. ICS) know the Wi-Fi standards supported by their infrastructure, the students do not know which standards are supported by their devices. A significant number of students did not know the Wi-Fi standard supported by their laptops and PCs (89.5%), or by their smartphones and tablets (89.8%) (see Figure 34 and 36). In addition, the students demonstrated limited knowledge of their Wi-Fi devices speed and memory. A significant number of students did not know the amount of memory supported by their laptops and by their smartphones (see Figure 34 and 36). Not using a device with a compatible Wi-Fi standard could negatively impact the perceived Wi-Fi quality. This shows that there is potential to buy the wrong devices which may not fully utilise the Wi-Fi services on campus. These results show that there is a need for ICS to have minimum device specifications for the effective use of Wi-Fi services on campus. For instance, purchasing devices which can access the 5 GHz spectrum could go a long way to solving the congestion problems occurring in different on-campus locations. Students should check the Wi-Fi specifications of their devices before purchasing them, to ensure that they will deliver the best Wi-Fi service experience.

5.2 Objective 2: Access point configurations and specifications provided on Westville campus

This study indicated that, overall, the access points on the Wi-Fi network were configured to support devices whose Wi-Fi cards support access to the IEEE 802.11a, IEEE 802.11b, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n and the IEEE 802.11ac Wi-Fi standards.

One major finding was that the 2.4GHz and 5GHz spectrums were the default configured spectrums on each of the access point. However, as reported by the administrator (Participant 1), most student devices supported the 2.4GHz spectrum. To accommodate these devices, the administrator configured some access points to support the 2.4GHz spectrum, thus eliminating the 5GHz spectrum. The literature reviewed in Section 2.3.3 indicates that users may achieve varying Wi-Fi service quality, dictated by the spectrum their devices access. For instance, if a user device accesses the 2.4GHz spectrum over the 5GHz spectrum, the user will send information over a more congested channel (Abdelrahman et al., 2015; Soyinka, 2010). Given that different standards support access to different spectrums, those devices with standards that only allow access to the 5GHz spectrum will not be able to access Wi-Fi service in those 2.4GHz locations. Moreover, from the interview with Participant 2, it was clear that while some student devices connected to Wi-Fi at the call centre, they failed to connect when students went back to another location. It is not clear whether this was attributed to changed Wi-Fi spectrum configurations. This would require further investigation by the ICS.

To provide security on the Wi-Fi network, access points were configured to authenticate the students before they accessed Wi-Fi services. Students had to login their authentication details like student numbers and passwords to ensure access.

ICS administrators did not use bi-directional antennas on the access points on the UKZN Westville campus; however, they employed omni-directional antennas to provide better coverage in a 360-degree radius. This configuration is less suitable for locations in straight passages like in on-campus residences (see image of residence in Figure 2), since signals are weaker and do not travel through the corridor as far as directional antennas would have (see Section 6.2.1.1).

5.3 Objective 3: Difficulties UKZN Westville students face when using Wi-Fi services on campus

The study showed that the two most reported difficulties were devices taking long to connect (52%) and no power plugs for devices (24.9%) (see Figure 39). It is important to note that the majority of the students who indicated that they did not have power plugs for devices in the library were students who stayed off campus (see Figure 42). Few on-campus residence students reported this problem because they used Wi-Fi mostly in their residences (see Figure 16) and they had power points for their devices. It can be argued that this may have been one of the reasons why more of the on-campus students used laptops in residences than any other location, since they were sure to find recharging points.

Most of the students indicated that their devices took long to connect in the library and in on-campus residences (see Figure 40). A major reason could have been because of congestion at the access points, which may have been caused by connecting multiple devices in these locations. In the library, an additional reason could be the fact that there are only two access points per floor, and also the high volumes of students who use Wi-Fi services at that location (see Figure 14 and 15). Similar problems were reported in the the Gururaj et al. (2016) study, where 48.3% of students faced problems with their Internet access speed; 28.3% faced frequent Wi-Fi disconnections; and 35.8% had limited Wi-Fi connectivity. The studies by Han (2008) and Chu and Lin (2006) also found that students experienced slow processing of Wi-Fi resources and slow Wi-Fi connectivity.

Students also faced difficulties logging into the Wi-Fi with credentials. This may have been because of slow Wi-Fi connection from congestion. In addition, it was reported that students especially face this problem when they forget their passwords and hence are not granted access to Wi-Fi resources. This finding is in agreement with Han (2008).

While many difficulties were reported by some students, others reported that they did not face any difficulties in their most-used Wi-Fi locations (see Figure 39). For instance, the majority of students who did not face difficulties were those who lived in on-campus residences. This may have been because there was less congestion on access points, or the ICS training has helped them resolve their issues.

This study filled a gap by finding out what students do when they face difficulties. The majority of students disconnected from the Wi-Fi when they had problems using Wi-Fi. However, students who stayed in residence devised ways of solving connection difficulties, more than students in other types of accommodation (see Figure 44). These included moving position, or reporting the problem to ICS and residence administrators. This may have been due to training given by ICS on the use of Wi-Fi. Also, it could be attributed to the fact that students who reside on campus used Wi-Fi more, and as a result, they may have been more adept at using the Wi-Fi on campus than any other students.

5.3.1 Difficulties UKZN Westville students report to ICS about the use of Wi-Fi services on campus

The results showed that students reported mainly connection-oriented difficulties to ICS employees (see Section 4.6.2). The majority of these difficulties were technical, and they were related to students' Wi-Fi devices.

It was surprising that, while students faced other problems like few seating places in locations and no power plugs for devices (see Figure 39), they did not report these difficulties to ICS administrators (see Section 4.6.2). While the study did not inquire of the students why they may not have reported difficulties to ICS, the results show that students learnt how to use Wi-Fi by asking others, rather than asking ICS (see Figure 11). In addition, while ICS installed infrastructure to facilitate logging calls about difficulties, the majority of the students (86.8%) did not know how to log a call to ICS to report Wi-Fi difficulties. The results indicate that most of the students who knew how to log calls to ICS were from on-campus residences. This may explain why they were the group who most reported Wi-Fi problems to ICS. In addition, this may be the reason why they were the group who reported most that they did not face any problems in their residences, showing that the ICS training at on-campus residences has been successful. It also shows that ICS has responded to the 2015 Westville SRC complaint of poor Wi-Fi quality in residences. In fact, 56% of students say they do not experience Wi-Fi difficulties in on-campus residences (see Figure 42). It would be beneficial for this training to be made available to other students living off the campus.

5.4 Objective 4: To report on UKZN Westville students' perceptions of the quality of service on campus.

Understanding how satisfied users are with services is very important in the delivery of quality services and in improving services. While studies have investigated perceptions of Wi-Fi among students, there is still a gap in understanding the overall perception of quality of service in terms of the different factors that may affect Wi-Fi service quality. This study sought to understand the overall perception of service quality based on three constructs. These constructs were accessing the outcome quality of Wi-Fi services, the physical design of Wi-Fi locations and the behaviour of administrators when interacting with students about Wi-Fi issues.

5.4.1 UKZN Westville students' perceptions of the outcome quality when using the Wi-Fi on campus at their most-used location

No studies were found which examined students' perceptions of Wi-Fi service quality based on the constructs of outcome quality, physical environment quality and quality of interactions. Questions to understand these constructs were designed as sub-constructs by the researcher, based on a review of the literature, and were tested to see if they explained service quality (see Section 4.7.1).

The study showed that there was a significant agreement on the outcome quality sub-constructs, which included availability, reliability, timeliness and stability. These results suggest that the variables identified in each outcome quality sub-construct may be used to improve students' perception of outcome quality.

5.4.2 UKZN Westville students' perceptions of the physical environment quality when using the Wi-Fi on campus at their most-used location.

There was a significant agreement on the physical environment quality sub-construct related to the ambient conditions in a Wi-Fi location. This result suggests that the variables identified under ambient conditions do influence students' perception of the quality of the physical environment at Wi-Fi locations. As a result, changes in these factors may lead to a good or bad perception of the quality of Wi-Fi locations.

It should be noted that there was no significant agreement on either the social factors or design quality sub-constructs. As such, changes to the variables identified under each of these sub-constructs will not influence the perception of the quality of the physical environment in which Wi-Fi services are delivered.

5.4.3 UKZN Westville students' perceptions of the interaction quality when using the Wi-Fi service on campus at their most-used location.

Finally, there was no significant agreement on the interaction quality sub-construct related to the behaviour of the ICS employees. As such, the variables under the behaviour sub-construct do not influence student perceptions of ICS interaction quality. However, there was a significant agreement on the interaction quality sub-constructs related to the attitude and expertise of the ICS employees. These results suggest that the attitude and expertise of the ICS employees does influence students' perception of interaction quality. Specifically, these results suggest that when ICS employees demonstrate a good attitude and expertise, students' perception of interaction quality increases. It should be noted, however, that 66.5% of students have never reported a problem to ICS (see Figure 45), so this rating may not be based on their own interaction with ICS staff.

5.4.4 UKZN Westville students' perceptions of the service quality when using the Wi-Fi service on campus at their most-used location.

The results indicated that, overall, most of the students agreed that they were satisfied with the Wi-Fi service delivered at locations on campus; and it was comparable to good Wi-Fi service they could get elsewhere. They were also satisfied with the general quality, the strength of the Wi-Fi signal delivered and the assistance they get from ICS when they have Wi-Fi difficulties. However, the results also indicated that there was still room for improving students' perceptions of quality (see Figure 55). All constructs were rated at slightly positive; ratings were between 4.25 and 4.53 where 4 was neutral on a seven-point Likert scale.

5.4.5 How user system device quality and access point configuration specifications affect outcome quality

The research investigated whether user system device quality and access point specifications influence outcome quality. The relationship was not possible to determine, since the students did not know the specifications of their Wi-Fi devices in adequate detail (see Figure 34 and Figure 36). This is an item for future work.

Regarding whether access point configurations may affect outcome quality, it can be argued that there is a possibility that the configuration of different spectrums could have affected the perceived Wi-Fi quality. The results show that there was a possibility of a mismatch between the spectrums accessed by students' devices, as reported by the ICS administrator (see Section 4.5.1). This is because students' devices support different Wi-Fi standards and students are not aware about Wi-Fi standards and their advantages. It is important to note that different Wi-Fi standards provide varying benefits and limitations that arise from the use of different spectrums, modulation techniques and antenna technology (Abdelrahman et al., 2015; Macha & Damodaram, 2016; Soyinka, 2010). As such, some standards provide better resistance to signal interference, longer signal range, and better signal penetration through obstacles than others. Moreover, when users use Wi-Fi devices with standards that are not compatible with the Wi-Fi standard adopted on the Wi-Fi network, they will not be able to access Wi-Fi services (Abdelrahman et al., 2015; Soyinka, 2010).

Also, another configuration that may affect the outcome quality may have been due to the installation of only omni-directional antennas which could have left blind spots in the Wi-Fi environment, like in corners of buildings. 7signal (2016) suggests that this could be because they deliver signals in 360 degrees and hence their signal strength is not as strong as the bi-directional antennas which focus it in one direction. As reported by the ICS administrator in Section 4.5.1.3, blind spots occur as a result of signals being weakened as they pass through thick walls or obstructions. This leaves weak signals on the other side of the obstructions away from the access point. As evident in the study, students reported that, indeed, some spots in the on-campus residences and library did not have Wi-Fi connection. It is important that ICS test connectivity in Wi-Fi locations and identify if some locations have many blind spots that would limit the use of Wi-Fi services. It is also important for the students' devices to be within the range of the access point.

5.5 Objective 5: To report how outcome quality, physical environment quality and interaction quality affect students' perceived service quality

To understand how outcome quality, physical environment quality and interaction quality affect students' perceived service quality, the researcher carried out principal axis factoring in SPSS of all 35 items that were chosen to understand the perception of Wi-Fi service quality. The new conceptual model (see Figure 59) included the outcome quality sub-constructs of availability, efficiency and stability. Physical environment sub-constructs included ambient conditions, social factors and design. The interaction quality sub-constructs included the behaviour, attitude and the expertise of ICS employees.

5.5.1 How outcome quality affects perceived Wi-Fi service quality

Results showed that the sub-constructs for outcome quality account for 51.8% of the variance of service quality. Of all of the independent variables, this relationship was the strongest.

The results indicate that all the sub-constructs of outcome quality are significant predictors of Wi-Fi service quality. Hence, when the university provides access to locations with Wi-Fi signals, students will perceive good outcome quality which will, in turn, improve the quality perceived. This finding confirms that various technical and functionality quality factors influence Wi-Fi outcome quality (Brady & Cronin Jr, 2001). In addition, the results confirm the argument by Grönroos (1984), who says that customers may base their evaluation on the service they receive as an outcome of the production process and the production process itself. This study shows that when the university provides access to all Internet resources, and students get the same good quality in the output of resources (YouTube, Gmail, Student Central), they will perceive good outcome quality which will, in turn, improve the quality perceived. Furthermore, when the university provides the same good signal quality in different positions in locations and students have fast connections to Wi-Fi in various locations, they will perceive good outcome quality which will, in turn, improve the quality perceived. In addition, if students login into the Wi-Fi quickly, and if resources take a short time to load, they will perceive good outcome quality which will, in turn, improve the quality perceived.

It is important for the university to implement measures to ensure a steady Wi-Fi connection for students to do their work once connected to Wi-Fi at a location. The results indicated that by implementing measures for stable Wi-Fi connections, and ensuring that the resources (YouTube, Gmail, and Student Central) do not freeze when using the Wi-Fi in Wi-Fi locations,

students will perceive good outcome quality which will, in turn, improve the quality of Wi-Fi services perceived.

5.5.2 How physical environment quality affects perceived service quality

The results showed that the sub-constructs for physical environment quality account for 22.7% of the variance of service quality. This was the weakest relationship between an independent variable and the dependent variable. The results showed that ambient conditions and the design of the physical environment affect the perception of service quality.

Hence, when the university ensures that the temperature at a Wi-Fi location is even and moderate, that there is fresh air and good lighting, students will perceive the good quality at the Wi-Fi locations, which will, in turn, improve the quality perceived.

In addition, measures to improve the design of Wi-Fi locations, such as by providing enough power plugs and enough places to sit, will lead students to perceive that the Wi-Fi locations are of good quality; which will, in turn, improve the quality perceived. However, social conditions, which included student behaviour at the Wi-Fi locations, did not have any effect on perceived service quality.

Two items were excluded in the inferential analyses. These were the questionnaire questions for the ‘social conditions’ and ‘physical design’ sub-constructs of the physical environment quality construct.

5.5.3 How interaction quality affects perceived service quality

The results show that the sub-constructs for interaction quality account for 29.1% of the variance of service quality. The ICS attitude and expertise sub-constructs were significant predictors of service quality. However, the behaviour of ICS employees was not a significant predictor of service quality.

These results indicated that if students can count on UKZN Westville ICS employees being friendly when interacting with them about their Wi-Fi needs, demonstrating their willingness to help them, and demonstrating enthusiasm when helping students with Wi-Fi needs, the students will perceive good interaction quality which will, in turn, improve the quality perceived. The results suggest that measures to encourage UKZN ICS employees to

demonstrate that they know their jobs by solving Wi-Fi problems quickly, and by being professional when addressing the students' Wi-Fi needs, will encourage students to perceive good quality interaction. This will also, in turn, improve the perceived quality of Wi-Fi services.

5.5.4 How outcome quality, physical environment quality and interaction quality affect students' perceived service quality

A regression analysis of the constructs (outcome quality, physical environment quality and interaction quality) explained 59.5% of the service quality. This is a moderately positive correlation. Outcome quality and interaction quality were both significant predictors of service quality. However, physical environment quality was not. When regression models were generated for individual locations, for the most part, the R^2 values increased, except for computer LANs and the Quad. The equation for the library as most-used location was the only regression model for which all the co-efficients were significant. As such, an increase in outcome quality, physical environment quality and interaction quality leads to an increase in perceived service quality in the library.

Administrators should use the additive regression model to understand students' perceptions of Wi-Fi quality in specific individual locations. They can use the conceptual model in Figure 59 as a guide.

5.6 Objective 6: Factors which affect Wi-Fi outcome quality on Westville campus

Several factors may affect the outcome quality of Wi-Fi services on campus. Firstly, proximity to access points: the closer a student is to an access point, the better his Wi-Fi signal; and consequently the greater his chance of a good Wi-Fi connection. This is because Wi-Fi signals lose their strength as they travel away from access points.

Secondly, student devices accessing the 2.4GHz spectrum could affect Wi-Fi outcome quality. The reason is that the 2.4GHz spectrum is more congested, as many other devices share the spectrum. This also makes it more prone to interference (Abdelrahman et al., 2015; Vladyko et al., 2016; Wong, 2003).

Thirdly, if power to an access point is switched off, disconnecting the access point, it will not be able to transmit signals (Held, 2003; Panko, 2003). Moreover, dropping signals were highlighted as one of the major factors affecting the perception of outcome quality; and hence could be affecting the reliability, timeliness and availability of Wi-Fi services (see Section 4.7.1 OQ11).

Too few access points at Wi-Fi locations leads to congestion on the existing access points. From the results, it can be deduced that the fewer the students in a Wi-Fi location, the better the Wi-Fi connectivity will be; indicating that congestion on the few access points is a factor affecting Wi-Fi on campus. This factor limits students' time on the internet and their ability to roam; and increases competition on the remaining access points (Chu & Lin, 2006; Tella, 2007).

The lack of access points in some locations, such as the Quad, has contributed to perceptions of poor quality. Students will always get signals through spillage. These are normally weak, thus affecting the outcome.

Students using multiple devices at a Wi-Fi access point at the same time will amplify the congestion on the access point and may increase interference, thus leading to slow Wi-Fi connections.

Availability of a Wi-Fi signal in different positions in a location ensures the reliability and availability of Wi-Fi resources. The results showed that students have to change position to get a stronger signal.

Students' ability to access Wi-Fi at inside locations with access points was a significant factor in Wi-Fi service availability (see section 4.7.1). This is because all access points on campus were placed within buildings, so students who had access to the buildings had a better chance of good Wi-Fi signal quality than those who used Wi-Fi outside buildings.

Another factor which could influence outcome quality is interference from objects in the surrounding environment. This interference may stream from the Wi-Fi devices in a location, or from other equipment using the same Wi-Fi spectrum. For instance, interference may stream

from security cameras and microwaves, or from other blue tooth devices (Held, 2003; Soyinka, 2010). However, this finding was not identified in the study.

5.7 Conclusion

This chapter showed the relationship between the research questions, research sub-questions and the interview questions. Results showed that students prefer to use the Wi-Fi services in different locations on campus, rather than any other method, to access Internet resources. While Wi-Fi was used in many locations on campus, including outside venues, students used Wi-Fi mostly within buildings as this is where the access points were located. Preference was given to the library and lecture venues, as all students had access to these locations. The library was one of the most-used Wi-Fi locations, yet it was also a location with some of poorest quality Wi-Fi. It is recommended that ICS investigates whether the Wi-Fi quality in the library can be improved.

It is evident from the both the literature review and empirical research that the successful use of any Wi-Fi services requires an understanding of Wi-Fi device characteristics. This was identified as a major gap in the knowledge, as there was no detailed information about the specification of Wi-Fi devices. This study identified that students used various devices in different locations on campus. However, they preferred to use some of them in specific locations. In addition, it was identified that the majority (89.8%) did not know what Wi-Fi standard their smartphones and tablets used. Similarly, 89.5% did not know the Wi-Fi standard supported by their laptops and PCs with wireless cards. Students connected multiple devices on Wi-Fi, which may have contributed to congestion and poor quality Wi-Fi signals. It was not possible to test whether system device quality affects outcome quality, as too few students knew the technical specifications of their devices. This is a matter for future work.

Several difficulties were identified in specific locations that may have limited the effective use of Wi-Fi services on campus. However, in spite of the provision of infrastructure by the administration to report these difficulties, the majority of students indicated that they did not know how to report Wi-Fi problems. This may have led to an escalation of problems in specific locations, with many of students stopping using Wi-Fi services.

On-campus residence students were better at logging calls, which shows that the training ICS has given them has been successful. It is recommended that similar training is given to other students as well.

The intention of the researcher was to develop a model that is both user friendly and easy to understand, as well as practical for use by all Wi-Fi providers. The main reason for this is that there is a growing demand for Wi-Fi services in different sectors of the economy. However, there is no model to guide improvements in the quality of Wi-Fi services.

This study proposed a conceptual model that can be used to assess the perceived quality of Wi-Fi services, using the three constructs of adopted outcome quality, physical environment quality and interaction quality. Individually all the constructs were significant predictors of service quality. However, PEQ was not a significant predictor of service quality in the additive regression model. The results indicated that in the additive regression model, the constructs account for 59.5% of the variance of service quality.

For the most part, the additive multiple linear regression model was a better predictor of service quality when applied to individual locations. This was particularly the case for the library, in which all constructs were significant predictors of service quality.

An analysis of all the factors which could influence Wi-Fi outcome quality completed the chapter. The next chapter presents the recommendations to improve the quality of Wi-Fi services provided on campus.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This research determined students' use of Wi-Fi and their perception of service quality when using Wi-Fi at the University of KwaZulu-Natal. This research further identified the opportunities which the university may exploit to provide or improve on-campus Wi-Fi services to students.

The research study followed a mixed methods approach, integrating results from students' responses and interviews with ICS employees to answer the chosen research questions. An in-depth literature review was conducted to determine the use of Wi-Fi on campus, identifying student usage patterns and infrastructure which operates on the Wi-Fi network.

The questionnaires were answered by 373 students who used Wi-Fi on campus. This means that the results are representative of Westville campus students' opinions and perceptions. Two interviews were conducted as part of this study to understand the deployment strategies adopted by the university to provide Wi-Fi services; and to understand the interaction between students and the administration regarding Wi-Fi usage on campus. The first participant was responsible for the Wi-Fi infrastructure set-up and administration; and the second participant was responsible for ICS student support services.

6.2 Conclusions

This study summarises the information on Wi-Fi usage according to the students' place of residence. This analysis is very useful for network administrators as students living in different types of accommodation had very different usage patterns. It is recommended that future studies perform similar analyses to identify the usage patterns of different types of students on campus.

The study identified that most students prefer to use the free Wi-Fi on campus, rather than any other method, to access the university network resources. In addition, the study found that the most-used Wi-Fi locations were on-campus residences, followed by the library and lecture venues. The locations in which students experience poor Wi-Fi signals are the cafeteria,

followed by the library and then the Quad. Students experienced the best Wi-Fi signal quality in the computer LANs, lecture venues and the on-campus residences.

Students used Wi-Fi the most in locations in which they perceived the best Wi-Fi quality. It is recommended that improvements in the quality of Wi-Fi in locations identified to have poor Wi-Fi, like the library, be carried out by ICS to increase the use of Wi-Fi in supporting students' learning.

The study details the time students spend using Wi-Fi daily, and the times when students use Wi-Fi on weekdays and weekends. It states when the best and worst Wi-Fi signal quality occurs in various locations on campus. This is useful to students as they may then be able to go to different locations which they perceive as having better Wi-Fi quality, if they experience poor Wi-Fi service at a location. ICS administrators could use this information to prioritise access point installations on campus. It is recommended that future studies perform similar analyses to identify times of day with poor and good Wi-Fi quality.

The top four resources accessed over Wi-Fi by students were WhatsApp, Google search, the UKZN mail and the Moodle learning management system. To improve the slow loading times for YouTube videos and UKZN mail, ICS should carry out an investigation on the email platform to identify if the cause is the Wi-Fi devices or the infrastructure handling the email services. To download YouTube, students may have to consider seating closer to access points if they want to stream videos, as this could increase data transfer speeds due to stronger Wi-Fi signals.

Wi-Fi users use various devices to access Wi-Fi services. The research not only focussed on identifying or listing the makes and operating systems of students' Wi-Fi devices, but also identified key characteristics which could impact the quality of Wi-Fi services students receive. The study found that, while network providers had knowledge of Wi-Fi device specifications, students exhibited little knowledge of the Wi-Fi standards and speeds of their devices. It is recommended that the ICS provide this information to prepare new entrants, and also to train those students already enrolled.

The study investigated the difficulties students face when using Wi-Fi on campus in their most-used Wi-Fi locations. Of the students, 52% say their device takes a long time to connect,

followed by 24.9% who have no power plugs for their devices (see Figure 39). The research indicated that Wi-Fi difficulties stop 38% of the students from using Wi-Fi; while 18.6% report the problem to ICS (see Figure 46). Of the students, 66.5% have never asked ICS for help, and 86.8% did not know how to log a call to ICS. On-campus residence students log the most calls, showing that ICS training has been successful.

A model to predict service quality was adopted from constructs suggested by (Brady & Cronin Jr, 2001), and included outcome quality, physical environment quality and interaction quality. Constructs from the Information Systems success model by William H Delone and McLean (2003), and quality of service metrics adopted by the IEEE 802.11 standard (Malik et al., 2015) were included in the theoretical framework. The sub-construct items were developed from the literature and were adapted to understand the perception of quality of a Wi-Fi service from a Wi-Fi network perspective.

Factor analysis was conducted to check the validity of the questionnaire items. All items developed in the questionnaire to measure various aspects of the constructs were found to be valid, except for two items in the physical environment quality section (PEQ4 and PEQ9). It was surprising that physical environment quality generally played the smallest role in predicting the perception of Wi-Fi service quality. It would be interesting to see if this is also true in other environments.

The overall service quality rating given by students was 4.52 out of 7. This indicates that there is room for improvement.

The R^2 for the Wi-Fi service quality regression model developed was 59.5% when all the constructs were tested as a whole. Of the three independent constructs, outcome quality contributed the most to the perception of Wi-Fi quality. When the additive regression model was tested in individual locations, the equation predicted service quality better in all but in the computer LANs and the Quad. The study could not tell if the characteristics of the Wi-Fi devices affect the perceived outcome quality. This is because very few students knew their device characteristics.

6.3 Limitations of the study

The results of the study cannot be generalised to represent those students using Wi-Fi on campuses in other Universities within South Africa and in other countries.

6.4 Recommendations to improve the quality of Wi-Fi services provided on campus

This section provides recommendations made in line with the results discussed in Chapter Five.

6.4.1 Recommendations on the provision of Wi-Fi services in on-campus locations

It is recommended that the administration carries out investigations at the Wi-Fi locations (most-used locations; locations where students experience the best and poor Wi-Fi signal quality) to make service improvements. These should identify and reduce possible sources of interference and obstructions in Wi-Fi locations.

Priority should be given to the locations in which students experience poor Wi-Fi signal quality, and where studying and learning is more likely to take place. For instance, the library is reported as the second-most-used Wi-Fi location, and it is used the most by students living off-campus, so the experiences in this location affect many of the students.

It is recommended that high density access points that can handle large amounts of congestion, or more access points, be placed (especially) in the library. In addition, the university may make more studying or learning locations available for use by students to reduce the congestion on access points in the library.

6.4.2 Recommendations on the use of resources over Wi-Fi

It is recommended that the ICS administration investigates the slow loading of the UKZN mail, particularly as it is the official communication channel between students, lecturers and the university administration.

6.4.3 Recommendations on the use of Wi-Fi devices in on-campus locations

The literature has shown that various characteristics, especially the Wi-Fi standard of the device, affect how a device will function when accessing Wi-Fi resources. However, this study has shown that students lack this knowledge. There is a need to improve student awareness about the characteristics of the Wi-Fi devices they use, particularly the Wi-Fi standards

supported by the Wi-Fi devices and the advantages students may achieve from purchasing laptops and smartphones which support the same Wi-Fi standard as is used in the university.

The university has a 'bring your own devices' policy to encourage the use of laptops on campus (Vithal, 2015). However, the research has shown that most of the students use smartphones more than laptops on campus (see Figure 25). It is important to note that most laptops may provide better computation power than smartphones; so one measure that could ensure the success of the policy would be to place power outlets in Wi-Fi locations across the university, and especially in the library.

Also, students should be advised to disconnect devices which are not being used over Wi-Fi. This will reduce the congestion on the access points and may improve the quality of Wi-Fi services for users accessing the same access point.

6.4.4 Recommendations on access point configurations

It is recommended that administrators configure the access points with dual band mode, which would allow the access point to deliver Wi-Fi signals on both the 2.4GHz and the 5GHz spectrums. In addition, it is recommended that the ICS administrators analyse the different identified locations to determine factors that may be contributing to the varying perceptions of Wi-Fi quality in each of those locations. Also, it is recommended that the university configures access points which have bi-directional antennas to send and receive signals in the hard-to-reach corners of buildings where the omni-directional antennas may not broadcast their signal.

It is recommended that the use of power over Ethernet on access points be investigated. This allows the access point to receive power from the local LAN cable connected to it, instead of a physical power source from the walls.

6.4.5 Recommendations for solving the difficulties faced by students while using Wi-Fi

ICS reported an intention to provide a YouTube video to help students. It is recommended that they train all students how to log a call about difficulties. ICS may also employ trained students (student Wi-Fi support points) to help with Wi-Fi challenges in the locations in which students experience many Wi-Fi related difficulties. In addition, they may train students how to identify the characteristics of their Wi-Fi devices so that they can purchase high-performing devices, especially those devices which have standards that access the 5GHz spectrum. In addition, the

ICS administrators could educate the students about measures to resolve Wi-Fi difficulties, like moving around when receiving a poor signal or moving closer to an access point.

The education process could be completed before students come to UKZN as first years and/or before they purchase the laptops, tablets or smartphones that they are going to use for their studies. This could be accomplished through a link that is sent on the receipt of their application telling them about the different Wi-Fi standards and devices to buy. If there were a YouTube video on how to connect to Wi-Fi, lecturers could make that link available in the first semester Moodle courses (particularly). The link could also be on other websites where students go, like the library website.

Lastly, when students face difficulties or problems with the Wi-Fi, demonstrations could be provided to students at the call centre so that they are able to assist each other in future to sort out the same problem.

6.4.6 Recommendations for using the model to predict the perceived Wi-Fi service quality

The investigation revealed that the proposed model predicted students' perception of service quality better when it was tested on individual locations, rather than at all locations at once. It is recommended that the ICS administrators use the additive regression model to test students' perceptions of Wi-Fi quality in specific locations; for example, on a particular floor in the library or in a particular lecture venue.

In the questionnaire, items need to be generated to replace the ones dropped during the factor analysis (i.e. PEQ4 and PEQ9).

The model needs to be tested on many locations, in many environments, to see if the physical environment quality construct contributes significantly to predicting perceived Wi-Fi service quality, or not.

6.4.7 Recommendations for further research

This research could be expanded in a number of ways:

- This study acts as a baseline for Wi-Fi use and perceptions of quality on UKZN Westville campus. This study could be replicated in future to determine if the use of Wi-Fi has changed, whether the difficulties experienced have increased or decreased, or if the perception of Wi-Fi quality has improved. A study could be conducted in off-campus residences as well, since most off-campus residences have Wi-Fi services delivered to them by the residence owners.
- The model can be used in a specific location (e.g. library) to determine service quality.
- The researcher could help the respondents to find out which Wi-Fi standards their device(s) use. Future studies could physically examine the characteristics of user devices and observe how people use these devices in different locations to bolster service quality questionnaire research.
- In the conceptual model, different items should be identified in the questionnaire to replace the dropped items to identify whether physical design (PEQ9) and social conditions (PEQ4) in the Wi-Fi locations affect the perceived service quality.
- Further studies may incorporate observations at Wi-Fi locations to investigate the presence of other factors which may affect the perception of service (e.g. walls and sources of Wi-Fi signal interference). The study could be conducted in other universities of South Africa and in other institutions (e.g. hospitals, hotels and airports).

The use of Wi-Fi is growing at a very fast rate. Many organisations are moving from the most common local area networks to using Wi-Fi services. It can be argued that there will be a growing demand from users to improve Wi-Fi services all over the world. During this transition, investigating how users use the delivered Wi-Fi service should be given a high priority. Organisations and institutions that will be able to engage users in understanding the quality of Wi-Fi services they get, in order to improve service quality, will go a long way in improving user satisfaction.

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APPENDICES

Appendix 1: Gate keeper's letter

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

2 May 2017

Mr Vicent Mbonye (SN 213571072)
School of Management, IT and Governance
College of Law and Management Studies
Westville Campus
UKZN
Email: vicentmbonye@gmail.com

Dear Mr Mbonye

RE: PERMISSION TO CONDUCT RESEARCH

Gatekeeper's permission is hereby granted for you to conduct research at the University of KwaZulu-Natal (UKZN), towards your postgraduate degree, provided Ethical clearance has been obtained. We note the title of your research project is:

"UKZN Westville students' use of On-campus Wi-Fi and their perceptions of quality of service".

It is noted that you will be constituting your sample by handing out questionnaires, and/or conducting interviews with students on the Westville Campuses.

Please ensure that the following appears on your notice/questionnaire:

- Ethical clearance number;
- Research title and details of the research, the researcher and the supervisor;
- Consent form is attached to the notice/questionnaire and to be signed by user before he/she fills in questionnaire;
- gatekeepers approval by the Registrar.

You are not authorized to contact staff and students using 'Microsoft Outlook' address book. Data collected must be treated with due confidentiality and anonymity.

Yours sincerely

MR SS MOKOENA
REGISTRAR

Office of the Registrar
Postal Address: Private Bag X54001, Durban, South Africa
Telephone: +27 (0) 31 260 8005/2206 Facsimile: +27 (0) 31 260 7824/2204 Email: registrar@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses — Edgewood — Howard College — Medical School — Pietermaritzburg — Westville

Appendix 2: Ethical clearance letter

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

18 May 2017

Mr Vicent Mbonye (213571072)
School of Management, IT & Governance
Westville Campus

Dear Mr Mbonye,

Protocol reference number: HSS/0550/017M
Project title: UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service

Full Approval – Expedited Application

In response to your application received on 16 May 2017, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

.....
Dr Shamila Naidoo (Deputy Chair)

/ms

Cc Supervisor: Ms Sue Price
Cc Academic Leader Research: Professor Brian McArthur
Cc School Administrator: Ms Angela Pearce

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)

Appendix 3: Questionnaire (with consent to participate and consent form)

University of KwaZulu-Natal

Researcher: Mbonye Vicent / 072 276 8769 / vicentmbonye@gmail.com

Supervisor: Sue Price / 031 260 3162 / pricec@ukzn.ac.za

Project Title: UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number HSS/0550/017M).

Consent form Date: 26-05-2017

Dear colleague,

I am an MCOM (IS&IT) student in the School of Management, IT and Governance. Please would you consider participating in my research study is entitled "UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service"?

It aims to investigate how Westville students use on-campus Wi-Fi, what difficulties they face when using it, and their perceptions of the quality of service. The study is expected to include 373 Westville students and an ICS Wi-Fi Administrator.

Completing the questionnaire will take around 10 minutes.

- ✓ The information you provide will be used to enhance and improve the quality of Wi-Fi services provided on-campus by the University of KwaZulu-Natal Westville campus.
- ✓ Your name will not be written on the questionnaire or be kept in any other records. We kindly ask you to fill it out with as much accuracy as possible.
- ✓ All responses you provide for this study will remain confidential. When the results of the study are reported, you will not be identified by name or any other information that could be used to infer your identity. Only researchers will have access to view any data collected during this research, and the responses will not be used for any purposes outside of this study.
- ✓ Your participation is voluntary and you may withdraw from this research any time you wish.
- ✓ Your refusal to participate will not result in any penalty or loss of benefits to which you are otherwise entitled to.

- ✓ All data, both electronic and hard copy will be securely stored during the study and archived for 5 years. After this time, all data will be destroyed.
- ✓ The research intends to abide by all commonly acknowledged ethical codes. You will receive no incentive or payment for your participation.

If you have any questions, you are free to ask them now.

In the event of any problems or concerns/questions later you may contact the researcher at **Email address:** vicentmbonye@gmail.com, **Telephone numbers** 072 276 8769 / 061 387 6562 or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban 4000 KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

If you have any questions or concerns about participating in the study, please contact me or my research supervisor at the numbers listed above.

Sincerely
Mbonye Vicent

Thank you for your time

University of KwaZulu-Natal

Researcher: Mbonye Vicent / 072 276 8769 / vicentmbonye@gmail.com

Supervisor: Sue Price / 031 260 3162 / pricec@ukzn.ac.za

Project Title: UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service

Consent to participate

I _____ (full names) have been informed about the study entitled "UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service" by Mbonye Vicent.

I understand the purpose and procedures of the study.

I have been given an opportunity to ask questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at **Email address:** vicentmbonye@gmail.com, **Telephone numbers** 072 276 8769 / 061 387 6562.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the research then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban 4000 KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

_____ _____

Signature of Participant **Date**

Thank you for your time

SECTION I (Biodata)

Indicate your response by ticking (√) the appropriate checkbox

1. Gender.

Male	Female

2. Age.

18 years	19 years	20 years	21 years	22+ years

3. Race

Black	Indian	Coloured	White

4. Where do you stay during the academic term? **(Select ONE option only)**.

On-campus residences (specify) _____	Off-campus residences	Private accommodation	Home	Other (specify) _____

SECTION II (Education)

5. In what college are you registered?

College of Agriculture, Engineering and Science	College of Law and Management Studies	College of Humanities	College of Health Sciences

6. What level are you studying towards?

Undergraduate	Honours	Masters	Doctorate

7. What year did you first register for your current degree?

Before 2011	2011	2012	2013	2014	2015	2016	2017

SECTION III (Wi-Fi usage)

This section is seeking your use of Wi-Fi in locations on-campus.

8. Do you use the on-campus Wi-Fi provided by UKZN Westville?

Yes	No

9. Indicate your agreement with the following statements:

	Statement	**Strongly disagree**	**Disagree**	**Slightly disagree**	**Neutral**	**Slightly agree**	**Agree**	**Strongly agree**
9.1	I prefer to use my own data as opposed to using the free Wi-Fi on-campus							
9.2	I prefer to use a LAN cable (Ethernet cable used by computers in the							

	Statement	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
	LANS) as opposed to using the free Wi-Fi on-campus							

10. How did you learn how to use Wi-Fi on-campus? (**Select the ONE option that applies most to you**)

I worked it out myself	I asked a friend	I asked my lecturer	I asked ICS	Other (specify) _____

11. Which of the following wireless device(s) do you use to access Wi-Fi on-campus in general? (**Tick all that apply**)

11.1 Smartphone	11.2 Laptop	11.3 PC with wireless card	11.4 Tablet

12. Do you usually connect two or more devices to Wi-Fi at the same time when using them on campus?

Yes	No

13. <u>If you connect two or more devices to Wi-Fi on-campus at the same time</u>**, indicate with a number to show how many of these devices you use <u>at the same time.</u>**

Number of Laptops		Number of Tablets		Number of Smartphones		Number of PCs with wireless card	

14. If you use Wi-Fi on-campus, indicate the locations in which you use it. (**You can select more than one option).**

Location	
14.1 Library	
14.2 Lecture venues	
14.3 On-campus residence	
14.4 Computer LANs	
14.5 Cafeteria	
14.6 Outside venues (Quad, cafeteria and outside buildings)	
14.7Other (specify) _____	

15. With respect to the chosen locations listed in question 14 above, indicate the **ONE** location where you use Wi-Fi the most on-campus (**Select ONE option only**).

Location	
Library	
Lecture venues	
On-campus residence	
Computer LANs	
Cafeteria	
Outside venues (Quad, cafeteria and outside buildings)	
Other (specify) _____	

16. **Indicate the difficulties** you face when using Wi-Fi in the **location you selected in Question (Tick all that apply)**

Difficulties	
16.1 No power plugs for device	
16.2 My device takes long to connect	
16.3 I have difficulty logging into Wi-Fi with my credentials	
16.4 Few seating places	

16.5 I do not experience difficulties	
16.6 Other (specify) _____	

17. What device do you use the most to access Wi-Fi in the location **you selected in Question 15**? (Select **ONE** option only)

Smartphone	Laptop	PC with wireless card	Tablet

18. Indicate the characteristics **of the device chosen above** (in question 17)

18.1 If you selected a **LAPTOP or a PC in question 17 above as most used device**, indicate its characteristics below; **otherwise go to question 18.2**

18.1.1 **Make of device**

	Apple	Samsung	Acer	HP	Lenovo	I do not	Other (specify)

18.1.2 **Operating System (OS)**

Windows	Macintosh (Mac)	Linux	I do not know	Other (specify) _____

18.1.3 **Wi-Fi Standard supported by the Wireless network adapter**

802.11a	802.11b	802.11 g	802.11n	802.11ac	I do not know	Other (specify) _____

18.1.4 **Memory** in gigabyte (GB)

Less than 1GB	1-3GB RAM	4-5GB RAM	I do not know	Other (specify)

18.1.5 **Speed** (GHZ)

< 1GHZ	1-3GHZ	4-5GHz	I do not know	Other (specify)

18.2 If you selected a **Phone or a Tablet as most used** device, indicate its characteristics; **otherwise go to question 19**

18.2.1 **Make of device**

Samsung	Apple	Nokia	Huawei	LG	Sony	I do not know	Other (specify) _____

18.2.2 **Operating System (OS)**

Windows OS	Android OS	Blackberry OS	Apple IOS	I do not know	Other (specify) _____

18.2.3 **Wi-Fi Standard supported by the Wireless network adapter**

802.11a	802.11b	802.11 g	802.11n	802.11ac	I do not know	Other (specify) _____

18.2.4 **Memory (GB RAM)**

Less than 1GB	1-3GB RAM	4-5GB RAM	I do not know	Other (specify)

18.2.5 **Speed (GHZ)**

< 1GHZ	1-3GHZ	4-5GHz	I do not know	Other (specify)

19. Indicate **ONE** location in which you experience poor Wi-Fi signal quality on-campus:

_____

19.1 In what time periods do you experience poor Wi-Fi quality in the location specified in question 19? **(Tick all that apply)**

Time period(s) you experience poor Wi-Fi quality							
19.1.1	19.1.2	19.1.3	19.1.4	19.1.5	19.1.6	19.1.7	19.1.8
Before 8am	**8am-<10am**	**10am-<12pm**	**12pm-<2pm**	**2pm-<4pm**	**4pm-<6pm**	**6pm-8pm**	**After 8pm**

20. Indicate the **ONE** location in which you experience the best Wi-Fi signal quality on-campus:

_____

20.1 In what time periods do you experience the best quality of Wi-Fi in the location specified in question 20? **(Tick all that apply)**

Time period(s) you experience good Wi-Fi quality							
20.1.1	20.1.2	20.1.3	20.1.4	20.1.5	20.1.6	20.1.7	20.1.8
Before 8am	**8am-<10am**	**10am-<12pm**	**12pm-<2pm**	**2pm-<4pm**	**4pm-<6pm**	**6pm-8pm**	**After 8pm**

21. What do you normally do when you experience a difficulty using Wi-Fi on-campus? **(Select ONE option only)**

I report the problem to ICS	
I change my position in the same location	
I stop using the Wi-Fi	
I go to another location with Wi-Fi	
I ask a person nearby for help	
I report it to my residence administrator	
I do not know	
Other (specify) _____	

22. Indicate the frequency (1 = not at all frequently to 7 = very frequently) with which you access the following Internet resources <u>using Wi-Fi on-campus.</u>

		Not at all frequently	**2**	**3**	**4**	**5**	**6**	**Very Frequently 7**
22.1	Moodle / Learn							
22.2	Whatsapp							
22.3	YouTube							
22.4	Online movie websites							
22.5	Student central							
22.6	Snap chat							
22.7	Instagram							
22.8	Yahoo mail							
22.9	Facebook							
22.10	Gmail							
22.11	Google search							
22.12	Online music websites							
22.13	UKZN mail							

		Not at all frequently	**2**	**3**	**4**	**5**	**6**	**Very Frequently 7**
22.14	Games							
22.15	Yahoo search							
22.16	Other (specify) _____							

23. In your experience, which of these resources loads slowest when using Wi-Fi on-campus? **(Select ONE option only)**

Moodle / Learn	
WhatsApp	
YouTube	
Online movie websites	
Student central	
Snap chat	
Instagram	
Yahoo mail	
Facebook	
Gmail	
Google search	
Online music websites	
UKZN mail	
Games	
Yahoo search	
Other (specify)_____	

24. Indicate the number of occasions you have asked ICS for help with difficulties you faced when using Wi-Fi in the last seven months.

Never	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**>10**

25. Indicate the number of times you have asked someone who is not part of ICS for help with difficulties you faced when using Wi-Fi in the last seven months.

Never	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**>10**

26. Do you know how to log a call to ICS about the difficulties you face when using Wi-Fi on-campus?

Yes	No

27. Indicate how many hours, on average; you make use of Wi-Fi on-campus per day. (**Select ONE option only**).

Hours per day using Wi-Fi on-campus (tick one)											
N/A Don't use	**Less than 1**	**1 to < 3**	**3 to < 5**	**5 to < 7**	**7 to < 9**	**9 to < 11**	**11 to < 13**	**13 to < 15**	**15 to < 17**	**17 to < 20**	**20+ hours**

28. Indicate the time period in which you use Wi-Fi the most, on average, during weekdays (Monday - Friday) when on-campus. (**Select ONE option only**).

Most used time period during week days (Monday to Friday)								
N/A	**Before 8am**	**8am-<10am**	**10am-<12pm**	**12pm-<2pm**	**2pm-<4pm**	**4pm-<6pm**	**6pm-8pm**	**After 8pm**

29. Indicate the time period in which you use Wi-Fi the most, on average, during weekends (Saturday and Sunday) when on-campus. (**Select ONE option only**).

Most used time period during weekends (Saturday and Sunday)								
N/A	**Before 8am**	**8am-<10am**	**10am-<12pm**	**12pm-<2pm**	**2pm-<4pm**	**4pm-<6pm**	**6pm-8pm**	**After 8pm**

30. Think about your experience in accessing Wi-Fi in the location in which you use Wi-Fi the most on-campus (**This is the location you selected in Question 15)**

    NB: Indicate the exact location at the top of the table for example; if you selected library as most usually used location indicate the level (**e.g. library level 3**)

    Indicate the exact location: _____

    Indicate the extent to which you agree or disagree with the following statements:

	Statement	**Strongly Disagree**	**Disagree**	**Slightly Disagree**	**Neutral**	**Slightly Agree**	**Agree**	**Strongly Agree**
OQ1	I am able to use Wi-Fi in this location whenever I want to use it.							
OQ2	A Wi-Fi signal is available in this location anytime I need to use it.							
OQ3	I can gain access to this location to use Wi-Fi anytime I need to.							
OQ4	I am able to access all Internet resources provided by the university every time I use Wi-Fi at this location.							

	Statement	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
OQ5	I always get the same good quality output of resources (YouTube, Gmail, Student Central) when I use Wi-Fi at this location.							
OQ6	I have the same good signal quality when using Wi-Fi in different positions at this location.							
OQ7	Getting connected to Wi-Fi at this location is fast.							
OQ8	It takes a short time to log in to Wi-Fi using my log in details at this location.							
OQ9	Resources take a short time to load when using Wi-Fi in this location.							
OQ10	My Wi-Fi connection remains steady enough for me to do my work once connected to it at this location.							
OQ11	My Wi-Fi connection never goes on and off at this location.							
OQ12	The resources (YouTube, Gmail, and Student Central) never freeze when using the Wi-Fi in this location.							
PEQ1	I find it pleasant to use Wi-Fi at this location because the							

	Statement	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
	temperatures are not too cold or too hot.							
PEQ2	I find it pleasant to use Wi-Fi at this location because it has fresh air.							
PEQ3	I find it pleasant to use Wi-Fi at this location because there is good lighting							
PEQ4	I have a pleasant Wi-Fi experience at this location since students are able to help me solve Wi-Fi connection issues.							
PEQ5	I have a pleasant experience using Wi-Fi at this location because students don't make a lot of noise.							
PEQ6	I have a pleasant experience using Wi-Fi at this location because it is not over-crowded with students.							
PEQ7	Using Wi-Fi at this location leaves me with a good experience because it has many power plug points on the walls.							
PEQ8	I have a good experience using Wi-Fi in this location because there are enough places to sit.							
PEQ9	Using Wi-Fi at this location leaves me with a good experience because it is clean.							

	Statement	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
IQ1	I can count on UKZN Westville ICS employees taking actions to address my Wi-Fi needs/requests at this location.							
IQ2	UKZN Westville ICS employees respond quickly to my Wi-Fi needs/requests at this location.							
IQ3	The behaviour of UKZN Westville ICS employees indicates to me that they understand my Wi-Fi needs at this location.							
IQ4	I can count on the ICS employees at UKZN Westville being friendly when interacting with me about Wi-Fi issues needs at this location.							
IQ5	The attitude of UKZN Westville ICS employees demonstrates their willingness to help me with Wi-Fi needs at this location.							
IQ6	UKZN Westville ICS employees show enthusiasm when helping me with Wi-Fi problems at this location.							
IQ7	I can count on UKZN Westville ICS employees knowing their jobs							

	Statement	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
	regarding Wi-Fi services at this location.							
IQ8	When I ask UKZN Westville ICS employees to help me with Wi-Fi issues, they solve my problems quickly.							
IQ9	UKZN Westville ICS employees are very professional when addressing my Wi-Fi needs at this location.							
SQ1	UKZN Westville offers an excellent Wi-Fi service at this location.							
SQ2	The Wi-Fi service at this location is comparable to good Wi-Fi service I can get elsewhere.							
SQ3	I am satisfied with the general quality of Wi-Fi services delivered by UKZN Westville at this location.							
SQ4	I am satisfied with the strength of the Wi-Fi signal delivered by UKZN Westville at this location							
SQ5	I am satisfied with the assistance I get from ICS when I have Wi-Fi difficulties							

31. Are there any other comments you would like to make about your use and experience of Wi-Fi on Westville campus?

_____

_____

_____

Thank you very much for your participation.

Appendix 4: Interview (with consent to participate and consent form)

University of KwaZulu-Natal

Researcher: Mbonye Vicent / 072 276 8769 / vicentmbonye@gmail.com

Supervisor: Sue Price / 031 260 3162 / pricec@ukzn.ac.za

Project Title: UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number_____).

Date: _____

Consent form

Greetings,

I am an MCOM (IS&IT) student in the School of Management, IT and Governance. Please would you consider participating in my research study is entitled "UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service"? It aims to investigate how Westville students use on-campus Wi-Fi, what difficulties they face when using it, and their perceptions of the quality of service. The study is expected to include 373 Westville students and an ICS Wi-Fi Administrator.

Completing the questionnaire will take around 10 minutes.

- ✓ The information you provide will be used to enhance and improve the quality of Wi-Fi services provided on-campus by the University of KwaZulu-Natal Westville campus.
- ✓ Your name will not be written on the questionnaire or be kept in any other records. We kindly ask you to fill it out with as much accuracy as possible.
- ✓ All responses you provide for this study will remain confidential. When the results of the study are reported, you will not be identified by name or any other information that could be used to infer your identity. Only researchers will have access to view any data collected during this research, and the responses will not be used for any purposes outside of this study.

- ✓ Your participation is voluntary and you may withdraw from this research any time you wish.
- ✓ Your refusal to participate will not result in any penalty or loss of benefits to which you are otherwise entitled to.
- ✓ All data, both electronic and hard copy will be securely stored during the study and archived for 5 years. After this time, all data will be destroyed.
- ✓ The research intends to abide by all commonly acknowledged ethical codes. You will receive no incentive or payment for your participation.

If you have any questions, you are free to ask them now.

In the event of any problems or concerns/questions later you may contact the researcher at **Email address:** vicentmbonye@gmail.com, **Telephone numbers** 0722768769 /0613876562 or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban 4000 KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za
If you have any questions or concerns about participating in the study, please contact me or my research supervisor at the numbers listed above.

Sincerely

Mbonye Vicent

Thank you for your time

University of KwaZulu-Natal

Researcher: Mbonye Vicent / 072 276 8769 / vicentmbonye@gmail.com

Supervisor: Sue Price / 031 260 3162 / pricec@ukzn.ac.za

Project Title: UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service

Declaration of Consent

I _____ (full names) have been informed about the study entitled "UKZN Westville students' use of on-campus Wi-Fi and their perceptions of quality of service" by Mbonye Vicent.

I understand the purpose and procedures of the study.

I have been given an opportunity to ask questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at **Email address:** vicentmbonye@gmail.com, **Telephone numbers** 0722768769 /0613876562.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the research then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban 4000 KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

I hereby provide consent to:

Audio-record my interview YES / NO

_____ _____

Signature of Participant **Date**

SECTION IV (Wi-Fi infrastructure information)

This section seeks to understand different Wi-Fi infrastructure on Westville campus

1. What Wi-Fi standard have you adopted in the provision of on-campus Wi-Fi at Westville?

   _____

2. How many different makes or models of access points do you employ to provide Wi-Fi services to students in different locations?

   _____

3. Are there any access points which are configured for only 2.4GHz spectrum? If so where are they located?

   _____

4. Are there any access points which are configured for only 5GHz spectrum? If so where are they located?

   _____

5. What antenna types have you adopted for access points on-campus?

   _____

6. Are there Wi-Fi locations in which access points have different antenna types? If so where are the access points located?

   _____

7. How much bandwidth do you allocate to each access point?

   _____

8. Are the allocated bandwidths the same on all the access points on-campus?

   _____

9. Are the bandwidths allocated to each spectrum the same on all access points, indicate the locations in which access points have different bandwidth configurations on spectrums.

   _____

10. What security mode is adopted in the Wi-Fi infrastructure?

    _____

11. Do all access points have the same number of channels configured on them?

    _____

12. On average, how many channels are configured on each access point?

    _____

13. How many Wi-Fi related difficulties have been reported by UKZN students in the last seven months?

    _____

    _____

14. Elaborate on difficulties that have been reported by students in regard to using Wi-Fi infrastructure?

    _____

    _____

    _____

SECTION V (Student difficulties with on-campus Wi-Fi)

15. What are the top 3 locations where students report Wi-Fi related difficulties?

    _____

    _____

    _____

16. How are Wi-Fi access points configured in the locations in question 15 above?

    _____

    _____

17. How are Wi-Fi access points configured in the locations reported by students to have poor Wi-Fi signal?

    _____

    _____

18. How are Wi-Fi access points configured in the following locations (locations reported by students to have the best Wi-Fi signal)?

    _____

    _____

19. Approximately how many calls were logged in the last seven months by students needing help in getting their device(s) connected to the on-campus Wi-Fi?

    _____

    _____

20. Is there is infrastructure in place for students to report Wi-Fi connection difficulties? If yes what type of infrastructure exists and where do students find it?

    _____

    _____

Thank you very much for your participation.

Appendix 5: Interview schedules with ICS staff members

Participant	**Date and time of the interview**	**Duration of the interview**	**Venue of the interview**
Participant 1	This interview took place on the 24/10/2017 at 9:29am.	20 minutes	Howard College ICS offices
Participant 2	This interview took place on the 23/10/2017 at 16:05pm.	28 minutes	Westville campus ICS offices
Participant 1	This was a follow up interview that took place on the 17/5/2018 at 3:10pm.	40 minutes	Howard College ICS offices

Appendix 6: Questionnaire Alignment matrix

Section I (Bio data information)

- **Qn1- Qn4**

Section II (Education information)

- **Qn5- Qn7**

Research questions and questions in the questionnaire to answer them

1. How do UKZN Westville students use Wi-Fi on-campus?

Questions in student questionnaire: Section III Wi-Fi usage information

- **Qn8 - Qn10 general questions**

a) In what locations do UKZN Westville students prefer to access Wi-Fi services on-campus?

- **Qn14** In what locations do UKZN Westville students use Wi-Fi services on-campus?
- **Qn15** In what locations do students use Wi-Fi the most on-campus
- **Qn19** In what locations do students experience poor Wi-Fi quality
- **Qn19.1** What time period do students experience poor Wi-Fi quality in the above location in question 19
- **Qn20** In what locations do students experience the best Wi-Fi quality
- **Qn20.1** What time period students experience the best Wi-Fi quality in the above location in question 20

b) How much time do UKZN Westville students spend accessing Wi-Fi on-campus?

Questions in student questionnaire: Section III Wi-Fi usage information

- **Qn27** How many hours do student spend using Wi-Fi on-campus per day?
- **Qn28** what time periods do students use Wi-Fi the most during weekdays?
- **Qn29** what time period do students use Wi-Fi the most on weekends?

c) What Internet resources do UKZN Westville students access when using Wi-Fi on-campus?

Questions in student questionnaire: Section III Wi-Fi usage information

- **Qn22** what is the frequency of accessing Internet resources when using Wi-Fi on-campus
- **Qn23** which of Internet resources load slower than others when using Wi-Fi on-campus on-campus

d) What devices do UKZN Westville students use to access Wi-Fi on-campus?

Questions in the student questionnaire: Section III Wi-Fi usage information

- **Qn11** which Wi-Fi device do you use to access Wi-Fi on-campus in general (not in the most used Wi-Fi location)
- **Qn12** do you usually connect two devices to Wi-Fi at same time
- **Qn13** How many devices do you connect to Wi-Fi at the same time on-campus?
- **Qn17** What Wi-Fi device do you use to access Wi-Fi when they are in their most used Wi-Fi location on-campus?
- **Qn18** what are the characteristics of Wi-Fi device that you use the most when using Wi-Fi in your most used Wi-Fi location on-campus

Question in the Administrator questionnaire:

- **Qn19** How many calls have been logged in the last seven months by students needing help in getting their device connected to Wi-Fi**.**

2. What access point configurations and specifications are provided on Westville campus?

Administrator questionnaire

Qn1- Qn12 what Wi-Fi access point configurations and specification are in different locations on-campus

Qn15 what are the location in which students use Wi-Fi the most On-campus

Most used locations on-campus

1. On-campus residence
2. Library
3. Lecture venues
4. LANs

Qn18 How are Wi-Fi access points configured in the following locations (locations reported by students to have best Wi-Fi signal **student questionnaire Qn20**)?

Locations with the best Wi-Fi quality

1. LANs
2. Lecture venues
3. On-campus residence

Qn17 How are Wi-Fi access points configured in the following locations (locations reported by students to have poor Wi-Fi signal **student questionnaire Qn19**)?

Locations with poor Wi-Fi quality

1. Cafeteria
2. Quad
3. Library

3. What difficulties do UKZN Westville students face when using Wi-Fi services on-campus?

    a) What difficulties do UKZN Westville students experience when using Wi-Fi services on-campus?

    - **Qn16** Please indicate the difficulties you face when using Wi-Fi in you most preferred Wi-Fi access locations on-campus

    - **Qn21** what do you do when you experience difficulties using Wi-Fi on-campus

    - **Qn25 please** indicate on how many occasions you have asked someone who is not part of ICS for help with Wi-Fi difficulties in the last seven months.

    b) What difficulties do UKZN Westville students report to ICS about the use of Wi-Fi services on-campus?

    - **Qn26** Do you know how to log a call to ICS about Wi-Fi difficulties on-campus

    - **Qn24 please** indicate on how many occasions you have asked ICS for help with Wi-Fi difficulties in the last seven months.

    Administrator Question in questionnaire:

    - **Qn13** How many Wi-Fi related difficulties have been reported by UKZN students in the last seven months?

    - **Qn14** Elaborate on difficulties that have been reported by students in regard to using Wi-Fi infrastructure?

    - **Qn20** Is there is infrastructure in place for students to report Wi-Fi connection difficulties? If yes, what type of infrastructure exists and where do students find it.

4. What are UKZN Westville students' perceptions of the quality of Wi-Fi service on-campus?

Questions in student questionnaire: Section III Wi-Fi usage information

- **Qn30 SQ1-SQ5**

a) What are UKZN Westville students' perceptions of the outcome quality when using the Wi-Fi service on-campus?

- **Qn30 OQ1-OQ12**

    - **Q30-OQ1-availability of Wi-Fi**
    - **Q30-OQ2-availability of Wi-Fi**
    - **Q30-OQ3-availabilityof Wi-Fi**
    - **Q30-OQ4-reliability of Wi-Fi**
    - **Q30-OQ5-reliability of Wi-Fi**
    - **Q30-OQ6-reliability of Wi-Fi**
    - **Q30-OQ7-timeliness of Wi-Fi**
    - **Q30-OQ8-timeliness of Wi-Fi**
    - **Q30-OQ9-timeliness of Wi-Fi**
    - **Q30-OQ10-stability of Wi-Fi**
    - **Q30-OQ11-stability of Wi-Fi**
    - **Q30OQ12-stability of Wi-Fi**

b) What are UKZN Westville students' perceptions of the physical environment quality when using the Wi-Fi on-campus?

Questions in student questionnaire: Section III Wi-Fi usage information

- **Qn30 PEQ1- PEQ9**

    - **Q30-PEQ1-Ambient Conditions in the most used Wi-Fi location**
    - **Q30-PEQ2-Ambient Conditions in the most used Wi-Fi location**
    - **Q30-PEQ3-Ambient Conditions in the most used Wi-Fi location**
    - **Q30-PEQ4-Social factors in in the most used Wi-Fi location**
    - **Q30-PEQ5-Social factors in the most used Wi-Fi location**

- **Q30-PEQ6-Social factors in in the most used Wi-Fi location**
- **Q30-PEQ7-Design quality of the most used Wi-Fi location**
- **Q30-PEQ8-Design quality of the most used Wi-Fi location**
- **Q30-PEQ9-Design quality of the most used Wi-Fi location**

c) What are UKZN Westville students' perceptions of the interaction quality when using the Wi-Fi service on-campus?

Questions in student questionnaire: Section III Wi-Fi usage information

- **Qn30 IQ1- IQ9**

  - **Q30- IQ1-Behavior of ICS employee**
  - **Q30 -IQ2-Behavior of ICS employee**
  - **Q30- IQ3-Behavior of ICS employee**
  - **Q30-IQ4-Attitude of ICS employee**
  - **Q30-IQ5-Attitude of ICS employee**
  - **Q30-IQ6-Attitude of ICS employee**
  - **Q30-IQ7-Expertise of ICS employee**
  - **Q30-IQ8-Expertise of ICS employee**
  - **Q30-IQ9-Expertise of ICS employee**

d) How do user system device quality and access point configuration specifications affect outcome quality?

Questions in student questionnaire: Section III Wi-Fi usage information

- **Qn18** what are the characteristics the Wi-Fi device that students use the most when they are in their most used Wi-Fi location on-campus

- **Qn30 OQ1-OQ12** what are UKZN Westville students' perceptions of the outcome quality when using the Wi-Fi service on-campus?

Administrator questionnaire question

- **Qn1- Qn15** what Wi-Fi access point configurations and specification are in different locations on-campus

5. How does outcome quality, physical environment quality and interaction quality affect students' perceived Wi-Fi service quality?

   Questions in student questionnaire: Section III Wi-Fi usage information

   - **Qn30 IQ1- IQ9, Qn30 PEQ1- PEQ9 and Qn30 OQ1-OQ12** against **Qn30 SQ1-SQ5.**

6. What factors may affect Wi-Fi outcome quality on Westville campus?

   - Interpretation of results from student questionnaire **Qn30 OQ1-OQ12**, **Qn18** and reported access point configurations in administrator Qn**1** and **Qn15**

Appendix 7: Wi-Fi specification of different makes of laptops, tablets and PCs with wireless cards.

A table showing Wi-Fi device manufacturing companies (Dell, Samsung, Sony, Apple and Hewlett Packard (HP)) is shown below. The different devices have varying specifications that impact device performance when accessing Wi-Fi services.

Device make	**Device type**	**Standard**	**Memory**	**Speed**	**Reference**
Dell Venue 11 Pro 5000	Tablet	IEEE 802.11n/802.11ac	Varies by user requirements	Varies by user requirements	Dell Incorporation (2017e)
Dell Inspiron Laptop	Laptop	IEEE 802.11a/b/g/n and ac	Varies by user requirements	Varies by user requirements	Dell Incorporation (2017b)
Dell latitude laptops	Laptop	IEEE 802.11a/b/g/n and ac	Varies by user requirements	Varies by user requirements	Dell Incorporation (2017d)
Dell Inspiron 20 all-in-ones desktop	Desktop	IEEE 802.11b/g/n	Varies by user requirements	Varies by user requirements	(Dell Incorporation, 2017c)
Inspiron desktops	Desktop	IEEE 802.11ac	Varies by user requirements	Varies by user requirements	Dell Incorporation (2017a)
Apple MacBook air	Laptop	IEEE 802.11ac	Varies by user requirements	Varies by user requirements	Apple (2017b).
Apple iPad mini	Tablet	IEEE 802.11ac	Varies by user requirements	Varies by user requirements	Apple (2017a).
Apple iPhone 5s	Smartphone	IEEE 802.11b/g/n	Varies by user requirements	Varies by user requirements	Apple (2017a).
Apple iPhone 6s	Smartphone	IEEE 802.11ac	Varies by user requirements	Varies by user requirements	Gsmarena (2017a).

Device make	Device type	Standard	Memory	Speed	Reference
Samsung RV510	Laptop	IEEE 802.11a/b/g/n	Varies by user requirements	Varies by user requirements	Samsung (2017d)
Samsung Notebook series 9 NP900X3N	Laptop	IEEE 802.11ac	Varies by user requirements	Varies by user requirements	Samsung (2017a)
Samsung 24 all in one-desk tops	desktops	IEEE 802.11 a/b/g/n/ac	Varies by user requirements	Varies by user requirements	Samsung (2017c)
Samsung Galaxy Tab s,	Tablets	IEEE 802.11a/b/g/n	Varies by user requirements	Varies by user requirements	Samsung (2017b).
Samsung Galaxy Note FE	Smartphone	IEEE802.11 a/b/g/n/ac	Varies by user requirements	Varies by user requirements	(Gsmarena, 2017b).
HP Pro Tablet 608	Tablets	IEEE 802.11a/b/g/n	Varies by user requirements	Varies by user requirements	Gadgets (2017).
HP ProBook 470 G4 Notebook PC	Laptop	IEEE 802.11a/b/g/n and ac	Varies by user requirements	Varies by user requirements	Hewlett Packard (2017b).
Pavilion Power - 15-cb004ni	Laptop	IEEE 802.11a/b/g/n and ac	Varies by user requirements	Varies by user requirements	(Hewlett Packard, 2017b)
HP ProDesk 400 G4	Desktop	IEEE 802.11ac	Varies by user requirements	Varies by user requirements	(Hewlett Packard, 2017a)

Device make	Device type	Standard	Memory	Speed	Reference
Microtower PC					
Sony Xperia Z1	Smartphone	IEEE 802.11 b/g/n/ac	Varies by user requirements	Varies by user requirements	Gsmarena (2017c).
Sony Xperia U	Smartphone	IEEE 802.11a/b/g/n	Varies by user requirements	Varies by user requirements	Gsmarena (2017c)