Nelson Mandela Metropolitan University

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*Department of Computing Sciences*

# Using Mobile Information Visualisation to Support the Analysis of Telecommunication Service Utilisation

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# Declaration

I, Gianni Twigg, hereby declare that the dissertation for the degree Magister Scientiae is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification.

Gianni Twigg

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# Summary

Telecommunication service utilisation (TSU) focuses on how customers make use of telecommunication services and can provide valuable information for decision making for improved customer service delivery. When a telecommunication service provider consults with customers, large amounts of static documentation on TSU data are compiled. Compiling this documentation for in-field investigation is manually intensive and the documentation does not effectively support decision making. Existing systems for visualising TSU data do not efficiently support in-field investigation of TSU and lack dynamic interaction. This highlights the need to investigate a solution to better support in-field investigation of TSU.

This research followed a Design Science Research methodology to develop and evaluate a solution to solve the problem identified. The use of tablet devices for in-field investigation of TSU was identified as a suitable solution. Mobile information visualisation (MIV) techniques were investigated to determine appropriate display and interaction techniques for the visualisation of TSU data on a tablet device. An existing visualisation framework for TSU was identified and extended to incorporate touch-based interactions. Three service usage views were identified for visualising TSU, namely a Trend, Network and Detail Usage View. A Dashboard View was also identified to provide a quick reference view of the different views. A prototype called MobiTel was developed on a tablet device. MobiTel incorporated the identified information visualisation techniques.

MobiTel was evaluated using an expert review and a user study to determine its usability and usefulness. The results indicated that MobiTel was perceived as being useful for in-field investigation and that the participants perceived the prototype to be easy to use and learn. The user study also indicated that the participants were satisfied with MobiTel.

This research has determined that MIV techniques can be used for in-field investigation of TSU. Design recommendations were devised for designing an interactive mobile prototype for visualising service usage information. Future work will involve using map-based visualisation for visualising TSU data on different customer sites.

**Keywords**: Design Science Research, Mobile Information Visualisation, Telecommunication Service Usage, Information Visualisation, Visual Analytics.

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# List of Abbreviations

| | |
|---|---|
| ASQ | After Scenario Questionnaire |
| BSS | Business Support System |
| CSI | Continual Service Improvement |
| DSR | Design Science Research |
| DSRM | Design Science Research Methodology |
| DSS | Decision Support System |
| ETM | Enterprise Telephony Manager |
| eTOM | Enhanced Telecommunications Operations Map |
| ICT | Information Communication Technology |
| ID | Identifier |
| IP | Internet Protocol |
| IPDR | Internet Protocol Data Record |
| IT | Information Technology |
| ITIL | Information Technology Infrastructure Library |
| ITSM | Information Technology Service Management |
| IV | Information Visualisation |
| MIV | Mobile Information Visualisation |
| MPLS | Multi-Protocol Level Switch |
| NMMU | Nelson Mandela Metropolitan University |
| NMS | Network Management System |
| OSS | Operation Support System |
| PC | Personal Computer |
| PSTN | Public Switched Telephone Network |
| SLA | Service Level Agreement |
| SNMP | Simple Network Management Protocol |
| SQL | Standard Query Language |
| TSM | Telecommunication Service Management |
| TSP | Telecommunication Service Provider |
| TSU | Telecommunication Service Utilisation |
| UI | User Interface |
| USE | Usability, Satisfaction and Ease of Use |
| VoD | Voice on Demand |
| VoIP | Voice-over Internet Protocol |
| VPN | Virtual Private Network |
| WIMP | Windows, Icons, Menus and Pointers |
| XML | eXtensible Markup Language |
| ZUI | Zoomable User Interfaces |

# Chapter 1: Introduction

## 1.1 Background

The emergence of new Internet technologies and social media has caused the telecommunication industry to focus more on data services than on voice services. New data-based services such as Video-on-Demand (VoD), Voice over IP (VoIP) and other e-services are increasing the pressure on the network infrastructures of telecommunication service providers (TSPs) (XO_Communications 2007). The high utilisation of resources by the services is placing strain on the networks, which can affect the quality of services (Hewlett-Packard 1999). TSPs need to monitor the services that run on these networks. Most network monitoring tools collect large amounts of data, which is analysed to identify possible faults or is viewed on a dashboard for decision making purposes. The telecommunication industry has the highest volume of real-time data, which has been growing at an exponential rate (Koutsofios *et al.* 1999). TSPs need to ensure that they adopt effective and efficient strategies to manage these high volumes of data. The data stored can be used to measure and monitor the network systems and enable effective analysis of the resources that have been utilised by the various services. Data is logged for telecommunication services that run over a network. Service usage data is logged every time a service is used by a customer. The service usage data can be processed and analysed for decision making purposes to improve the network systems and customer services. The management of how customers use a telecommunication service is known as telecommunication service utilisation (TSU).

TSPs need to adjust their management strategies to focus more on service management than on network management (Wong, Ting and Yeh 2007). Management of the networks is a challenge for TSPs and the management of the services running over the networks is an even greater challenge (Keeney and Serrat-Fernndez 2012). Management approaches that focus on network level monitoring are not able to provide high-level information required for managing services running across the networks. TSPs need to use suitable tools to analyse data adequately to determine customer service usage patterns. In analysing customer service usage data, two aspects of the information require examination.

The first aspect is the real-time analysis of network usage and the actions that should be taken to respond to the results obtained (Sybase 2011). The real-time analysis is predominantly an automated process handled by the network management system (NMS), which is a tool used to monitor and control the networks. The NMS is able to respond automatically in real-time to any events that may occur. An example of an event would be if the traffic flow from the service utilisation on a server is too high then the NMS will notify the applicable systems to make changes to reduce the load on the server.

The second aspect requiring examination is an analysis of the network usage in the context of the TSP's business model. This type of examination requires data mining to be performed on the service usage data and then present the information for further, expert human analysis. The software tools used to present the information for expert human analysis need to do so in an efficient and effective manner.

The competitive and ever-evolving telecommunications market creates a need for management of TSPs to receive information with the minimum of delay, regardless of location. The goal is to transform data into business decisions within minutes (Koutsofios *et al.* 1999). Mobility can assist in this regard by allowing information to be received ubiquitously and allow business decisions to be made faster. Mobility brings various business benefits, such as providing productivity away from the conference room through to the customer site (Dell and Intel 2010). Uploading and downloading information from corporate databases is no longer a time-consuming issue with mobile devices as mobile-data bandwidth have improved. The limitation of mobile devices such as processing power, is becoming less of a concern, due to technology improvements and thus allows more powerful applications to be used on mobile devices (Cass 2010). This has brought about a shift from desktop to mobile applications.

Mobile devices and applications can be used to support businesses, by empowering their employees during the customer engagement process to make informative decisions (Pegasystems 2012). Therefore, business models are evolving to incorporate mobility to better exploit computing and communications (Dell and Intel 2010). TSPs can make use of mobile technology to enable their employees to obtain information rapidly and ubiquitously. A challenge exists in how to effectively present the information on the mobile devices to support customer service representatives of a TSP during the customer engagement process to make informed decisions.

Effective decision making is highly dependent on the quality of the information resources available. Effective decisions are made by considering various sources of information to ensure that different solutions have been considered (Ribarskya, Fisher and Pottenger 2009). Analytical reasoning is an important part of how decisions are made, where assumptions and conclusions are deduced from the artefacts. Decision making is supported by analysing and interpreting information. Software tools are required to process and present the information to support analysis. Decision Support Systems (DSSs) are systems that assist the decision making process by processing information in a suitable format and by presenting the information effectively to the user (Flynn, Curran and Lunney 2002). The main components of a DSS are the user interface (UI), the data processing component and the data storage component. The UI is the component of the DSS which has direct interaction with the user. More focus needs to be placed on how the UI should be designed for the user to fully understand the system. The UI needs to be carefully designed so that the user can easily use the system and interpret the information being presented.

Visual analytics is a field focused on the presentation, interaction and knowledge extraction of information. Visual analytics investigates how systems should be developed to support interactive exploration of the information space as well as to assist in knowledge extraction (Wong and Thomas 2004). Visual analytics covers a range of research fields from statistical analysis to data management, visualisation and knowledge representation (Keim, Mansmann, Schneidewind *et al.* 2008). Information visualisation (IV) is a field of study focused on investigating the interaction, visualisation and presentation of abstract data to improve the human understanding of information (Card, Mackinlay and Shneiderman 1999). IV includes determining what visualisation and interaction techniques are most suitable for visualising specific data types. IV can assist the decision making process by facilitating the knowledge discovery process.

Considerable research has been done for IV on desktop personal computers (PCs), but the results of the research conducted cannot simply be applied to smaller screens (Chittaro 2006). Research on IV techniques for small screens, such as mobile devices, is still in its infancy. Mobile information visualisation (MIV) is aimed at investigating how to develop user interfaces to support searching and exploring large information spaces on small screens (Buering 2008). MIV can be used to map IV techniques to small screens on mobile devices.

## 1.2 Problem Identification

There is a continuous growth in demand for new user services which is affecting telecommunication networks (DANMS 2011). The new services that are emerging are increasing the network utilisation and thus create problems for TSPs, in terms of management of the networks and services. TSPs need to look at different aspects of the services that can be used to improve the quality of the services, such as monitoring service utilisation. TSPs need to monitor the customer service usage, as a lack of service utilisation can indicate that the customers may perceive the service as unreliable or costly (Narayana 2011). During the customer engagement process, service usage information is used to support decision making about different customer packages. When a TSP customer service representative consults with a customer, large amounts of documentation are compiled. This documentation includes information about the customer, service level agreements (SLA) and service usage information. The use of large documentation during the customer engagement process is time-consuming and inefficient. This information is static and does not support interactive exploration, which could possibly, better support the decision making process. Software tools are thus required to support the TSP's customer service representative during the customer engagement process, to understand how the customers use the telecommunication services. The process of being able to analyse information on-site is known as in-field investigation (Pattath *et al.* 2006). Software tools also have to consider how to present the service usage information to support efficient decision making. There is currently a lack of understanding of how visualisation can be used to support management decisions (Al-Kassab *et al.* 2011).

Based on the above, the following problem statement was identified:

*There is a lack of existing software tools for the visualisation of telecommunication service utilisation to effectively support in-field investigation.*

Telecommunication systems contain large amounts of data and to allow effective exploration of the data, visualisation analysis tools and techniques need to be implemented to support the telecommunication data management systems (Keim, Koutsofios and North 1999). Improved understanding of the information can allow management to make effective strategic decisions (Koutsofios *et al.* 1999). The utilisation of the services by customers produces large volumes of data and the capacity to store the data is increasing, but the tools for analysing the data are improving at a slower rate (Keim, Mansmann, Schneidewind *et al.* 2008). Obtaining a competitive advantage could be achieved if data could be utilised to quickly identify sound business decisions (Koutsofios *et al.* 1999). Businesses need to adopt a strategy where they can provide employees with access to information anywhere and anytime to allow business decisions to be made more quickly (Dell and Intel 2010). Mobile devices can be used to support this need. Mobile devices can be used to access information, such as a customer's service usage behaviour, which can be used by TSP customer service representatives during the customer engagement process.

Over the last decade there has been a greater adoption of the use of mobile devices rather than the typical desktop computers, due to the advantages that mobility provides (Chittaro 2006). Previous disadvantages of mobile devices such as performance, connectivity and storage are becoming less of an issue due to improvements in technology. Mobile devices, such as tablet devices, provide an intuitive means to interact with the device through the use of touch-based interaction. Tablet devices are increasingly penetrating the business environment as a mobile tool to access information (Weiss 2011). Tablet devices provide a larger screen size while maintaining the portability factor and therefore are increasingly used in business environments. The larger screen size of tablet devices, compared to smartphones, provides a real estate advantage to display more information. Tablet devices also have an ease-of-use factor, as these devices do not make use of a mouse or any other pointing device.

When designing interactive visualisation systems for tablet devices, IV techniques for large screens cannot be simply mapped from desktop displays to tablet screens. Tablet devices present the problem of enhancing the cognitive complexity of navigating the visualisation on the smaller screen and the user can lose global context when exploring details of the visualisation. The field of MIV addresses these kinds of issues.

The problem identified is that during the customer engagement process for TSPs, information about service usage is compiled into a large amount of documentation which is static. The static information does not support interactive exploration and efficient decision making. An investigation needs to be done to develop a solution to support in-field investigation of the service usage information. Tablet devices can be used to support in-field investigation, but how to present the service usage information on a small screen requires further investigation.

## 1.3 Research Objectives

The primary objective of the research is to develop a solution for the visualisation of TSU data to support in-field investigation. The following research objectives are identified for the research:

1. To investigate TSU and identify shortcomings of current software tools for TSU;
2. To determine the nature of TSU data and derive requirements for reporting on TSU;
3. To identify suitable IV techniques for TSU data and determine how to use MIV techniques to support visualising TSU data on a tablet device;
4. To propose and implement design decisions based on the identified visualisation techniques to visualise TSU data on a tablet device;
5. To evaluate the solution for visualising TSU data on a tablet device;
6. To communicate the findings of the research and design recommendations as well as suggestions for future work.

## 1.4 Research Questions

The research objectives will be answered using the following research questions:

1. How is TSU currently handled by TSPs?
    1.1. What management approaches are used for managing TSU?
    1.2. What are the shortcomings of existing software tools used to manage TSU data?
2. How is TSU data used to support decision making?
    2.1. What is the importance of TSU data?
    2.2. How is TSU data obtained?
    2.3. What is the structure of TSU data?
    2.4. What are the requirements for reporting on TSU?
3. How should TSU data be visualised on a tablet device to support in-field investigation?
    3.1. What suitable IV techniques can be used to visualise TSU?
    3.2. How can MIV techniques be used to support visualisation of TSU data on a tablet device?
4. How can the selected IV and MIV techniques be designed and implemented to visualise TSU?
    4.1. How can the design decisions for visualising TSU data be implemented on a tablet device?

   4.2. What touch-based interactions should be used to support visualising TSU data on a tablet device?
5. To what extent is the solution useful and beneficial for in-field investigation?
   5.1. How should the prototype be evaluated?
   5.2. What design implications can be identified based on the results?
   5.3. What are the proposed design recommendations for visualising TSU data on a tablet device?
6. What are the contributions and suggestions for future work resulting from this research?

## 1.5 Scope and Constraints

The focus of this research is on the visualisation and interaction of TSU data on a tablet device to support in-field investigation. Proposed design decisions will be derived after investigating suitable IV and MIV techniques for TSU. A prototype will then be developed on a tablet device using the proposed techniques.

As the focus of the research is on the mobile interface presented to the user, the research will not investigate the retrieval of the TSU data from the various data sources. Consolidating the data from multiple sources requires investigations to develop a middleware layer and is thus considered out of scope, as this does not directly impact the research problem. The research will only focus on the visualisation of TSU. The research will not include projection analysis to provide projected information, which could possibly be used to support in-field investigation. There are several telecommunication services that offer unique properties and only a selected number of services available will be used as a proof-of-concept.

The prototype will be deployed on a tablet device which will be purchased based on the resources available. The research will not focus on developing on a range of different platforms as the solution will serve as a proof of concept. The platform considerations are not directly relevant to the selection of the visualisation and interaction techniques.

## 1.6 Research Methods

Section 1.2 identified the research problem and Section 1.3 provided the objectives of the research. The research aims to develop a solution for visualising TSU on a tablet device to support in-field investigation. The Design Science Research (DSR) approach will be followed to develop a solution for the problem identified. DSR focuses on building and evaluating information technology (IT) artefacts that are created to solve organisational problems (Hevner *et al.* 2004). The IT artefacts which can be produced from the research are products such as constructs, models, methods and instantiations. The goal of DSR is to produce useful artefacts that solve the problem identified. DSR requires the purposeful creation of artefacts for a specified problem domain and hence the goal is usefulness. The product that is created needs to either address an unsolved problem or provide a more effective or efficient solution to a known problem. The creation of the product needs to be rigorously defined and an iterative search process for the most optimal solution should be conducted. The results from the DSR need to be effectively communicated to the appropriate audience.

Peffers *et al.*(2007) proposed a Design Science Research methodology (DSRM) and the objective of DSRM is to provide a nominal process for conducting DSR; to build upon prior research and provide a template for a structure of research outputs. The process model consists of six phases to support design and development studies incorporating DSR. This research follows the DSRM proposed by Peffers *et al.*(2007) to develop a solution for visualising TSU data on a tablet device. Each of the research questions discussed in Section 1.4 was mapped to the relevant phase(s) in the DSRM. Practice rules for DSR, proposed by Hevner *et al.* (2004), will be used to evaluate the deliverables from the research.

The first phase of the DSRM is the identification and motivation of a problem. Section 1.2 identified that there is a lack of software tools to effectively support in-field investigation of TSU. A literature review will be conducted into TSU and the management of TSU to provide theoretical support for the problem identified. An interview study will also be conducted with a TSP by using semi-formal interviews to obtain a practical understanding of the problem domain. The first phase addresses the first research question.

The second step is to define objectives for a solution, which is derived by further investigating the problem identified. A literature review will be conducted to identify the shortcomings of current solutions for visualising TSU data and the nature of TSU data will be investigated. An interview study will be conducted to identify requirements for visualising TSU. These requirements will be used to determine the objectives which the solution should meet to solve the identified problem. This phase of the DSRM is used to answer the second research question of investigating the TSU data that needs to be visualised.

Once the objectives for a solution have been defined, the design and development phase of the DSRM commences. The objectives determined from the previous phase will be used to define the functionality of the artefact, which is produced during this phase. The artefact will be created in the form of a prototype, which will be based on design decisions derived from a literature review on IV techniques for mobile devices. Iterative prototyping will be used to develop the prototype and then a refinement of the prototype will be completed to create a more optimal solution. The design and development phase will address the third and fourth research questions by making design decisions for visualising TSU data on a mobile device.

Part of the search process for an effective solution is the demonstration of the artefact to solve an instance of the problem. The demonstration phase of the DSRM should involve the artefact's use in experimentation, simulation etc. (Peffers *et al.* 2007). An expert review will be conducted with usability and domain experts to identify early usability issues with the prototype. The expert review forms part of iterative prototyping so that a more effective solution can be obtained. Design changes will be made to the artefact based on the expert review. This phase will address part of the fourth research question by identifying possible issues that can be used to improve the design decisions.

A critical part of the DSRM is the evaluation phase, where the artefact is observed and measured to determine how well the solution solves the problem. The prototype will be evaluated by using a user study. This evaluation will be conducted to identify the usefulness and usability of the prototype. The fifth research question will be addressed by the evaluation and determining the usefulness and user satisfaction of visualising TSU data on a mobile device to support in-field investigation.

The final phase is the communication of the problem, artefact and other findings from the research (Peffers *et al.* 2007). Design recommendations will be proposed for visualising TSU data on a tablet device based on the evaluation of the final prototype. This phase will address the last research question by communicating the findings of the research and by recommending future work using critical analysis.

## 1.7 Dissertation Structure

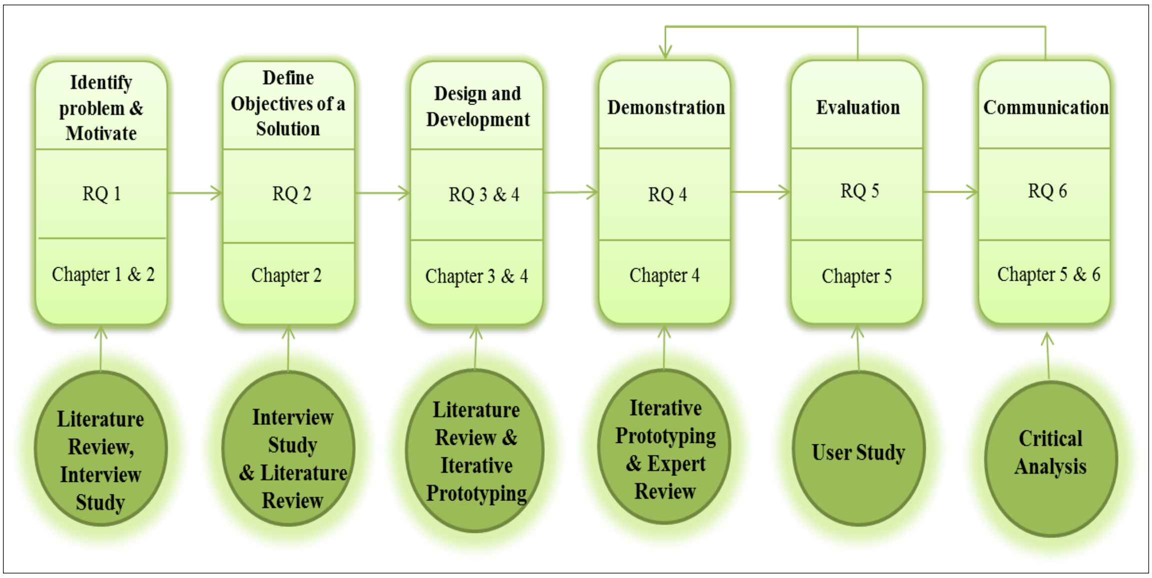



**Figure 1-1: Dissertation Structure Mapping to DSRM**

The dissertation consists of six chapters which will aim to follow the DSRM identified in Section 1.6. Figure 1-1 illustrates the phases of the DSRM and the research question that each phase addresses. Figure 1-1 also includes the research methods used to address each phase and the mapping of the chapters to the DSRM. The research objectives will be addressed in each chapter using the research methods discussed in Section 1.6. The deliverables from each chapter will be evaluated using the DSR practice rules proposed by Hevner *et al.* (2004) for a good DSR project.

Chapter 2 will address the first two phases of the DSRM by investigating the identified problem and deriving objectives for a solution. Chapter 2 discusses the management of TSU and how TSU supports decision making on service improvement. The nature of TSU data is investigated to determine requirements for reporting on TSU using a literature review. An interview study will also be conducted to obtain requirements for reporting on TSU data and the rationale for the problem identification. The shortcomings of existing systems used to report on TSU data are also investigated in this chapter. The requirements will be used to determine objectives for a solution to support visualising TSU data on a tablet device.

Chapter 3 will focus on MIV to develop a solution to the problem identified in Chapter 2. Chapter 3 is the first of the design chapters which will make use of a literature review to investigate alternative solutions for visualising TSU. Chapter 3 supports the design and development phase of the DSRM by providing a theoretical investigation of alternative solutions to the problem. Suitable visualisation techniques for presenting TSU data on a mobile device will be investigated. Chapter 3 will investigate existing models and frameworks for visualising TSU data.

Chapter 4 will focus on the design and implementation of the prototype for visualising TSU data on a tablet device. Design decisions will be based on the visualisation techniques identified in Chapter 3. Iterative prototyping will be used to develop the initial prototype and, which will then be evaluated by using an expert review. The prototype will then be refined to incorporate any changes suggested based on the expert review. The framework or model identified in Chapter 3, will be extended in Chapter 4 to incorporate the use of touch-based interaction based on the design decisions made.

Chapter 5 will focus on the evaluation of the prototype, where a user study will be conducted. A user study will be conducted with domain experts in order to determine the usefulness and usability of the prototype. This supports the DSRM as the evaluation of the prototype can provide insight into the usefulness of the solution to the identified problem. Design implications will be identified and recommendations for improvement to the prototype will be provided.

Chapter 6 concludes the research done by communicating the findings identified from the study. Chapter 6 will also provide design recommendations for visualising TSU data on a tablet device. The research concludes by discussing any limitations of the research and suggestions for future research.

# Chapter 2: Telecommunication Service Utilisation

## 2.1 Introduction

The previous chapter identified that there is a lack of software tools to visualise TSU data to effectively support in-field investigation. The first phase of the DSRM is the problem identification and motivation phase. Chapter 1 identified the research problem and defined the research objectives. This chapter will complete the first phase of the DSRM by further investigating the problem domain. This chapter will address the first and second research questions by investigating what TSU is and how it is managed. A background on telecommunication services and networks will be discussed to provide insight into the problem domain. Existing systems for reporting on TSU will be examined to determine any shortcomings. This chapter will also address the second phase of the DSRM by providing objectives for a solution to the problem identified. An interview study will be discussed, which was conducted in a South African TSP to gather requirements for reporting on TSU. The literature and interview study will be used to gather objectives for a solution.

## 2.2 Telecommunication Services

Telecommunication is better referred to as “electronic communications” to reflect the convergence with the Internet and social media (Średniawa 2010).  A service is something that delivers value to customers by meeting the customer’s expectations without the customer having to take ownership of specific costs and risks associated with the service (TNS 2011). Telecommunication services are defined as a set of user-information transfer capabilities provided to a group of users via a telecommunication system, by a TSP (Linfield 1990).

Over the last decade there has been a shift from TSPs predominantly offering voice services only to offering more data services. The first telecommunication services were services such as telephone services, but due to the growth of the Internet and adoption of the Internet Protocol (IP) based networks, newer services have emerged, such as Voice over Internet Protocol (VoIP) and cloud storage services. Among the main contributors to drive the creation of new telecommunication services offered are: the full digitisation of networks; mobility, broadband; the evolution of the Internet; and the integration of networks and services (Średniawa 2010). These driving factors allow new services to be offered. Through broadband, new services can be created that can transfer larger amounts of data and mobility drives the creation of mobile services such as location-based services. The variety of new services offered can be used to achieve the different goals that the user needs to achieve. The type of goals refers to objectives, such as obtaining location based information and transferring multimedia content.

Figure 2-1, which provides a taxonomy for the telecommunications domain and illustrates the convergence of telecommunications with Internet technology as well as the user needs that new services should meet (Średniawa 2010). The new services offered, provide the ability to transfer different content such as voice, images and rich multimedia. This allows more flexible, context-aware services to be offered to cater for different scenarios where location or semantic-based information needs to be transferred. Figure 2-1 also illustrates that different communication methods are available through telecommunication services such as multi-session and multi-model services.

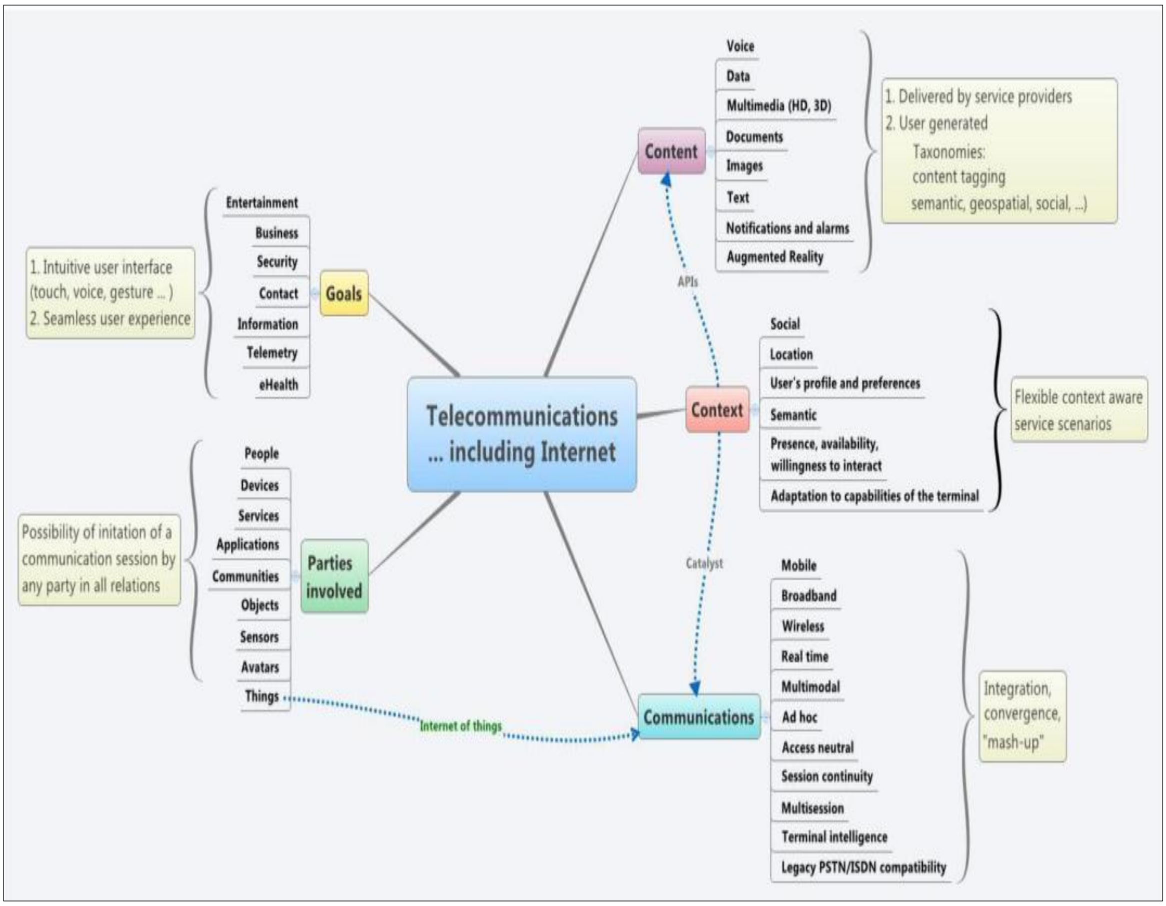



**Figure 2-1: Taxonomy of Telecommunications (Średniawa 2010)**

Although there is a variety of new telecommunication services being offered, all the services have certain basic components. Four basic components are required to provide a telecommunication service (Sherif 2006):

- *Networking Technology* is the component that provides the underlying physical infrastructure such as cabling and the transmission lines. This component also includes network elements, such as routers and switches.
- *The Operation Support Systems* (OSS) component refers to the various NMSs which are responsible for handling the provisioning, security and other administrative tasks of the networks.
- *The Methods and Procedures* component for a telecommunication service relates to the installation, maintenance, operations and user support aspects of a service.
- *The Content and Applications* component refers to the content creation or packaging. For example: electronic data interchange, web hosting and voice messaging, which are generated and transferred through the use of the service.

TSPs need to monitor, control and understand the various service layers from the physical infrastructure to the application layer. Other aspects of the services that management needs to understand are the attributes of a telecommunication service.

### 2.2.1 Service Attributes

A service attribute is a property of a service that describes a particular aspect of service behaviour. It is important for TSPs to have a clear understanding of the service attributes to understand how the service behaves, which can affect customer satisfaction (Pezeshki, Mousavi and Grant 2009). A clear understanding of service attributes can assist management with decision making to improve the service. Relevant attributes of telecommunications service relating to customer satisfaction are availability, security and quality (O'Sullivan, Edmond and Hofstede 2002). Availability is the property of a service that describes whether the user can make use of the service. If a service is not accessible due to events, such as network failures, then customer satisfaction can be negatively affected. The security attribute of a telecommunication service refers to whether the user can safely transmit and receive confidential information. This is important as the security of a service determines whether the customer will want to use the service. Service quality is the measure of the difference between the expected and actual outcome or performance received from a service (O'Sullivan, Edmond and Hofstede 2002).

Service quality is an important attribute of a service, which has a direct effect on customer satisfaction. Figure 2-2 illustrates that service quality has a direct impact on overall customer satisfaction, which affects customer retention and loyalty and thus affects profitability (Pezeshki, Mousavi and Grant 2009). Figure 2-2 also identifies three service attribute classifications for service quality, which are basic, performance and exciting. Basic attributes of a service describe what the service must do to satisfy customer satisfaction, such as providing a customer with required information. Performance attributes are attributes that enhance customer satisfaction, such as retrieving information efficiently. Exciting attributes are unexpected attributes of a service that result in high levels of customer satisfaction.

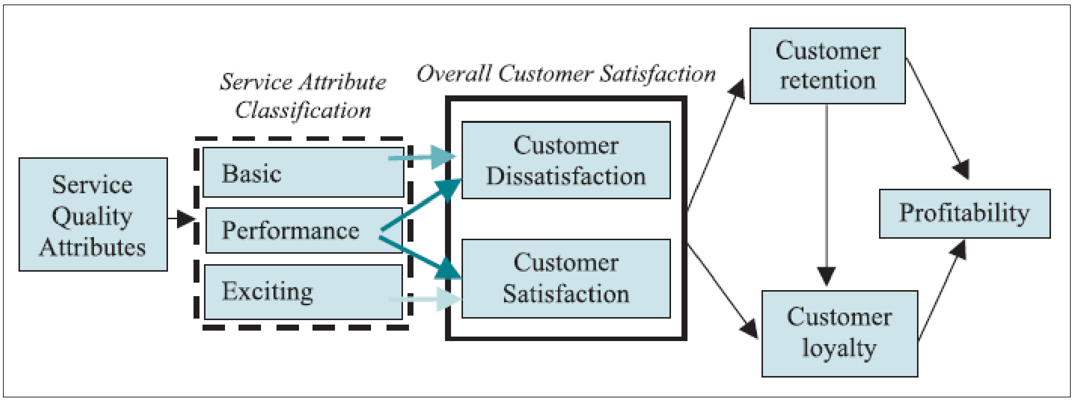



**Figure 2-2: Impact of Service Quality on Customer Satisfaction (Pezeshki, Mousavi and Grant 2009)**

The properties of a service that define service quality and provide an indication of the customer's perception of the service are: reliability, responsiveness, assurance, empathy and tangibleness (O'Sullivan, Edmond and Hofstede 2002). *Reliability* focuses on how accurately the service provides the expected outcomes. *Responsiveness* provides an insight on the efficiency of the service when utilised and *Assurance* refers to the user's trust and confidence in using a service. *Empathy* refers to the level of support provided to the user, such as value-added services. *Tangibleness* refers to the physical aspects associated with a service, for example, cleanliness and if the installation of equipment installed for a telecommunication service on a client's site is done neatly.

The extent to which the customers make use of a service can be reflected in the customers' perception of the service in terms of the service attributes. For example, customers may not want to use a service because they perceive the service as unreliable. The customers' service usage behaviour can provide an indication into the customers' perception of the service in terms of the service attributes.

To fully understand how telecommunication services are used by customers, an investigation needs to done on an operational level. The operational level refers to how the service operates and how services are made available. Telecommunication services run on networks, which are briefly discussed in the next section.

## 2.3 Telecommunication Networks

A telecommunication network consists of a set of smaller networks, managed by a TSP, where each network has a specific function to contribute towards the provisioning of a service (EFORT 2010). The smaller networks are the transmission network, switching network access network, signalling network, mobile network, intelligent network and management network. Depending on the type of telecommunication network (fixed-line or mobile), some of these smaller networks are integrated to provide applicable services for the network type. A telecommunication network is composed of two parts. The first part is the network and the second part is the business and technical information system. The network consists of the smaller networks whereas the business and technical information system consists of an Operating Support System and Business Support System (BSS) (EFORT 2010). Figure 2-3 illustrates the original type of telecommunication network which is used for fixed voice network, known as a Public Switched Telephone Network (PSTN). As shown in Figure 2-3, a PSTN consists of the following networks (EFORT 2010):

- **Transmission network** is responsible for carrying the different types of traffic such as voice, data and video. This network consists of nodes and links to support carrying the different types of traffic;
- **Switching network** is responsible for ensuring that the traffic is sent from the source to the correct destination by making use of switches. The switching network makes use of the transmission network to direct the traffic;
- **Access network** allows the user’s equipment to be attached to the switching and transmission network. The user may, for example, have an analogue or an integrated services digital network line, which will be attached to the access network providing access to the PSTN. A TSP provisions services to a customer by linking the customer’s equipment to the access network;
- **Signalling network** controls the exchange of information by determining to which switches in the switching network the information must be sent.

- **Intelligent network** is used to provision value-added services on the network. It also provides voice network services such as virtual private networks (VPNs), account card calling and Freephone as managed on this network;
- **Management network** is required to allow the management of the network. OSS provides the TSP the ability to set up the network and services. The BSS is used to manage the customers that make use of the network and the services.

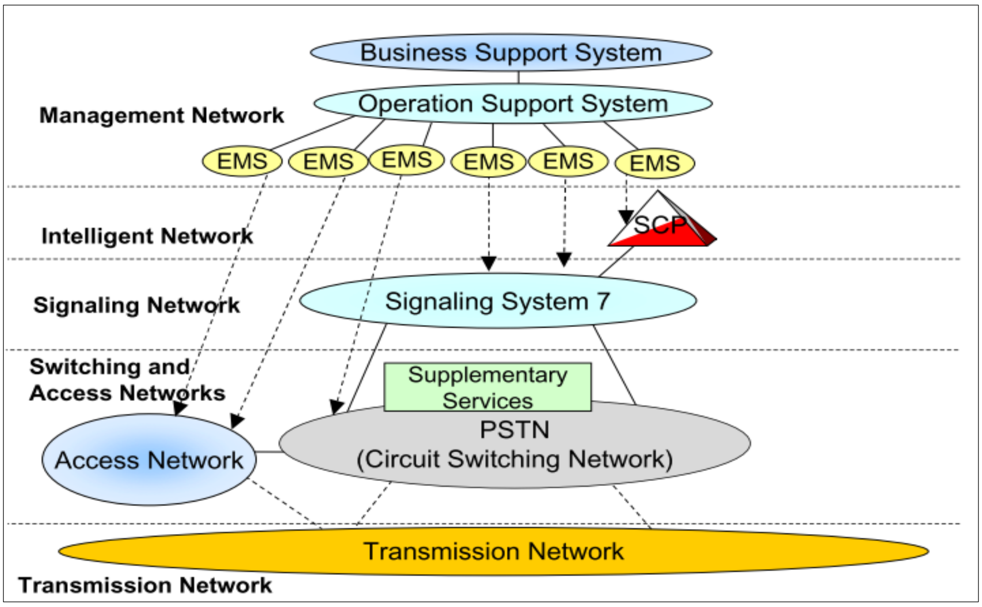



**Figure 2-3: Fixed Voice Network - Public Switched Telephone Network (EFORT 2010)**

Telecommunication networks are moving away from the PSTN type networks, which make use of analogue transmission, to using digital transmission through the use of the IP. IP is a protocol which breaks the data into packets and transmits the data across the network. Figure 2-4 illustrates the IP network, which makes use of the transmission network and can be accessed by networks such as broadband access networks. The IP-based networks allow IP Services such as IP television and IP telephony (VoIP and VoD) as well as Internet Services (mail, web services etc.) to be made available to the user.

TSPs are responsible for managing the networks and the services that run over the networks. TSPs manage the services using the BSS and OSS, which is also used to monitor how the customers make use of the services. The next section discusses how the management of TSU is handled by TSPs.

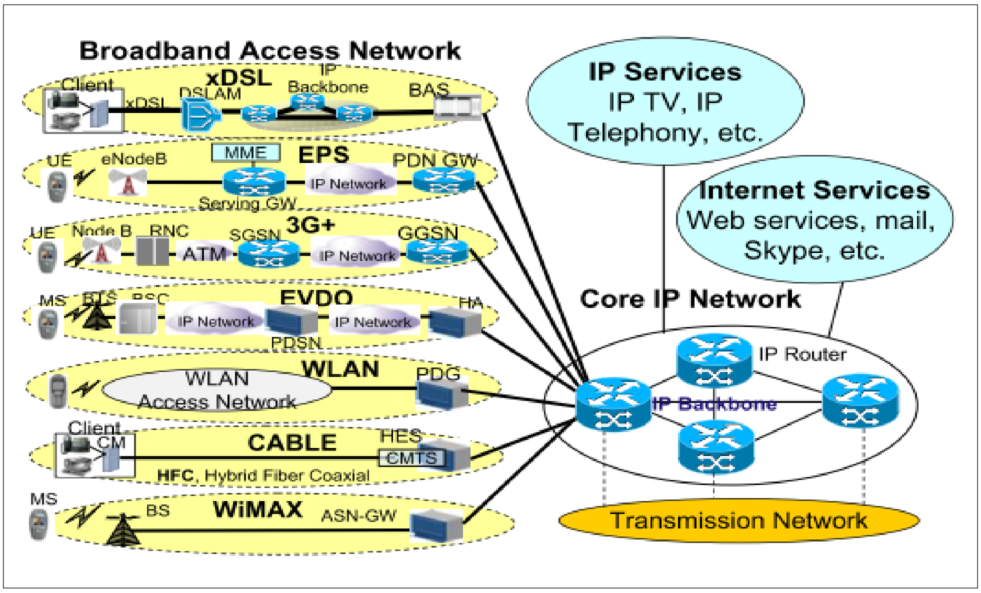



**Figure 2-4: Telecommunication Network using IP Network (EFORT 2010)**

## 2.4 Telecommunication Service Management

Telecommunication service management (TSM) is focused on the provisioning, fulfilment and assurance of telecommunication services (Buford 2001). The diverse and digital convergent services provided by TSPs introduce several challenges as the various services cannot be managed in exactly the same manner (Chen *et al.* 2010). TSPs are finding it difficult to offer differentiated value added network services that can effectively meet the expectations of the customer. TSPs need to ensure that they adopt an agile approach in their management strategies to ensure that they can respond to the fast-changing multi-technology environment. The use of software support systems can be used to supplement an agile approach by readily providing information to decision makers. OSS can effectively support decision making, which can assist in providing competitive services. The OSS needs to ensure proactive and reactive monitoring of services for quality assurance purposes. TSPs invest extensively in OSS for their existing network and to assist with the management of the networks and services (Buford 2001). In order to effectively utilise OSS, an understanding of the various components of managing the services is required.

To ensure effective and efficient management of telecommunication services, TSPs need to follow a framework for managing services. Two widely adopted management frameworks are the Enhanced Telecom Operations Map (eTOM) and the Information Technology Infrastructure Library (ITIL) (Hewlett-Packard 2008).

The eTOM is a framework that models the various business processes, specifically designed for TSPs, and provides guidelines on how the various business processes should be integrated for effective service management (Bertin, Fodil and Crespi 2007). The eTOM model focuses on how business processes should be integrated to improve customer service quality rather than focusing on handling network problems (Wong, Ting and Yeh 2007). The eTOM model does not directly specify the processes for managing service utilisation (Bertin, Fodil and Crespi 2007). Service usage operation processes should be considered when implementing the eTOM model as controlling and monitoring of service utilisation can provide management with valuable information as to how services can be improved to provide more value to the customer. An alternative framework that is commonly used is the ITIL framework which is discussed in the next section.

### 2.4.1 Information Technology Infrastructure Library

The convergence of the Internet and telecommunication has led to TSPs adopting the information technology service management (ITSM) approach to the normal service management approach. ITIL is an ITSM framework, which provides a set of best-practice guidelines for managing services (Zhu, Song and Song 2009). ITIL is considered the most popular framework that describes best practices for management of IT services (Cartlidge *et al.* 2007). The ITIL framework describes five main stages for the management of services: service strategy; service design; service transition; service operation and Continual Service Improvement (CSI). Service strategy refers to understanding and determining which services to offer as well as identifying the target market. The business will need to specify how the services are classified and evaluated for quality purposes. Service design looks at how to apply best practices to design innovative services which includes how the services architectures, policies and documentation need to be completed to meet the business requirements. The service transition phase is dedicated to evaluating, testing and validating a service before the service is transitioned into the live environment. Service operation is the phase which describes what management should do to ensure that the agreed upon levels of service are delivered to the customer. This includes the technology and infrastructure required to utilise the services.

The CSI phase of service management is focused on ensuring that the customers receive the value they require from the services (Cartlidge *et al.* 2007). This is done by constantly evaluating and improving the quality of the services. CSI incorporates quality management, change management and capability management. CSI has three key activities which are the seven-step improvement process: Service Measurement and Service Reporting. The seven-step improvement processes collects and analyses data about a service to identify issues. This information is passed on to management for decision making. The seven-step improvement process focuses more on how the services can be improved to assist the organisation on a strategic level. The seven-step improvement process starts off by defining the measurements and what can be measured in order for the organisation to achieve set goals. The next few steps focus on gathering, processing and analysing data to support the measurements. The final steps focus on presenting information and implementing corrective actions to improve the services in order to meet the organisation's goals.

Service measurement looks at ways to evaluate the service. The three types of metrics that need to be collected are: technology metrics (performance, availability), process metrics (critical success factors, Key Performance and activity metrics) and service metrics (metrics specific to the service). The ITIL model specifies that services should not just be measured at a component level, but should also capture a view of the customer experience of using the services. The third activity of CSI is reporting, which focuses on aggregating information on the delivery of quality service to the customers. The reports need to include historical information which highlights events that continue to occur, seen as threats. The ITIL model states that reporting on whether SLA have been met is not enough, as the reports need to build a more actionable approach of how the service has been used. Thus the ITIL framework motivates reporting on service utilisation. Service measurement and service reporting are used alongside the seven-step improvement process to improve the services as shown in Figure 2-5.

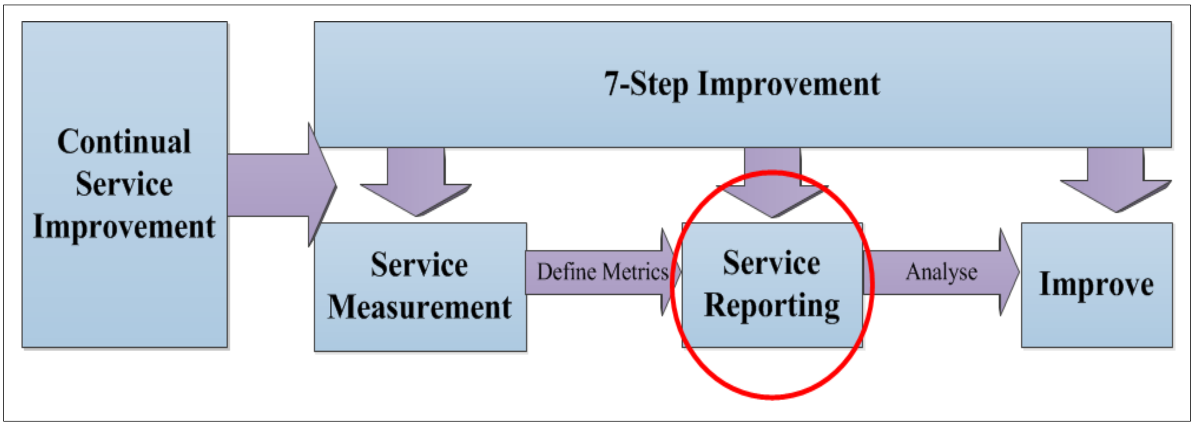



**Figure 2-5: Continual Service Improvement Phase of the ITIL Service Model (Cartlidge *et al.* 2007)**

The ITIL framework for management of telecommunication services support reporting on service utilisation. The management framework does not clearly describe how to handle service utilisation, which is important in affecting the service quality. Research has been proposed to include a service usage operation process in the eTOM framework to describe the management of TSU (Bertin, Fodil and Crespi 2007). The next section focuses on TSU and discusses the importance of the management and reporting on TSU.

## 2.5 Management of Telecommunication Service Utilisation

TSU focuses on what services a customer uses and the behaviour of the service when in use. TSM frameworks specify that part of service management involves reporting on TSU (Section 2.4.1). An investigation is required to explain the importance and how to report on TSU. The subsections will discuss the importance of analysing service utilisation and the data captured when a service is used by a customer.

### 2.5.1 Importance

Information about customer-service usage can support TSPs to better understand customer behaviour and to respond to unexpected events (Koutsofios *et al.* 1999). Analysis of telecommunication service data can lead to an improvement of services for customers, as an understanding of previously hidden relationships can be obtained. TSM therefore needs to monitor the services to make decisions about how to improve the service. Service utilisation information can provide valuable information about customer behaviour, which can assist in a variety of ways (Hewlett-Packard 1999):

- Having information about customer behaviour assists market research as the TSP can target a specific customer for certain services;
- Customer service representatives can identify potential problems, using customer behaviour information, and make recommendations to the customer about upgrading or changing the customer's current solution;
- Network engineers will have a better understanding of the services and can make architectural changes to offer better levels of service;
- Customer behaviour information will also assist in identifying any SLA violations experienced by the customers.

TSU data is aggregated and used for strategic marketing, capacity planning, usage-based billing and fraud management (Hewlett-Packard 1999). Suitable usage-monitoring software needs to be in place to collect and store service usage data which will be used for decision making purposes as discussed above. The next section discusses how service usage data is captured and the structure of the TSU data.

### 2.5.2 Service Monitoring

Service monitoring is the real-time observation of the behaviour of services and records how the services are used (Microsoft 2011). The goal of service monitoring is to:

- Monitor that the services are functioning correctly;
- Perform the necessary actions to handle any service incidents or system events that may occur;
- Capture and provide the data on the service that can be used in decision making to improve the services.

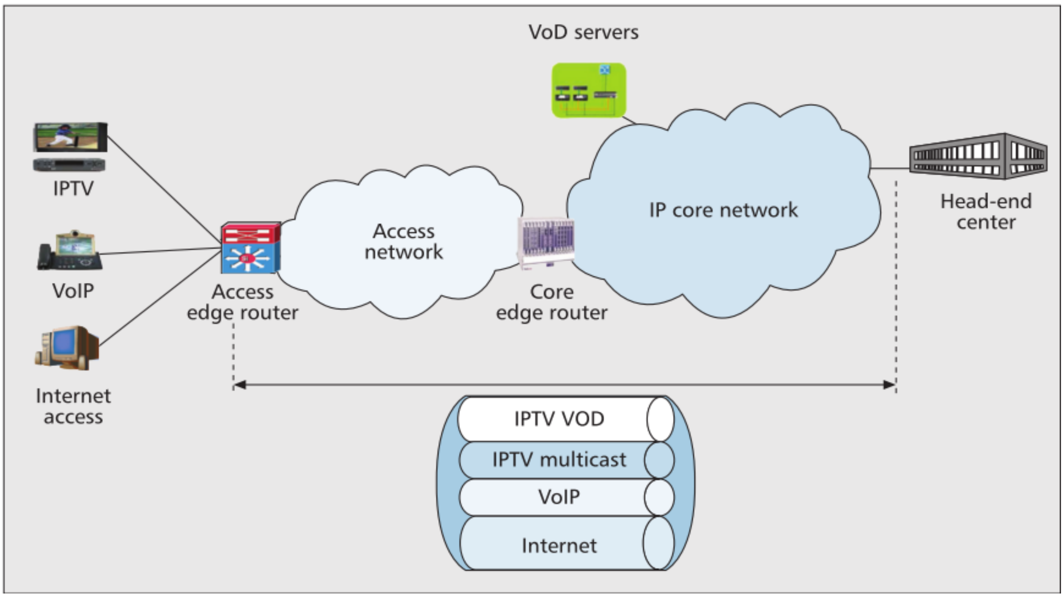



**Figure 2-6: Multiservice IP Network Environment (Choi *et al.* 2010)**

There are multiple services that run simultaneously over an IP network (Figure 2-6). The services are made available via the access network, which is connected to the IP core networks. When the IP services are used by a customer, the traffic flow is passes through the routers and other network devices. These devices on the network collect traffic flow information about the service that is running over the network (Choi *et al.* 2010). Legacy traffic management systems collect incoming/outgoing traffic from the network devices and can analyse flow-level traffic and application-level traffic but cannot monitor service traffic management. Newer complex traffic management systems are being implemented on IP networks to support analysing service traffic flow. These systems are able to generate user behaviour log data, which includes service usage data. The traffic flow data that is collected is measured from end-to-end sessions, which means that information is gathered from the source to the destination of the traffic flow data.

There are different approaches to capturing the traffic flow data to extract service usage related information. The next section focuses on what information is stored concerning the usage of a service by looking at what is captured from the various telecommunication services.

### 2.5.3 Service Usage Data

A usage log is generated every time a user makes a request from a service where a method is invoked, causing an event to occur. Figure 2-7 illustrates a high-level database diagram, which is used to store the event information when a customer uses a service (van der Schuur, Jansen and Brinkkemper 2008). The diagram illustrates that there is a many-to-many relationship between the customer and services as a customer can have many services. A service can be utilised by multiple customers and thus the *servicePerCustomer* class is used to store services for which a customer is registered. Each service has one or more methods which are invoked to utilise a service. For example, an email service would have a method called "send message" which will send an email when invoked.

When a service is used, information about the results of the service is logged, which is called an Event. The event describes how the service has been used. The purpose of having events is to allow the construction of metrics that will be used in the context of service usage logging (van der Schuur, Jansen and Brinkkemper 2008). RequestEvent captures the methods that the various services have invoked and ResponseEvent stores information about how the service performed the request.

The information stored about service events, as illustrated in Figure 2-7, provides insight into the service performance but does not incorporate detailed service usage information. Figure 2-7 provides knowledge that an event is stored every time a service is utilised. In order to report on service utilisation, the format in which the service usage information is stored needs to be investigated. This subsection will discuss a suitable approach that can be used to collect and store service usage information.

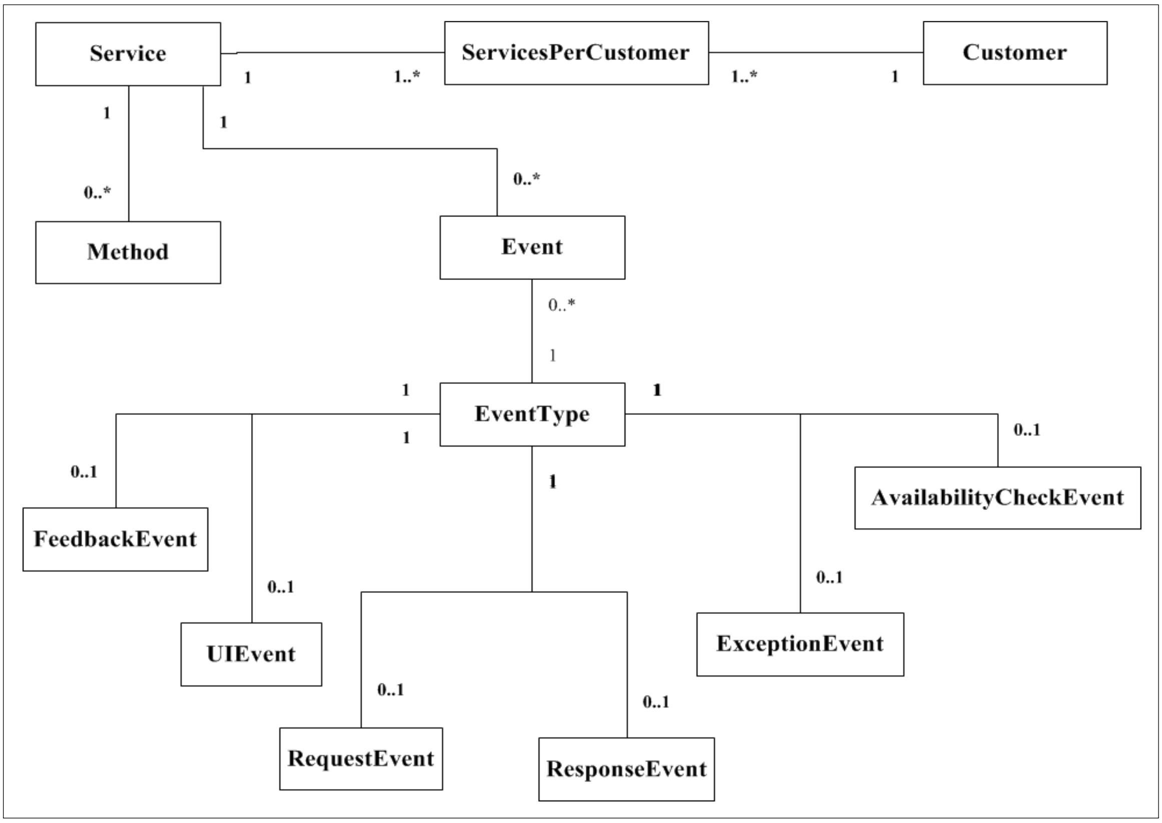



**Figure 2-7: Database Diagram for Capturing Service Usage (van der Schuur, Jansen and Brinkkemper 2008)**

#### 2.5.3.1 Internet Protocol Detail Record

Internet Protocol Detail Record (IPDR) is a protocol that addresses the challenge of transferring network measurement and management information, specifically service usage information (Cotton 2000; Guo, Dunstan and Finkelstein 2011). This protocol can provide for effective extraction of usage information, which can be used by the OSS and/or the BSS to assist decision making. IPDR provides the advantage of being able to describe the different types of usage information that can be obtained for a service. The IPDR protocol can only be used on IP networks to collect service usage data. Section 2.3 identified that there is a greater adoption of IP networks due to the shift from voice to data services and thus the IPDR is becoming a more suitable format for storing TSU data.

IPDR protocol specifies that service usage information should be captured in an IPDR document, which is an eXtensible Markup Language (XML) template for storing usage information for different IP-based services. The IPDR document records contain five common attributes of a service that provides usage information. Table 2-1 contains the high level attributes and the description of the attributes. The attributes of an IPDR document in Table 2-1 describe a specific network event that has occurred such as an email being sent or a voice call that has been made (Guo, Dunstan and Finkelstein 2011). A requirement of the IPDR record structure is that it needs to characterise any type of service usage information that is collected from an IP-based network or application service (Cotton 2000).

**Table 2-1: High Level Common Attributes of IPDR (Guo, Dunstan and Finkelstein 2011)**

| Type | Description |
|---|---|
| Who | User ID or Device |
| When | End Time or Event Time |
| What | Service Usage Measures<br>Quality of Service Measures<br>State Information<br>Event Code |
| Where | Traceability/Context<br>Source Identifier<br>Destination Identifier<br>Service Element Identifier |
| Why | Event trigger type |

In analysing the type of common attributes in Table 2-1, the following types are described for the purpose of the research:

- "Who" refers to the customer that is making use of the service;
- "When" refers to the time and duration that the service was in use;
- "What" is an attribute that is different for each service. Each service has a specific set of usage measures to describe the behaviour of the service during use. Table 2-2 illustrates an example of the usage measures used for an email service;
- "Where" will refer to the customer site from which the service is utilised;
- "Why" is not applicable as it refers more to how a service is stopped from being used.

**Table 2-2: Example of Usage Measures for Email Service using IPDR Format (Cotton 2000)**

| Category | Usage Attribute Name | Data type |
|---|---|---|
| What | ProcessingTime | Integer |
| What | Storage | Integer |
| What | StorageDuration | DateTime |
| What | BytesTransferred | Integer |
| What | EventTime | DateTime |

The IPDR format can be used for various BSS. Figure 2-8 illustrates the various layers involved in the transfer of IPDR data to support billing, analysis and reporting, DSS and network operations. The bottom layer is the network and service elements which contain all the equipment required to provide a service such as routers or other access devices to a customer. The mediation layer, in terms of handling service usage data, is responsible for capturing all the usage data from the network and service elements to provide the information to the BSS. The mediation layer aggregates and normalises the usage data for further processing by the BSS. The BSS layer consists of systems such as DSS, market analysis and fraud detection system, etc.

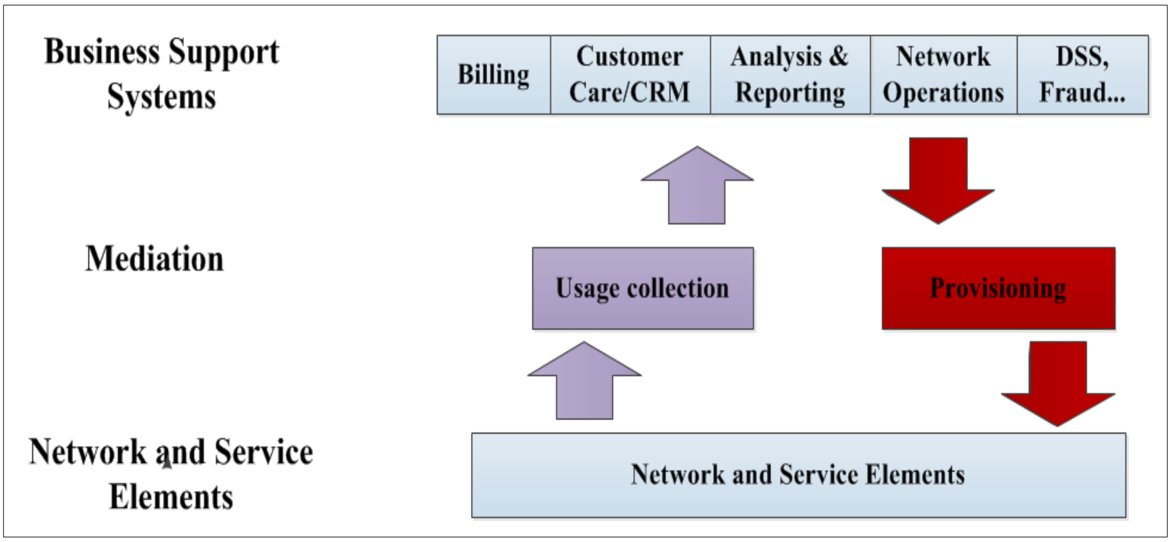



**Figure 2-8: The IPDR High-Level Flow Model (Cotton 2000)**

IPDR can be used to effectively manage the services by assisting with the following (Finkelstein and Schnitzer 2009):

- Billing of a service based on subscriber usage;
- Network capacity analysis and planning;
- Service optimisation and product development;
- Quality of experience monitoring.

IPDR provides the capability for gathering detailed per-customer, per-service flow information which can be used to perform advance analysis. The usage pattern of a service can more easily be obtained by using IPDR data format. The IPDR data is temporal as the service usage is logged at time intervals. The service usage information obtained from an IPDR contains four dimensions on which reporting can be done: “Who”, “When”, “What” and “Where”.

There are three basic types of usage records that can be collected and are important for defining the usage measure of a service (Ryan *et al.* 2004). The usage measure for a service is important for applications such as usage-based billing, where the customer is billed based on how the service is used. The basic types of usage records are:

a) **Duration-based** usage records relate to services, where the usage attributes are based on the duration of time the service is used. For example, a VoIP service will have a duration-based usage record as a start time and end time are recorded. The duration of the call can be calculated and used as a metric to evaluate the usage of a VoIP service (Ryan *et al.* 2004).

b) **Event-based** usage records relate to services, where information about the number of times the service is used is of value. Text messaging services are stored as event-based usage records (Bhushan *et al.* 2005).

c) **Volume-based** usage records store the amount of service usage, such as how much data is transported when using a Wireless local area network service. Internet services, such as email and the internet access, store the volume of data exchanged between the customer and the service as the usage measure (Bhushan *et al.* 2005).

The type of usage measure for a service needs to be known when service usage information is being analysed. Insight into the type of usage measure for a service can assist to determine how the service is used, which is valuable knowledge. A service is not restricted to having a specific type of usage measure (Bhushan *et al.* 2005). Table 2-3 and Table 2-4 contain a description of the types of questions that could be asked when analysing usage data for a specific usage measure, which relate to the average, ranking and trend information (Aogon and Ogao 2007).

**Table 2-3: Types of Questions that can be Answered per Usage Measure Type**

| Usage measure Type | Information that can be obtained for a service |
|---|---|
| Duration-based | • What is average period that a service is used?<br>• What is the longest or shortest duration a service is used?<br>• Are there any periods where the service is used for an abnormal duration? |
| Event-based | • What is the average number of times a service has been used?<br>• When the service is used the most or least?<br>• Are there any periods where the service is used an abnormal number of times? |

**Table 2-4: Types of Questions that can be Answered per Usage Measure Type (Continued..)**

| Usage measure Type | Information that can be obtained for a service |
|---|---|
| Volume-based | • What is the average amount of data (bytes) transferred when a service is used?<br>• What is the largest or smallest amount of data that a service has transferred when used?<br>• Are there any abnormal amounts of data transferred when a service has been used for a period of time? |

### 2.5.4 Related Systems

Reporting tools in the telecommunication industry are mostly geared toward monitoring the network and not on the services that run on the network. Two reporting applications identified, that can provide some type of service usage reporting, were identified. The first is SecureLogix's enterprise telephony management (ETM) usage manager and the second is a customer portal by Comcast.

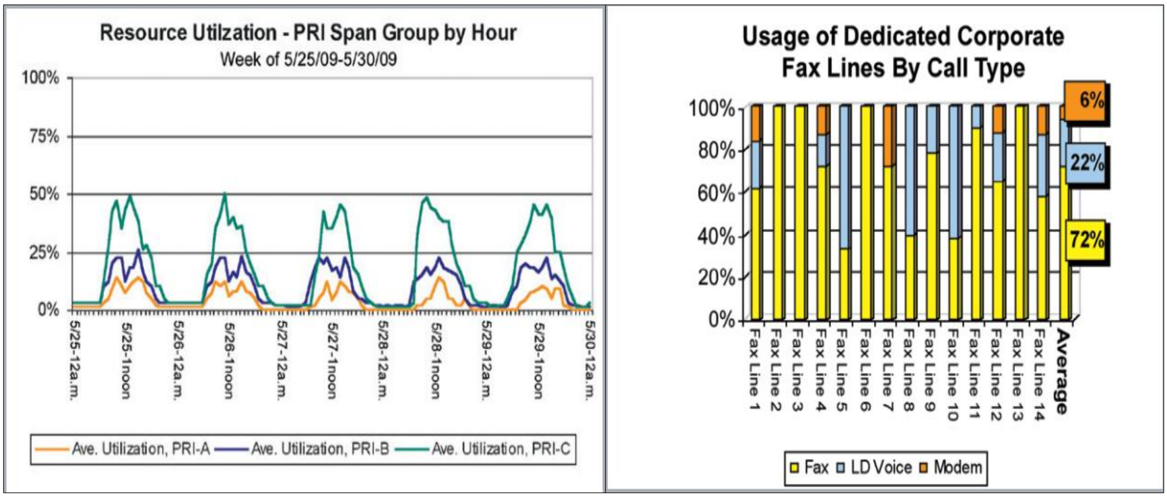



**Figure 2-9: Examples of Usage Reports Generated from ETM Usage Manager (SecureLogix 2011)**

ETM Usage Manager is a reporting application for voice-based services that provides usage and performance information (SecureLogix 2011). ETM Usage Manager assists with capacity planning and service management. Figure 2-9 illustrates a snapshot of two reports generated by ETM Usage Manager. The user can analyse volumes, trends and traffic patterns of call data. The reports generated in Figure 2-9 visualise the resource utilisation on the network for a period of time and the second report illustrates the usage of the fax lines by call type. The reports are generated by selecting criteria and to obtain a different view of the information, another query needs to be performed.

Figure 2-10 illustrates the Comcast Usage meter, which monitors and reports on the amount of traffic a customer uses for a period of time (Sevcik 2010). The goal of the system is to reflect only the customer traffic that passes through a cable modem. The customer accesses the usage meter via a customer portal and requests to view details of the service usage. The system aggregates traffic information and displays the service usage information over the different months the service has been used. Comcast Usage Meter makes use of IPDR documents and extracts usage information from these documents. Users are able to have multiple views of the usage data by specifying whether they want to view usage on a computer, the network or on the meter.

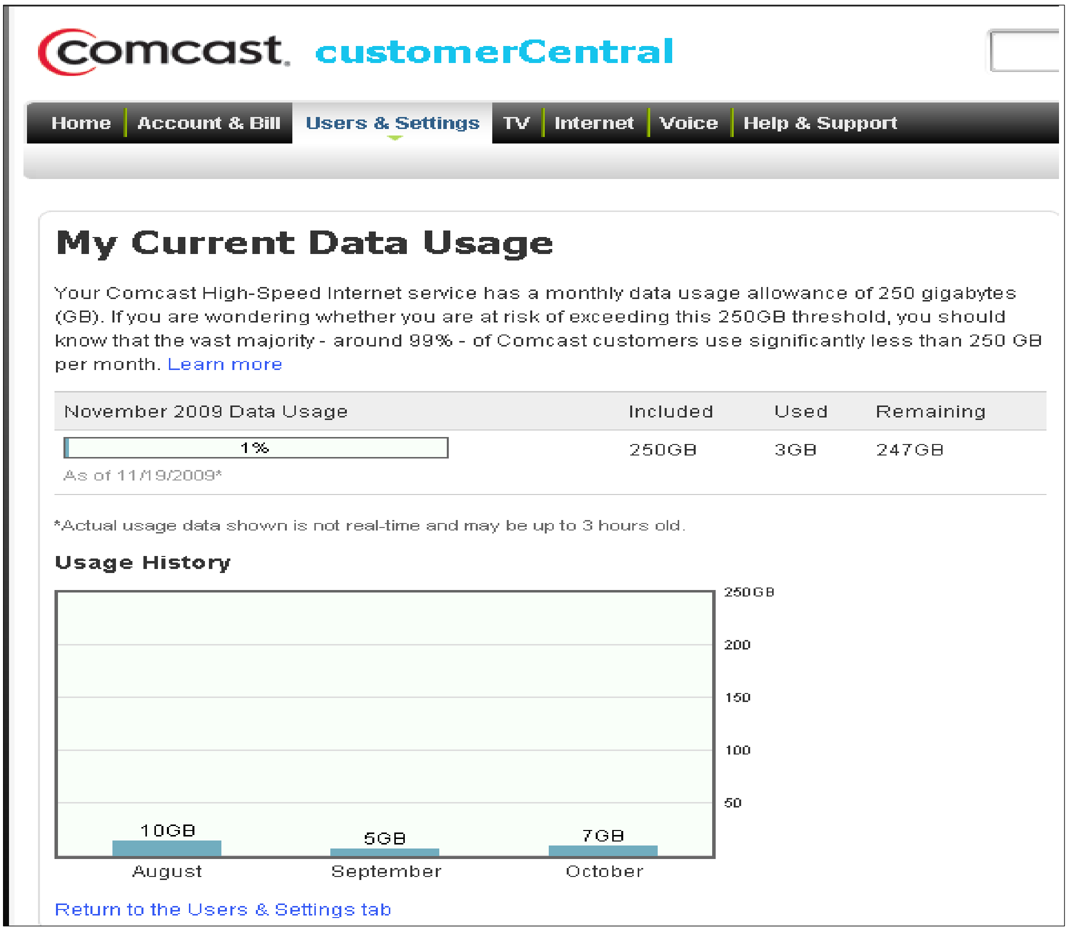



**Figure 2-10: Comcast Report Illustrating Customer Internet Usage Data History (Sevcik 2010)**

The reporting tools identified are not focused on reporting on different types of service usage. The tools are focused on a particular service, which will not be able to provide a customer with an overall view of the service usage. Another issue identified was that the reports are static, thus not allowing any form of manipulation. The ETM usage manager provides different templates to be generated, but the process for doing so is not fluent. Different views cannot be easily obtained. The software tools will not be suitable to effectively support the visualisation of TSU data for in-field investigation. Current software tools for TSU do not cater for different types of service types.

The literature study has identified that service usage information is important, to improve the quality of the service needed for customer satisfaction. The next section will focus on an interview study conducted to gather requirements for reporting on service usage and understanding how TSU is handled in practice.

## 2.6 Interview Study

Two interview studies were conducted to gain insight into the TSM domain and gather requirements for reporting on TSU. The first interview study was conducted with a TSP in South Africa. The second interview study was conducted with Information Communication Technology (ICT) system engineers from the Nelson Mandela Metropolitan University (NMMU).

### 2.6.1 South African TSP Interview Study

An interview study was conducted with a large TSP in South Africa. A semi-structured interview was performed with the company with the purpose of gathering information to understand how the TSP manages its services. The interview was guided using the questionnaire in Appendix A. The interview was recorded on a dictaphone and the recording was saved, and transcribed to perform content analysis. Six participants were interviewed who had expertise in various fields in the management of telecommunication services. The job roles of the participants varied from Senior System Engineer to Chief Solution Architect. The participants assisted in obtaining different perspectives on how telecommunication services are managed and the management of TSU. The company will be referred to as “Company A” in this section for confidentially purposes.

#### 2.6.1.1 Services

Company A classifies their services as shown in Table 2-5 into the following categories: Communication, Connectivity and Cloud. The choice for the specific classification is that it allows clients of Company A to easily interpret the services that are offered. Communication Services referred to in Table 2-5 are services that provide human-to-human communication through the use of Internet-technology enabled network. The Connectivity category used by Company A refers to services that provide reliable, secure and appropriate access to networks such as the Internet. Cloud relates to all the services that Company A offers which focus on managing a client's data. This includes providing storage facilities that are accessible, secure and interoperable with the client's systems. The classification of services into categories allows Company A to describe service bundles by the category in which the services fall. For example, a service bundle can consist of email, fax and voice which would then be described to the customer as a communication service bundle. A Voice-over Internet Solution is a VoIP service which has been renamed for branding purposes by the company.

Company A provides their customers with a connection to a multi-protocol level switch (MPLS) network, which provides backhaul connectivity for the different geographical regions. A VPN is created on the MPLS network for each customer, which is cheaper than creating a circuit between the different customer sites. Company A provisions the telecommunication services by integrating the services with the MPLS network. The customer can then access the services through the provisioned VPN.

**Table 2-5: TSP Services in Service Categories**

| Category Name | Service examples |
|---|---|
| Communication | • Voice over Internet Solutions<br>• Mail, Messaging<br>• Fax |
| Connectivity | • Fixed Broadband<br>• Mobile Broadband<br>• Managed Data Network Services<br>• Internet Access |
| Cloud | • Cloud Managed Services<br>• Security and Cloud IP Services<br>• Domain<br>• Co-Location |

### 2.6.1.2 Service Utilisation

During the interview, one of the interviewees from Company A stated that "service usage information is important".

Company A has systems in place to monitor the network utilisation for a particular customer. It makes use of a system called Fenix, which generates graphs that illustrate the line usage for different services. An example of a graph generated by Fenix is shown in Figure 2-11, which provides information about how the available capacity of a line being used. The graph uses a 2-D graph to show the bits per second transferred for a period of time. Fenix makes use of threshold line to illustrate high or low usage. The threshold line is shown as a dotted line in Figure 2-11. Specifying thresholds is important, as it assists in better understanding of the context of the usage information, in terms of what is deemed as high and low usage levels. The reports that are generated by Fenix are static reports based on a specified query.

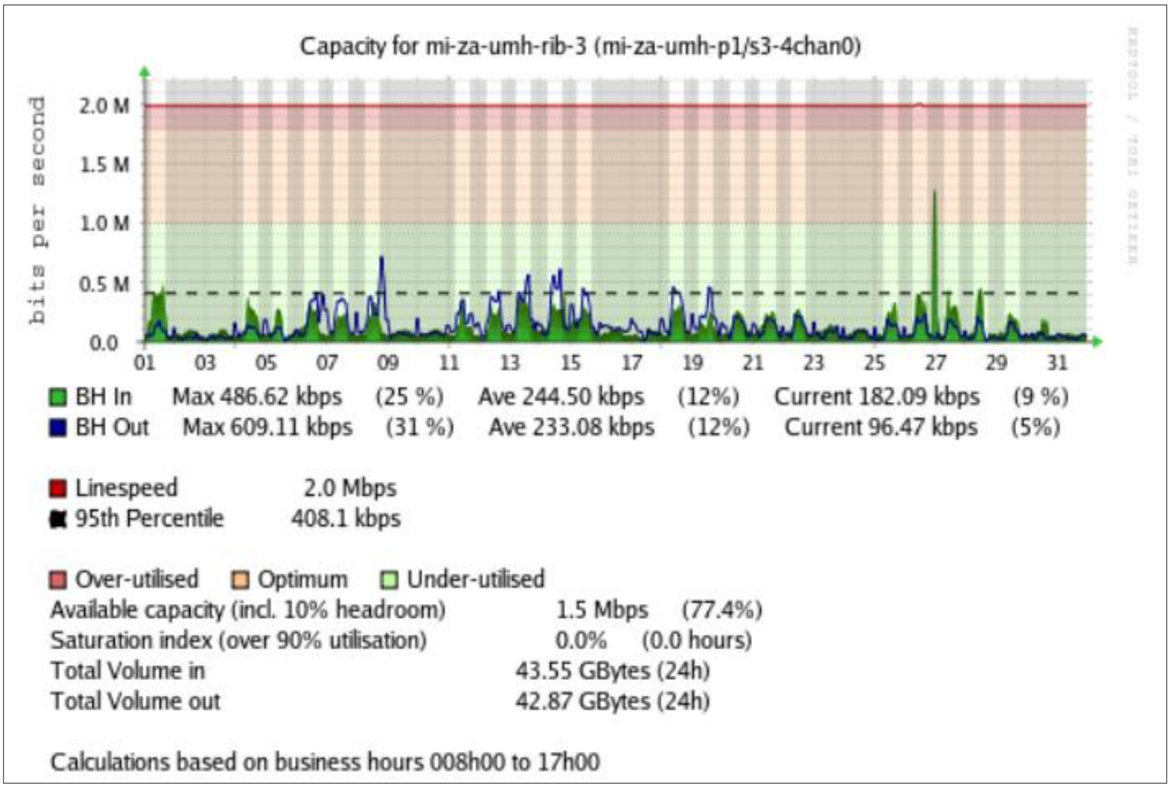



**Figure 2-11: A Graph Generated Using Fenix to Show the Capacity Usage**

The problem with the reports generated by Fenix is that it assumes that the person reading the reports has an understanding of the underlying technology and how the technology works. The report is difficult to interpret and is suited to technical personnel but is not suitable and is irrelevant to the customer. The presentation of the information is therefore not suitable for communicating the customer service usage during in-field investigation. Company A also has tools for hosting services, where the customer can make use of a traffic usage service to view how the traffic is flowing on the customer’s network.

Company A provides its customer with an Internet portal known as Customer Zone. Customer Zone provides the customers with the ability to understand the underlying network. The portal provides line tag information, which can provide multiple graphs on information such as availability, traffic utilisation and latency. The graphs on Customer

Zone are static and the portal is out-dated. The information made available on the customer portal is not easily understandable and requires assistance to understand it. Other information that the portal provides is granular statistics, which provides information such as source IP, destination IP and how much data flows between the points in the network.

Company A currently, have an initiative in place, to provide the customer with a type of a dashboard reporting for all the monitoring and statistics about the customer's services. This will provide the customer with an overall view of their services and detailed information such as service performance, SLA violations, *inter alia*. An interviewee mentioned that dash boarding could be applicable for mobile devices and more summary data could be presented on a smaller screen. A dashboard view of the customer could serve as an effective tool when communicating with a customer about the customer's TSU details.

Company A has a problem that the information about each service, customer data and service utilisation data is all stored in separate databases with no aggregation available. Aggregation of all this information can assist in obtaining an overall view of the services, which clients use which services and how they use these services. This overall view can assist in effective strategic decision making. Therefore a visualisation tool could support this need as it will provide an aggregated view of how the different services are used.

The participants commented that when a customer service representative goes out to consult with a customer, large amounts of documentation need to be compiled. This information is static and thus cannot be dynamically manipulated.

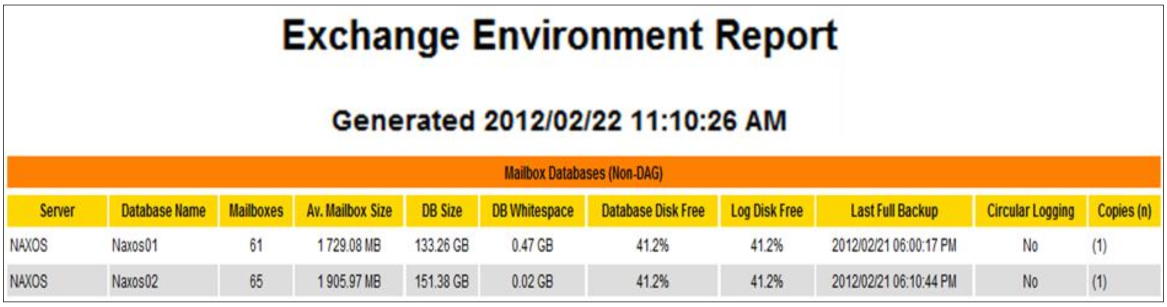
The interview study with the South African TSP supports the problem identified in this research. The current reporting methods for TSPs do not provide interactive exploration of the service usage information and do not support visualising the usage of different types of services.

### 2.6.2 NMMU ICT Staff

A second interview study was conducted with ICT engineers from the NMMU. The goal of this study was to gather requirements for reporting on service utilisation. A semi-formal interview was conducted with three ICT engineers who have experience with networking, email and end user management and thus have experience with TSU. The interview was guided using the questionnaire in Appendix B. The information gathered from this interview study is categorised and discussed in the following subsections.

#### 2.6.2.1 Data Views

There are many different views for service usage that are required for reporting. The views include information for different time periods, such as day, month and year. Statistical indicators, such as means, averages and total counts, are also required in the different views. Email statistics are more valuable if these can be viewed for a particular day, month and year. Information that can be viewed about email is the number of emails sent or received for a particular time period. The top users that send or receive emails also need to be reported on. The IT engineers require reports about email usage: for example, a comparison of the email usage from a year ago with the last twelve months. Other information about the email usage is the average mailbox sizes and the mailbox size per user. Figure 2-12 illustrates a report that can be generated for mailbox sizes for a particular server and includes the average mailbox size for the server. For Internet usage monitoring, the IT engineers require information about the usage for a certain time of the day. The internet usage data can be viewed on a particular switch or a router. It is also required for internet usage to make comparisons between the different years. Another type of usage monitoring done by the IT engineers is log-in usage, where information about the highest number of log-ins has to be obtained for a particular machine.



Exchange Environment Report

Generated 2012/02/22 11:10:26 AM

| Mailbox Databases (Non-DAG) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Server | Database Name | Mailboxes | Av. Mailbox Size | DB Size | DB Whitespace | Database Disk Free | Log Disk Free | Last Full Backup | Circular Logging | Copies (n) |
| NAXOS | Naxos01 | 61 | 1 729.08 MB | 133.26 GB | 0.47 GB | 41.2% | 41.2% | 2012/02/21 06:00:17 PM | No | (1) |
| NAXOS | Naxos02 | 65 | 1 905.97 MB | 151.38 GB | 0.02 GB | 41.2% | 41.2% | 2012/02/21 06:10:44 PM | No | (1) |

**Figure 2-12: Report Generated for the Email Mailbox Sizes at NMMU**

#### 2.6.2.2 Thresholds

The current norm that is used to indicate the different levels of thresholds is to use a colour coding scheme. The reporting systems that the IT engineers use, indicate the level of usage by using green, orange and red. Green represents that the usage level is normal; orange represents minor issues and red indicates that there is high utilisation and that a major issue has occurred. The IT engineers make use of thresholds for the network utilisation information, which is a fixed value of 40% of the resources available. The use of thresholds allows the user to identify concerns about the utilisation easily.

#### 2.6.2.3 Monitoring Systems

NMMU makes use of Cisco software to monitor the networks. The network monitoring tools are focused on providing information about the data that is being transferred over the network and cannot provide information, such as usage count. OpenNMS, which is a network management application platform, is used by the IT engineers to manage the network. OpenNMS makes use of the simple network management protocol (SNMP) to collect network usage information. The SNMP protocol allows network-related information to be gathered, such as, when there are outages and if something has gone wrong with a server. The thresholds mentioned above are used to indicate to the IT engineers any issues identified from this information. OpenNMS also provide mobile solutions which are available for the iPad and iPhone. The mobile solution provides the ability to view event details and resource graphs, but does not provide service usage information.

#### 2.6.2.4 Decision Making Support

There are many types of decisions that can be made regarding the users email and internet usage on the networks. Managers can make informed decision about the Internet line speed that should be used, based on the Internet usage information. A manager could view usage information from five years ago where a 512 kilobyte line was used and decide, based on the increase of the utilisation, that a 1 megabyte line should be installed. Knowledge about the services that are running over the network and the usage of the services affect the Internet bandwidth. For example, if email, voice, video conferencing, enterprise resource planning systems and Internet traffic are running on a network, then a 1megabyte line would be insufficient and thus an analysis of the services on the network needs to be done.

Each user is allocated a fixed mailbox size and the size can be increased if the request for an increase is well-motivated. The number of users does not affect the size of the mailbox. Information that needs to be obtained about email is the user that sends the highest amount of email and the effect on the storage space. Information about whether a user reaches the maximum storage cannot be obtained as the user is allowed to exceed the storage limits but will not be able to send and receive emails.

For the managers to make decisions about increasing the internet capacity, historical data is required as current information is not able to provide trend information. Service usage information can also be applied when viewing SLA. For example, the manager would want to know if the email SLA has been met, which states that a certain percentage of email messages have been delivered within a specified time period. The managers prefer a dashboard approach with the reports, as it provides an overall view.

#### 2.6.2.5 General Comments

The IT engineers were asked to comment on the use of mobile devices, such as tablet devices, in the working environment. The general consensus was that it would be useful to provide reporting functionality on a mobile device. Mobile devices provide the advantage of constant connectivity and easy access. The tablet device is not applicable for more than two people as the orientation of the users sitting and the screen size limit what can be viewed. The Exchange engineer commented that email reporting is shared through SharePoint, which is the communication protocol used. The network engineers make use of their Blackberry smartphones to access network information.

Another problem that was identified is that some of the systems that report on usage information require a lot of scrolling, which is found to be frustrating. TENET is the TSP used by NMMU to provide internet access and information about the internet traffic going in and out can be obtained via the TSP’s website. The site provides powerful reporting capabilities but lacks intuitive interactive features.

In conclusion the key points that can be identified from the interview study are:

- Service usage information is important for decision making;
- Thresholds should be used to specify the different levels of service utilisation;
- Information made available on the customer portal is static and not easily understandable;
- Dashboard reporting can provide an overall view of the customer’s service usage;
- Dashboard reporting can be used on a mobile device as an effective communication tool;
- Descriptive statistics for TSU data should be reported on;
- Aggregation of a customer’s service usage information is required;
- Engineers requires time related information to support decision making;
- Current software tools for reporting on usage information lack intuitive interaction and cannot be used for in-field investigation.

## 2.7 Requirements for Reporting on Service Utilisation

From analysing the literature study and the interview study conducted in this chapter, requirements for reporting on service utilisation are tabulated in Table 2-6.

**Table 2-6: Functional and User Requirements for Effectively Reporting on Service Usage Data**

| Ref No | Requirement | Section(s) |
|---|---|---|
| | | |
| | **Functional Requirements** | |
| R1 | Load IPDR data | 2.5.3.1 |
| R2 | Support different types of service usage data types | 2.5.3.1 |
| R3 | Display service usage information from different perspectives | 2.6.2.1 |
| R4 | Allow thresholds for service usage information to be specified | 2.6.1.2, 2.6.2.2 |
| R5 | Provide mobile access to TSU data | 2.6.2.5 |
| | **User Requirements** | |
| R6 | Request a customer’s service usage data | 2.5; 2.6 |
| R7 | Dynamically manipulate TSU reports | 2.5.4, 2.6.2 |
| R8 | Switch between different view of service usage information | 2.5.4, 2.6.2.1 |
| R9 | Provide a dashboard for quick view of information | 2.6.2.4 |
| | **Information Requirements** | |
| R10 | View information about when, where and how the service has been used | 2.5.3.1 |
| R11 | View the usage measures for a specific service | 2.5.3.1 |
| R12 | View information about customer usage patterns | 2.5,2.6 |
| R13 | View statistical information about service usage such as average, ranking and outliers | 2.5.3.1<br>2.6.2.1 |
| R14 | View service usage for different time periods | 2.5.4<br>2.6.2.1 |
| R15 | View the overall customer service usage | 2.5<br>2.6 |
| R16 | View the service usage per customer site | 2.6.1.2 |
| R17 | View of dashboard of customer service usage | 2.6.1.2 |
| R18 | View service usage information that has exceeded the specified usage threshold | 2.6 |

## 2.8 Conclusion

The objectives of the chapter were to address the first two research questions, concerning the management of TSU and how TSU can be used to support decision making. ITIL is a framework describing the management of services and supports reporting of TSU. There is currently, no clear process for the management of TSU but the chapter has identified the importance of TSU and how it can be used to assist decision making for service improvement.

This chapter completes the first phase of the DSRM by investigating the problem domain and by motivating the rationale of the problem identified. This chapter addresses Hevner *et al.* (2004) practice guideline, where the DSR approach needs to be applied to relevant business problem which was discussed in this chapter. Reporting on TSU was identified as important, but current systems do not effectively support reporting on TSU for decision making for in-field investigation. The current systems do not support dynamic interaction and mobility, which is required to effectively support in-field investigation. The interview study confirmed that during the customer engagement process, much documentation is compiled which is manual and inefficient. It was also identified in the interview study that the participants perceive the use of mobile devices as useful for reporting purposes.

This chapter also completes the second phase of the DSRM by providing objectives for a solution in the form of requirements. It was identified that current systems lack dynamic interaction and do not support different perspectives of the TSU data to be viewed. It was also identified that current systems do not support viewing service usage information for different service types. The interview study provided insight into the functionalities and information provided by systems used by TSPs. The deliverable produced from this chapter is the objectives for a solution to the problem identified, which is illustrated in Table 2-6.

The next phase of the DSRM is the design and development of the solution, based on the objectives identified in this chapter. The next chapter will investigate MIV as a possible solution to support reporting of TSU for in-field investigation.

# Chapter 3: Mobile Information Visualisation

## 3.1 Introduction

Chapter 2 discussed TSU and investigated the shortcomings of existing software to support reporting of TSU for in-field investigation. Chapter 2 completed the Problem Identification and Motivate phase of the DSRM. Chapter 2 also addressed the second phase of the DSRM, which is to define the objectives for a solution. The objectives in Chapter 2 were identified in the form of requirements. The next phase of the DSRM is to design and develop a solution for the problem, based on the objectives defined. Chapter 3 begins the design and development phase of DSR by investigating suitable solutions for the problem. This chapter is the second of the literature chapters, which investigates how MIV can be used to develop a solution to the problem. This chapter addresses the third research question, which is to determine how TSU should be visualised on a tablet device to support in-field investigation.

The research question is addressed by reviewing suitable IV techniques for visualising TSU. The chapter begins with a background of visual analytics and IV. An existing framework for TSU is discussed and MIV techniques for TSU are identified. MIV techniques are then proposed for visualising TSU on a tablet device.

## 3.2 Visual Analytics

Visual Analytics is the combination of visual representation with human interaction to provide the ability to confirm the user's expectations and discover new knowledge within large and dynamically changing information spaces (Wong and Thomas 2004). Applications are producing large volumes of data and the capacity to store this data is increasing, while the tools to analyse the data are improving at a slower rate (Keim, Mansmann, Schneidewind *et al.* 2008). The field of visual analytics is growing as it focuses on how to present and manipulate large volumes of data to support the analytical reasoning process. The analytical reasoning process is a series of steps that provide the ability to recognise, understand and reason, complex and dynamic data about a particular situation (Ribarskya, Fisher and Pottenger 2009). Analytical reasoning is an essential part of decision making, by which the final decision is made, based on evidence and assumptions deduced from various artefacts. A decision is made, based on a problem, which reflects the analyst's understanding of a situation by considering assumptions, supporting evidence and any uncertainties. There are various types of analysis that can be performed for decision making:

- **Assessment** requires thorough analysis of the current situation and the events leading up to that situation;
- **Forecasting** requires making predictions by effectively analysing various artefacts;
- For **development options,** analysis is required to assess alternative scenarios. For example, when introducing a new product or service, an analysis needs to be performed and a feasibility study could also be conducted.

For all types of analysis, decisions are made by analysing the evidence used and assumptions made. Effective decisions are made by searching and processing various sets of information to ensure that alternatives have been considered (Ribarskya, Fisher and Pottenger 2009). The analytical reasoning process reflects the on-going dialogue between the analysts and the resources utilised. In Computer Science this is referred to as analytical discourse where there is a technology component involved to facilitate the dialogue between the analyst and the information. The analytical reasoning process is also referred to as sense-making (Card, Mackinlay and Shneiderman 1999). The analytical reasoning process follows four tasks which are performed iteratively to effectively make deductions as shown in Figure 3-1.

The first phase of the analytical reasoning process is to gather information to assist in understanding the situation that requires analysis. The information gathered, needs to be transformed into a representation that is more structured and allows easy interpretation. For example, raw data needs to be mapped to data tables or graphs. The representation needs to allow manipulation to develop insight of the information. The manipulation includes providing different perspectives on the information.

The last phase of the analytical reasoning process is to produce results. This entails the creation of knowledge which is deduced from analysing the information. The process is iterative as alternative results need to be produced and the results from the previous cycle need to be re-evaluated.

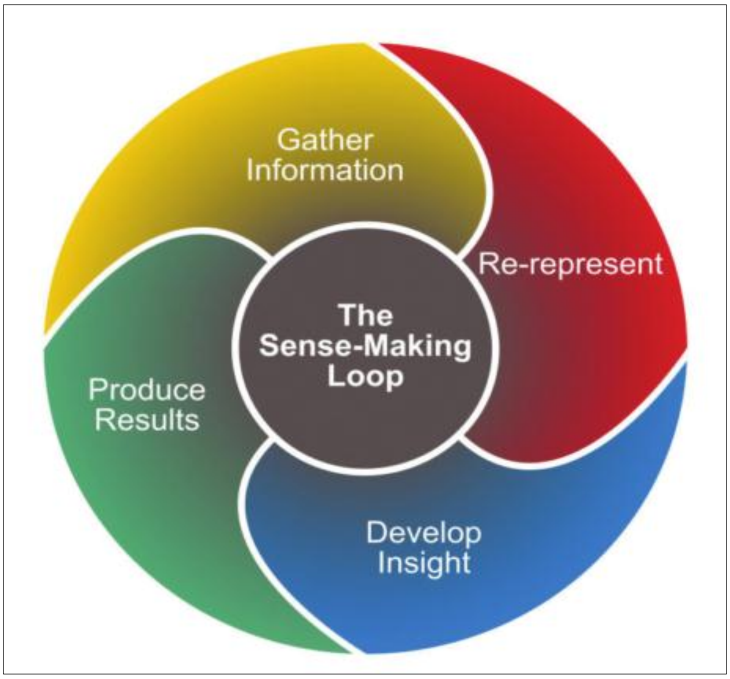



**Figure 3-1: Analytical Reasoning Process (Ribarskya, Fisher and Pottenger 2009)**

Visual analytics describes how software can be created to assist the analytical reasoning process to enhance human capacity to interpret and understand complex and dynamic data. For visual analytics to assist the analytical reasoning process, the following requirements need to be met (Shrinivasan and van Wijk 2008):

- The analysis artefacts such as evidence, hypotheses and assertions need to be highlighted as well as the links between the artefacts;
- The analysis of artefacts and the links between the artefacts need to be structured in order to support or contradict a statement made;
- Facilities need to be in place to allow revision of the exploration process;
- Facilities need to be in place to link analysis artefacts and visualisations that support the analysis artefacts;
- The ability to share any findings made.

These requirements provide a guideline that an interactive exploration tool should meet to allow effective analysis of the information. TSPs require effective and efficient software tools to assist with providing interactive exploration of TSU data to support decision making. The rest of this chapter will investigate how TSU data should be presented and manipulated in order to support analytical processing of the information.

Figure 3-2 illustrates the abstract visual, analytical process which has the four main phases shown as ovals. The process starts with the raw data being collected from the heterogeneous data sources, consolidated and transformed into a consistent format for further processing (Keim *et al.* 2010).

There are two alternatives for analysing the information. The first approach is through automated data analysis, where data mining techniques are applied to generate models of the data. The models can be refined by altering available parameters. The second approach is the visual data exploration approach, where the information is visualised and requires user interaction. Valuable insight can be obtained by the user drilling down and viewing the information from different perspectives, thus allowing deductions to be made.

The user can build a model from the visualised information to improve understanding of the behaviour of the data. After one of the two approaches is followed, knowledge can be gained for decision making. To follow and support the analytical reasoning process, visual analytics is also iterative where the knowledge gained can be re-evaluated to extract more detailed knowledge about the data. Having more insight on the data can improve the decision making.

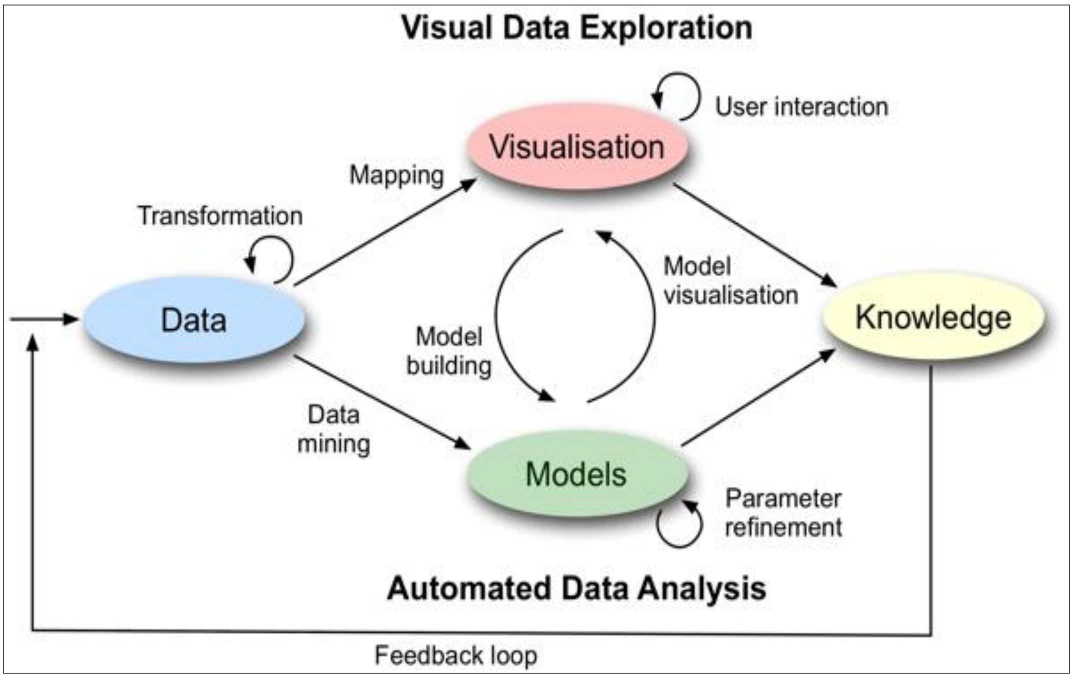



**Figure 3-2: Visual Analytical Process (Keim *et al.* 2010)**

The visual data exploration approach has multiple advantages over automatic data analysis techniques. The first advantage is that visual data exploration better handles heterogonous or noisy data better as compared to automated data analysis techniques (Keim *et al.* 2010).

The second advantage is that visual data exploration requires no pre-knowledge of complex, statistical or mathematical algorithms. Based on these advantages, more effective and efficient results can be achieved through visual data exploration and the user can feel more confident about the findings through direct interaction with the data.

It is important for decision makers that they are able to extract relevant information from large volumes of data (Keim, Mansmann, Schneidewind *et al.* 2008). Decision makers may require the ability to manipulate multi-dimensional, multi-source or time-varying data to allow decisions to be made in time-constrained situations. The visual representation of the information can also assist with decision making as a good representation can reduce the cognitive work required to interpret the information and thus faster actions can be taken. The way in which raw data is mapped to a visual representation is not a trivial task as there could be alternative ways to represent the same data and it can be unclear which representation is the most suitable. With visual analytics it is not sufficient just to extract and display data by using a visual metaphor (Keim, Mansmann, Oelke *et al.* 2008). The ability to analyse the data, using interaction models, increases the value of interest and improves the user experience.

Visualisation provides the ability to communicate effectively and explore information when computational methods fail (Keim, Mansmann, Schneidewind *et al.* 2008). One of the goals of visual analytics is to synthesise techniques from the field of IV with those of computation transformation and data analysis (Ribarskya, Fisher and Pottenger 2009). The next section will investigate the field of IV, by discussing the components of IV and the taxonomy of the various techniques available.

## 3.3 Information Visualisation

IV focuses on assisting human cognition through the use of computer-generated, interactive visual representations of abstract data (Card, Mackinlay and Shneiderman 1999). Extracting meaningful information from large quantities of data which is presented in text or tabular format is a difficult task (Chan 2006). IV assists in the difficult task of presenting large quantities of data by providing techniques to develop effective graphical representation to assist human cognition. There are multiple ways in which IV can improve cognition (Card, Mackinlay and Shneiderman 1999):

- More resources, such as extra memory and processing, assist in capturing information;

- Time to search for information is reduced, as the search space can be reduced;
- The detection of patterns is more possible through the use of visual representations;
- IV encourages interactive exploration of the data, which is not possible with static diagrams.

### 3.3.1 Information Visualisation Process

The IV process describes the various stages involved in transforming raw data into effective visualisations to assist human cognition. The IV process to allow interactive visualisation of data is described by a Reference Model developed by Card *et al* (1999). The Reference Model, shown in Figure 3-3, illustrates the phases to transform the data into an interactive abstract visual representation that will amplify cognition (Card, Mackinlay and Shneiderman 1999). Figure 3-3 illustrates that there are four phases in the IV process which are raw data; data tables, visual structures and views. There are three transformation operators that may require user interaction, namely data transformation, visual mappings and view transformation. The components of the Reference Model in Figure 3-3 are the following (Card, Mackinlay and Shneiderman 1999):

- **Raw data:** The original data that was captured from an input source without being altered in any way;
- **Data tables:** The data is organised into a relational form, consisting of rows and columns, which is more structured arrangement than the raw data. The data tables include metadata which facilitates providing a visual representation of the data;
- **Data transformations:** Involve mapping raw data to data tables with or without human interaction. This can be done through a selection of the raw data to be visualised or by categorising the data;
- **Visual structures:** Consist of spatial substrate, marks and the mark's graphical properties. Spatial substrate specifies how the view space is allocated to the visual representations. Marks are visible things such as lines, points and areas. The mark's graphical properties are properties such as colour and transparency. The selection of the visual structures can have a major impact as to whether the user will be able to interpret the information as it can create misinterpretations. An example of a visual structure is a scatter plot or line graph;
- **Visual mappings:** The information from the data tables is mapped to the visual structure selected. The user can affect the visual mapping by specifying criteria such as the variable used in the axis for a scatter plot graph;

- **View transformations:** Allow interactive modifications of the visual structures to transform static presentations to dynamic visualisations. This is done by altering graphical parameters to create views of the visual structures. There are three main view transformations: location probes, viewpoint controls and distortions. Location probes can provide additional information on demand, when selected on the visual structure. Viewpoint controls allow the perspective of the visual structure to be manipulated through zooming, panning and other means. Distortion alters the visual structure to provide Focus + Context views;
- **View:** This is what the user sees and can be altered by manipulating the visual structures through view transformations.

The Reference Model describes the process involved to provide effective visualisations of the data. The model serves as a base guideline for what has to be considered when developing or implementing IV techniques.

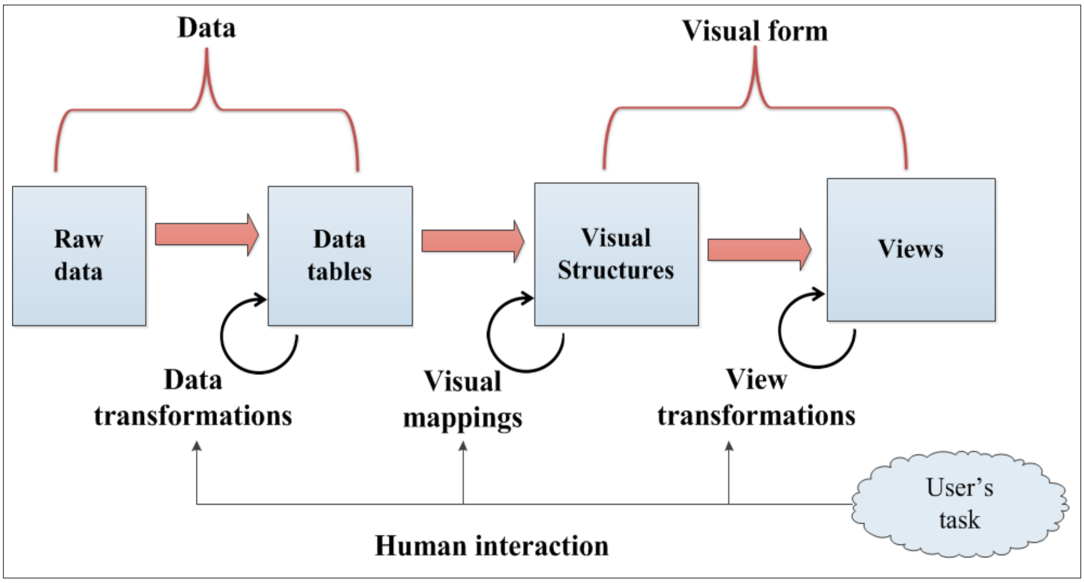



**Figure 3-3: Reference Model for IV (Card, Mackinlay and Shneiderman 1999)**

In addition to the Reference Model for IV, there are also other guidelines that explain how data should be presented to assist with cognitive understanding. Shneiderman (1996) provides guidelines for describing how information should be presented so that it is most effective for users (Craft and Cairns 2005). Shneiderman (1996) proposed a principle for visual design called the *Visual Information Seeking Mantra*, which states (Shneiderman 1996):

*"Overview first, zoom and filter, then details on demand"*

Visual data exploration follows this principle, where the user is initially provided with an overview of the data and is thereafter encouraged to explore the information space (Aogon and Ogao 2007). The user is required to interact directly with and alter the visualisation, based on exploration objectives. Exploration of the data may reveal interesting patterns and new knowledge can be gained.

The intentions from Shneiderman (1996) were that the principle should be more descriptive and explanatory than prescriptive on how to design for IV (Craft and Cairns 2005). Much research done in the field of IV makes use of the principle to propose or evaluate visualisation techniques. The principle can thus be used as a starting point to select and evaluate IV techniques. The principle proposes seven tasks to support the visualisation of information (Shneiderman 1996):

- **Overview:** Provide an overview of the entire data set;
- **Zoom:** Zoom in or out to achieve different levels of interest on the data;
- **Filter:** Be able to remove unwanted information;
- **Details-on-demand:** Be able to select an item of interest and obtain more details on the selected item;
- **Relate:** Be able to view relationships between items;
- **History:** Monitor the user's actions to support undo and redo of their actions;
- **Extract:** Allow the ability to save what the user has done, for example, queries or view manipulations.

The reason for Overview to occur first is that it provides the general context for understanding the dataset and the users can then decide where they want to focus. Zooming in produces more specified information to be viewed, while Zooming out is used to obtain more contextual information. Filter is an important task as it allows the user to specify criteria for the information that is of interest. Dynamic filters can be of great use for this task as this allows the user to see how the visual representation changes as filter parameters are manipulated. Details-on-demand, which is useful for small screens, allow the user to get more information on a specific item without changing the original visual representation. For example, if a user selects an item on a graph, a pop-up window will contain additional information on what has been selected. The Relate task can be used by allowing items to be selected and by showing which items are related. This can assist in better understanding how the information is linked. The History task is important as this will allow the user to return easily to previous or succeeding states and assists with exploration of the information space. Users may want to save what they have discovered, which could be used to communicate with other users. The Extract task allows the user to save any findings made.

There are many IV techniques that have been developed over the years and the next section focuses on classifying IV techniques. A taxonomy of IV techniques will be discussed to assist in selecting the most suitable IV techniques for visualising TSU data.

### 3.3.2 Taxonomy of IV Techniques

There is no universal consensus on which taxonomy is the most suitable for IV techniques. A well-known taxonomy for IV techniques is that provided by Keim (2002). IV techniques consist of three components to allow interactive visualisation of the data: Data that is intended to be visualised; the visualisation technique and the interaction and distortion technique. This is shown in Figure 3-4 where the components are shown along the X, Y and Z axis to classify IV techniques.

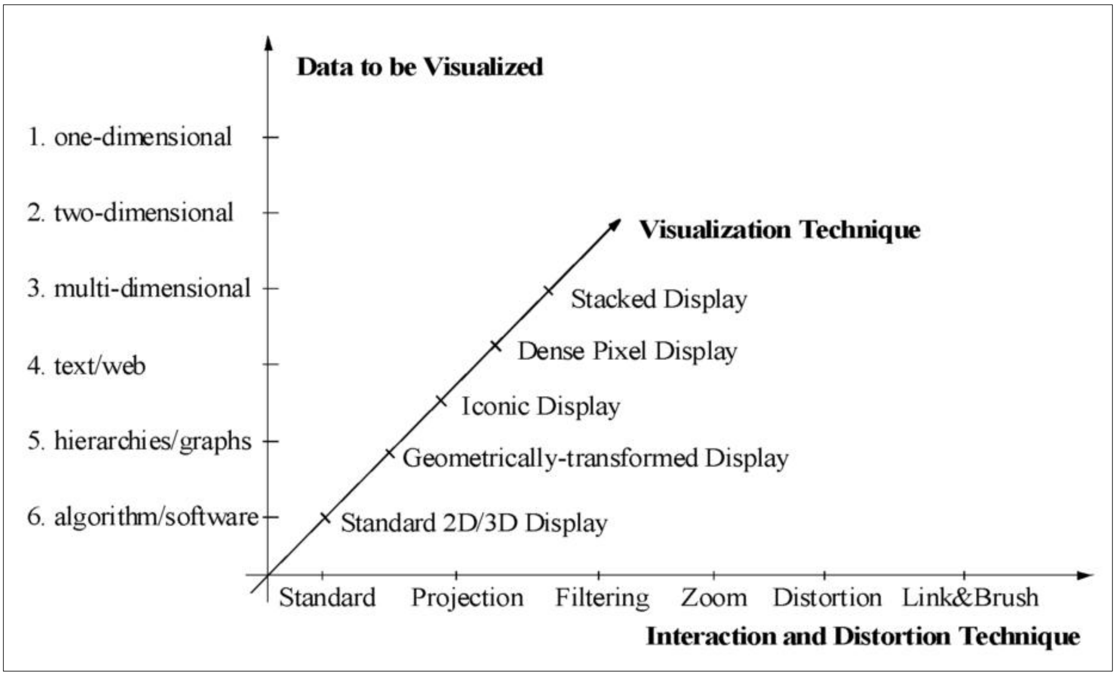



**Figure 3-4: Classification of IV Techniques (Keim 2002)**

There are different classification schemes used for the various data types in IV. Shneiderman (1996) considers seven main data types that are commonly found in IV systems, which are:

- **1-dimensional (1D)**: Includes linear data types, such as an alphabetic list of names, which maps an attribute to a set of objects;
- **2-dimensional (2D)**: Includes map or planar data which, is commonly used to represent objects such as geographical maps;
- **3-dimensional (3D)**: Refers to real-world objects that have attributes, such as volume or complex relations with other objects;
- **Multi-dimensional**: Commonly includes relational datasets where items in the dataset have *n* attributes;
- **Temporal**: Temporal data is data that includes a time attribute which is not included in 1D data;
- **Network**: Network data contain attributes with an arbitrary number of relationships among other attributes;
- **Tree Data**: Tree structures are data where each data item has a link to a parent item, except for the root node.

The visualisation technique specifies how the data will be presented graphically, such as bar chart, scatterplots etc. (Keim 2002). There are five main visualisation techniques that are shown in Figure 3-4:

- **Standard 2D/3D display:** Standard 2D/3D displays make use of techniques such as x-y plots, line graphs, bar charts etc. This display technique can be used for 1D, 2D, 3D and temporal data;
- **Geometrically-transformed Display:** This display technique is aimed at finding interesting transformation for multi-dimensional data sets. Display techniques included are scatterplot matrices and other geometric projection techniques;
- **Iconic display:** This technique maps the multiple attributes from multidimensional data items to features of an icon. Icons can vary from little faces to stick figure icons or even colour icons;
- **Dense-pixel Display:** With this display technique, each dimension value is mapped to a colour pixel and pixels belonging to the same dimension are grouped;
- **Stacked Display:** The data is partitioned into a hierarchical structure with more important dimensions being higher in the hierarchy.

Shneiderman (1996) proposed that the visualisation technique should be selected, based on the data type that is to be visualised. Keim (2002) also recommends certain visualisation techniques that are applicable to certain data types. Table 3-1 shows the data types and the appropriate visualisation techniques identified by both authors.

**Table 3-1: Visualisation Techniques Categorised based on Data Type (Shneiderman 1996)**

| **Data Type** | **Visualisation Technique** | |
|---|---|---|
| | **Shneiderman (1996)** | **Keim (2002)** |
| 1-Dimensional | Graphs, Pie Charts | Standard 2D/3D |
| 2-Dimensional | Heat map, Scatterplot | Standard 2D/3D |
| 3-Dimensional | Scatterplot, Heat map | Standard 2D/3D , dense pixel |
| Temporal | Timeline | Same as ID |
| Multi-Dimensional | Scatterplot Matrix, Matrix Chart, Pie chart, Radar chart | Iconic; Geometrically transformed; dense pixel |
| Tree | Treemap | Stacked |
| Network | Network graph | Stacked |

Together with the visualisation technique selected, suitable interaction and distortion techniques should to be selected to allow effective exploration of the data (Keim 2002). Interaction techniques provide the user with direct interaction with the data, thus the user can dynamically alter the visualisation according to any exploration objectives that must be achieved. Distortion techniques provide the ability to place focus on details whilst still being able to have an overview of the information space. The concept behind distortion techniques is to have higher levels of detail on certain parts of the data while other portions are at a lower level of detail. The interaction and distortion techniques are very similar to the tasks for the visual seeking information mantra (Section 3.3.1). The interaction and distortion techniques classifications shown in Figure 3-4 are:

- **Dynamic Projections:** These types of techniques are suitable for multi-dimensional data where the user has the ability to alter the projection of the visualisation. The number of projections is relative to the dimensions of the data. This technique is more automatic, in the sense that it does not require much user interaction and is thus termed as a dynamic technique.
- **Interactive Filtering:** Interactive Filtering allows a subset to be selected by specifying criteria that the data to be viewed should meet. Interactive filtering allows interaction with a subset of the entire collection as browsing through all the information can be time intensive. Many interactive filtering techniques have been developed to support reducing the information space to be searched.

- **Interactive Zooming:** Interaction techniques need to allow different levels of detail to be viewed by zooming in and out of the data. Zooming, in this context, does not refer to altering the size but the level of detail displayed.
- **Interactive Distortion:** Interactive Distortion allows the ability to drill-down into the information space whilst still maintaining an overview of all the information. This allows the users to view high levels of detail while still viewing lower levels of detail of the data. Well known distortion techniques make use of hyperbolic and spherical distortions.
- **Interactive Linking and Brushing:** This category describes interaction techniques that allow different visualisation techniques to be combined due to the shortcoming of an individual technique to visualise multi-dimensional data. Linking and brushing can be used to combine multiple scatterplots, bar charts and pixel displays.

The taxonomies for IV techniques discussed in this section highlight the components of an IV technique. The main components, identified from the taxonomy of IV techniques, are the data, display techniques and interaction techniques. The alternative taxonomies for IV techniques, discussed in this section, can be used to select the components for an IV technique suitable for the visualisation of TSU.

## 3.4 Visualisation of Usage Data

An analysis of TSU data was conducted in Section 2.5.3 where it was identified that an event is captured each time a service is utilised. The information requirements identified in Chapter 2 (Table 2-6) indicate that there are different aspects of the service utilisation that have to be visualised. For example, information about total usage for a period of time, service usage per customer site, etc. A single visualisation technique cannot be used for different data types as indicated by the taxonomy of IV techniques in Section 3.3.2.

A Visualisation Framework for the visualisation of subscriber usage patterns is illustrated in Figure 3-5 (Aogon and Ogao 2007). This Visualisation Framework was proposed to evaluate different visualisation tools and to show these tools can effectively visualise subscriber usage patterns. The subscriber usage patterns used, provide information about call usage data, such as which days have the highest and lowest call usage. Figure 3-5 illustrates that the aspects that can be visualised on subscriber usage data are trends, unique patterns and ranking patterns. The trends provide temporal information about the usage, the unique patterns identify outliers such as abnormalities in the usage and the ranking patterns provide indication of high and low usage. The Visualisation Framework describes display techniques and interaction techniques for service usage, which is consistent with the taxonomy of IV techniques discussed in the previous section. This Visualisation Framework can be applied to TSU data because of similarities of the data. Call usage data is a type of telecommunication service specifically focused on voice data.

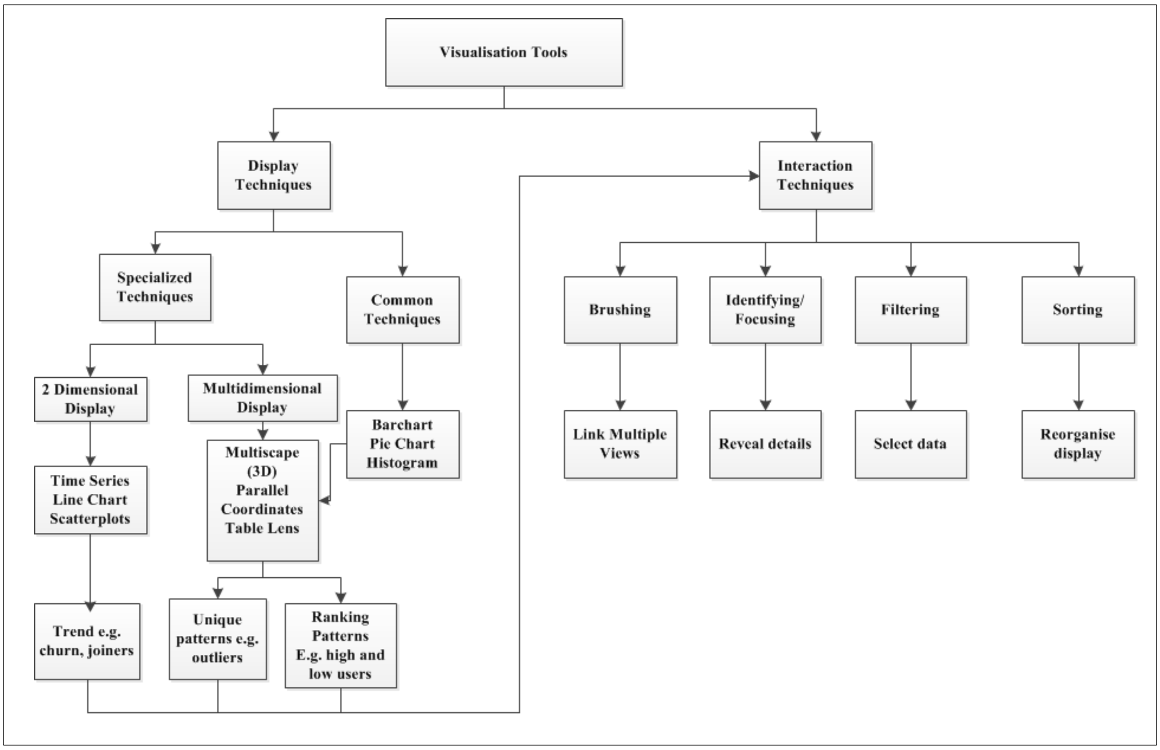



**Figure 3-5: Framework for Visualising Subscriber Usage Patterns in Telecommunications (Aogon and Ogao 2007)**

From the Visualisation Framework and the requirements in Table 2-6 , three views for the visualisation of the service usage data were identified:

- A **Trend Usage View** provides information about how the service usage varies over time;
- A **Network Usage View** provides ranking patterns such as high and low usage on the different customer sites;
- A **Detail Usage View** provides information on the usage measures for a service to identify any abnormal service usage.

Each of the three views requires a different display and interaction technique. The Trend Usage View needs to show temporal information. Based on the taxonomy of IV techniques discuss in Section 3.3.2, Standard 2D/3D display techniques can be used. The Visualisation Framework recommends using either a times series, line or scatterplot chart. A time series chart is more suitable for visualising trend information and thus will be selected for the Trend Usage View. For the Network and Detail Usage Views, the nature of the TSU data is multivariate and the Visualisation Framework suggests that multidimensional visualisation techniques should be used. Table 3-1 and Figure 3-5 illustrates that there are multiple multidimensional IV techniques available and the selection of the most suitable IV techniques for TSU data is discussed in the next section.

## 3.5 Multidimensional Visualisation Techniques

There are many multidimensional visualisation techniques that exist where each technique is aimed at analysing a certain aspect of the multivariate data (Chan 2006). Multidimensional visualisation techniques are used in many different situations, where the goal is to gain an in-depth understanding of the distribution of the data as well as the inter-relationships between the various attributes. There are many challenges in visualising multivariate data in a single display, which require consideration (Chan 2006):

- Determining how to map the multivariate data in a 2D form. Consideration needs to be taken to ensure that the manner in which the data is mapped does not overwhelm the viewing ability;
- When the dimensionality of the data is high, the difficulty of visualising the information and providing interactive exploration increases. Another consideration with dimensionality is the ordering of the dimensions, which affects the conclusions drawn from the visualisation (Keim 2000);
- The design trade-offs that need to be made between providing an overview of the complex datasets, so that the user can identify patterns or trends, and sacrificing the ability to show details of the attributes. The trade-off is accuracy, simplicity and the amount of information that can be shown;
- How to assess that the visualisation technique utilised, provides valuable insight into the data.

Selecting a multi-dimensional visualisation technique requires consideration of the challenges identified above. Based on the taxonomy of IV techniques, the appropriate visualisation techniques for multidimensional data are geometric projections, pixel-oriented and iconographic displays. Table 3-2 highlights the advantages and disadvantages of the different multidimensional techniques as proposed by different authors (Keim and Kriegel 1996; Ferreira de Oliveira and Levkowitz 2003; Chan 2006; Cao 2011).

Pixel-oriented and iconographic display requires training to understand the representation, which indicates that usability issues can occur with these techniques. Geometric projections provide the advantage of allowing outliers and correlation between the dimensions to be identified. This could be useful when reporting on TSU data as it could provide information about, for example, how the service utilisation changes over time or between the different customer sites.

**Table 3-2: Comparison of Multidimensional Visualisation Techniques**

| Visualisation Technique | Advantage(s) | Disadvantage(s) |
|---|---|---|
| **Geometric Projections** | • Good for detecting outliers and correlations between the different dimensions<br>• Can handle large datasets with appropriate interaction techniques<br>• Not much effort required to understand the representations | • Issues arise when the dimensionality of the data is too high (Visual cluttering and overlapping) |
| **Pixel-oriented** | • Can handle high dimensionality<br>• User can observe interrelationship between attributes<br>• Record overlapping and visual cluttering not likely | • Requires training to understand the visualisation<br>• Difficult to interpret |
| **Iconography** | • Intuitive means to represent data<br>• More natural to human perception<br>• Provides good comparison | • Can easily introduce bias into the results<br>• Requires training to understand representations<br>• Supports a limited number of dimensions |

Geometric projection display raises issues when there is a high dimensionality in the data set. This problem can be overcome by using clutter- and overlapping-reduction techniques. Geometric projection display will be used to visualise TSU data as it is easy to interpret and can provide insight into the behaviour of the data. Geometric projection displays encourage exploration, which is a requirement for supporting the analytical reasoning process. Geometric projection displays are most suited for visualising TSU data, which is discussed in the next section.

### 3.5.1 Geometric Projection Displays

Geometric projection display techniques project and transform multidimensional datasets to provide insight into the data. These visualisation techniques are well suited for detecting outliers and correlations between the different dimensions and provide the capability for appropriate interaction techniques for large datasets. Geometric projection techniques consist of graph and coordinates-based visualisations (Pham *et al.* 2010). Graph-based visualisations are more commonly used when there are explicit relationships in the data. Coordinate-based visualisations are an extension of 2D/3D displays where the data is projected and transformed onto coordinate axes. The different data attributes are treated equally when visualised. The following coordinate-based visualisations are applicable for visualising multidimensional data:

a) *Scatterplot Matrix:* A scatterplot is used to display two attributes along x-y axes (Chan 2006). A scatterplot matrix organises the multidimensional data into a matrix containing a collection of scatterplots, to provide information about the correlation among the attributes. The scatterplot provides the advantage of allowing the user to observe patterns in the relationships between the pairs of attributes as shown in Figure 3-6. Comparing the attributes of service usage is not valuable and thus the scatterplot matrix is not suitable for TSU data.

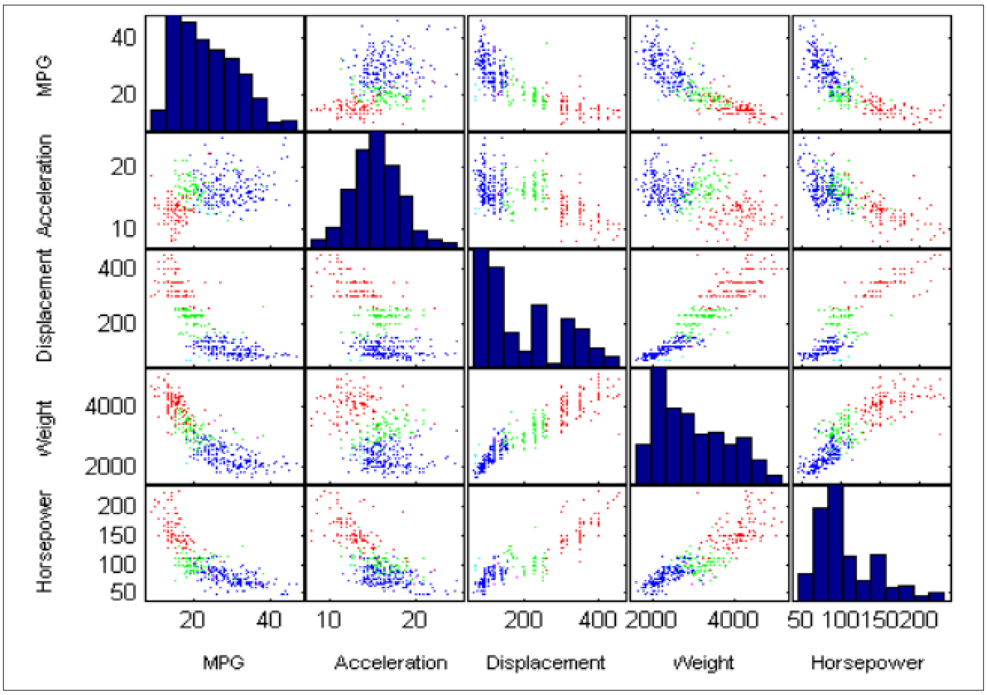



**Figure 3-6: Scatterplot Matrix for Multivariate Data (Chan 2006)**

b) *Parallel Coordinates*: The attributes are displayed by using parallel vertical axes, where the points on the axes are scaled within the data range for an attribute. Every data record is displayed as a polygon line which joins each axis (Figure 3-7). Parallel coordinates provide the advantage of showing the data distribution and also support interactive exploration. Correlations between the attributes can also be identified by using this technique (Pham *et al.* 2010). The disadvantage is that there is limited space available and as the number of records increases, visibility decreases. This can, however, be resolved by using interaction techniques such as brushing, to highlight certain aspects of the data (Chan 2006). This display technique can be used for TSU data for the Detail Usage View, as each of the service usage attributes can be represented on a vertical axis.

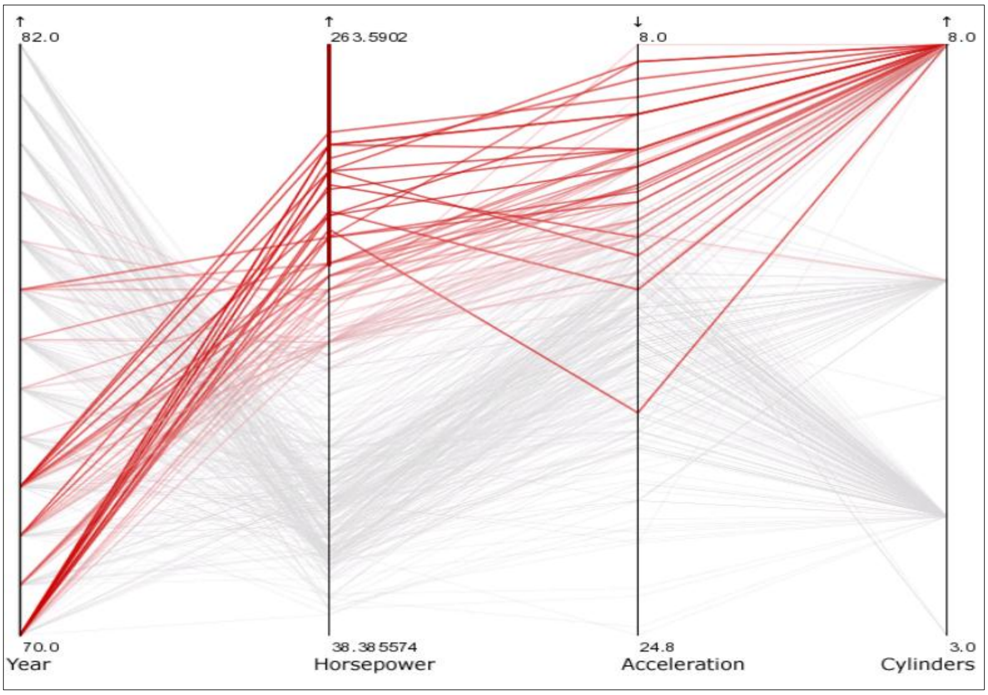



**Figure 3-7: Parallel Coordinate Display Technique (Hauser, Ledermann and Doleisch 2002)**

c) *Table Lens:* With a table lens display, each column refers to an attribute and each row represents a data record (Chan 2006). Each column is displayed as a histogram as shown in Figure 3-8. Table Lens applies the "Focus and Context" principle where the user first has an overview of the data and can then focus on specific items within a specific context (Waloszek 2004). The user can alter the graphical layout of the data records by performing actions such as sorting the attributes. Table Lens supports data exploration and assists the user to visually detect any underlying relationships, such as associations and correlations among the various attributes (Du 2003). The shortcoming of the Table Lens display is that cannot detect any complex patterns such as relationships between several attributes and it cannot handle high dimensional data. The Table Lens is also inappropriate for visualising large object sets. This is not suitable for TSU data which contains a large amount of data.

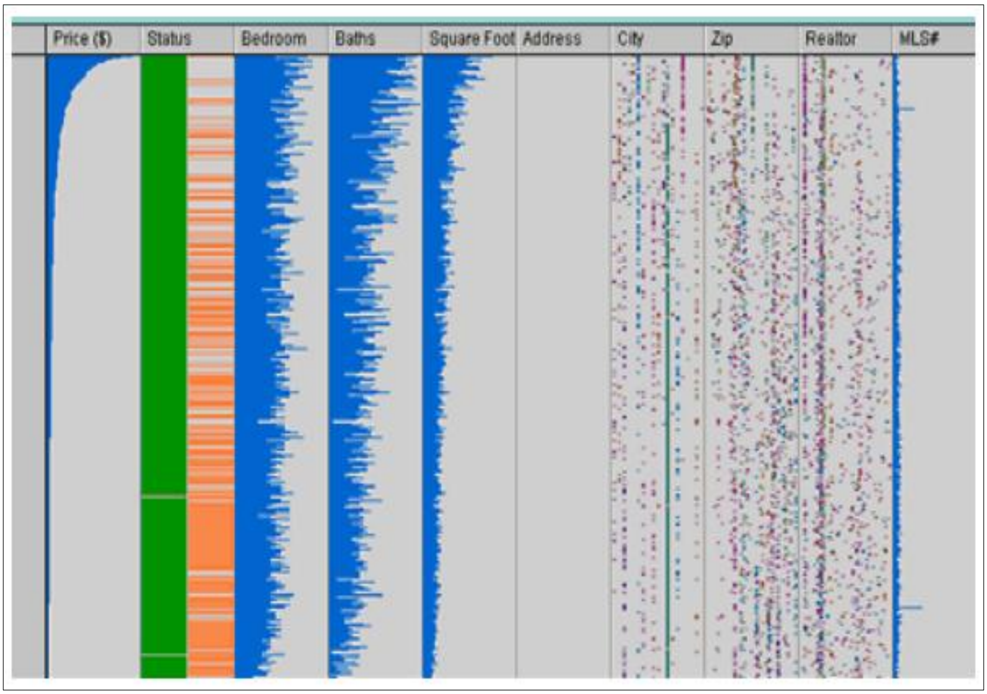



**Figure 3-8: Table Lens Display Technique (Waloszek 2004)**

d) *Star Coordinates:* Star Coordinates is appropriate for visualising the overall distribution of the data (Pham *et al.* 2010). The star coordinates extends scatterplots to higher dimensions where the data records are represented as a point and the attributes are axes (Chan 2006). The angles between the axes are equal and have the same length as shown in Figure 3-9. The disadvantage with this technique is that several data records can be presented as an equal point because the data records will have equal vector sums, which will place the point in the same location. This visualisation technique is more suited for hierarchically clustered dataset. This visualisation allows the user to place focus on an attribute by altering the site of an axis to make an attribute more or less correlated with other attributes. This visualisation is not suitable for TSU as there is no direct correlation between the attributes and the structure of the data is not hierarchical.

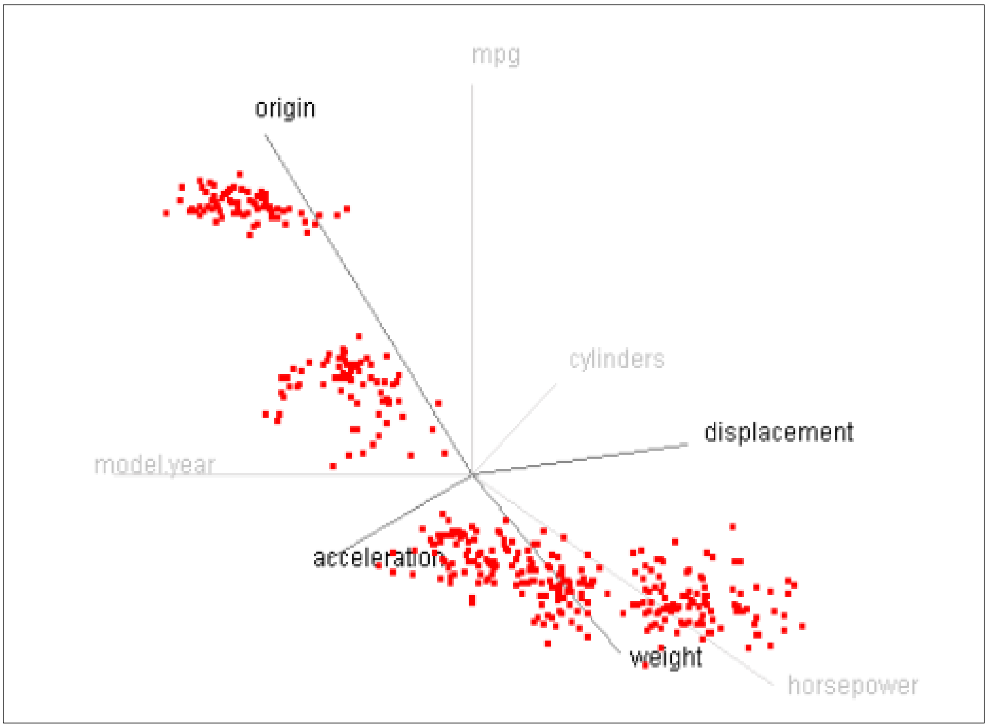



**Figure 3-9: Star Coordinates Display Technique (Kandogan 2000)**

e) *Radar Chart:* The radar chart is a simplified version of the star coordinates chart which is often seen in the context of business management software (Chang *et al.* 2012). The radar chart is a good visualisation technique for displaying multidimensional data (Figure 3-10). The radar chart is an efficient way to display a variety of data on a single display (Saary 2008). The disadvantage of the radar chart is that as the number of spokes increase, the more cluttered the chart becomes. Each spoke on the radar chart can be used to represent a category or an attribute of the dataset. The radar chart can be used to visualise TSU where each spoke on the chart represents a customer site. The radar chart is a simple visualisation technique and can be used in the Network Usage View.

This section has discussed the different geometric projection displays by identifying the advantages and disadvantage of each visualisation technique for TSU. The parallel coordinates chart was selected for the Detail Usage View to support the visualisation of the usage measures of the services. A radar chart was selected to display the service usage for the customer sites on the Network Usage View.

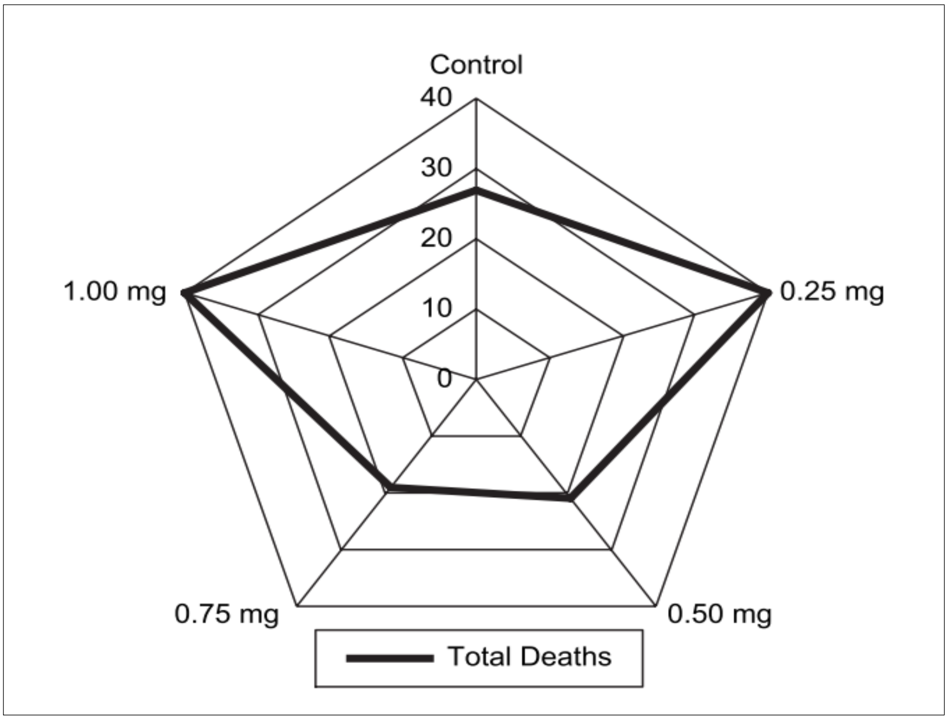



**Figure 3-10: Radar Chart Display Technique (Saary 2008)**

## 3.6 Mobile Information Visualisation Techniques

MIV is a field of study which aims to develop more efficient and satisfying user interfaces for searching and exploring information spaces on small screens (Buering 2008). MIV is a growing concept due to the improvements in mobile technology. In designing the user interface for visualising information on mobile devices, designers need to consider carefully the space limitations to avoid overlapping information (Buering, Jens and Harald 2006). Studies have shown that IV cannot simply be scaled from large to small interfaces due to differences in colours, input devices and connectivity (Hao and Zhang 2007). There is also a lack of standardised visualisation techniques specifically for mobile devices (Paelke, Reimann and Rosenbach 2003).

There are various limitations that are associated with mobile devices which require different approaches to the traditional visualisation for desktop applications (Yoo and Cheon 2006). The following limitations are associated with mobile devices:

- The input peripheral, such as small keypads, are not well suited for complex tasks;
- The input techniques are different, such as, using a stylus or the one-hand thumb-based input;
- On-board hardware is less powerful than desktop PCs;
- The graphics libraries on mobile devices are not as powerful.

Visualisation techniques developed for desktop computers do not scale well to mobile devices because of the limitations identified (Yoo and Cheon 2006). There is a lack of knowledge available on how to develop visualisations for mobile devices (Chittaro 2006). The field of IV is not meant for mobile devices, but certain ideas relating to the design process can be applied to mobile visualisation. This subsection will investigate how IV techniques have been adapted for mobile devices in other research. The combination of mobile visualisation techniques and IV techniques provide MIV techniques for mobile devices.

### 3.6.1 Existing Mobile Visualisation Techniques

Hardware performances of mobile devices are improving, but the problems of displaying information remains (Yoo and Cheon 2006). A common problem that users experience when using mobile devices is that users get lost when navigating the information space. A common assumption with visualising information on a mobile device is to solve the limited space problem by providing navigation functions such as scroll and zoom to allow the user to navigate over the different parts of the visualisation (Chittaro 2006). This assumption is false as it is cognitively complex to navigate the visualisation and the global context of the visualisation is lost when the user looks at details. Information layout methods and visualisation algorithms that consider the small screen attributes of mobile devices need to be determined (Karstens, Kreuseler and Schumann 2003). There are various desktop-based visualisation algorithms that have been used on mobile devices. The common visualisation techniques are Overview + Detail, Focus + Context and Zooming and Panning which will be discussed in the following subsections.

#### 3.6.1.1 Overview and Detail

The Overview + Detail visualisation algorithm is commonly used to visualise information on desktop computers, but usually fails when applied on mobile devices (Chittaro 2006). This approach provides two views simultaneously, where a smaller display shows the context and the larger displays are used for displaying the details of the visualisation. The view that displays the context is a downscaled version of the information space and highlights the area that is displayed in the detail view by using a rectangle (Burigat, Chittaro and Gabrielli 2008). The overview of the information space assists the user to navigate while viewing detail information. On a small screen, the space is limited and thus it is difficult to provide multiple displays and maintain clarity of the information visualised. Figure 3-11 illustrates the use of Overview + Detail on a mobile device used to provide the user with an overview of where the user is currently positioned on a map. If implemented correctly, Overview + Detail technique can lead to task completion in a shorter time (Burigat, Chittaro and Parlato 2008).

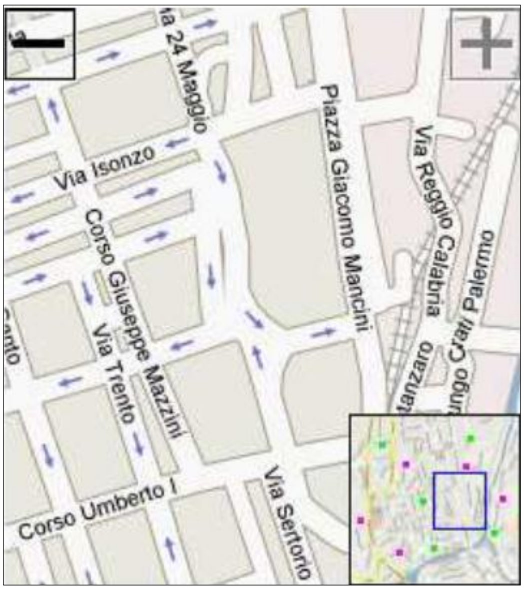



**Figure 3-11: Overview + Detail for Map-Based Visualisations on a Mobile Device (Burigat, Chittaro and Parlato 2008)**

### 3.6.1.2 Focus and Context

The Focus + Context algorithm is similar to Overview + Detail in that it simultaneously provides more than one view (Chittaro 2006). A context view and a focus view are presented when using this approach. The most common use of Focus + Context is the fish-eye view. The fisheye view takes a point that the user selects and magnifies this point to focus the user’s attention. The more distant points from the selected point are decreased, based on the distance from the selected point. The implementation of the fisheye view is not a simple task but can be of great advantage if implemented correctly. The Focus + Context approach differs from the Overview + Detail by not separating the different views (Burigat, Chittaro and Gabrielli 2008). The disadvantage with the Focus + Context technique is that when information gets distorted, to magnify a selected point, it can become difficult for the user to process the information in a task that requires geometric precision. Focus + Context is similar to zooming (discussed in the next section), where magnification of the information is obtained. Figure 3-12 illustrates the Focus + Context technique using the fisheye view to find information about a point by navigating through magnification.

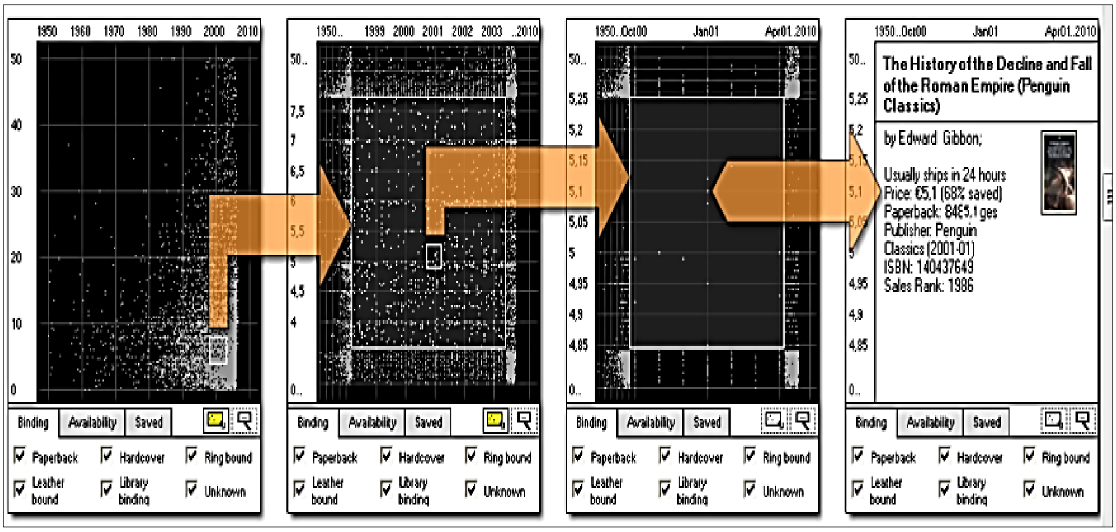



**Figure 3-12: Fish Eye View used to Focus and Select a Point (Buering, Gerken and Reiterer 2006)**

### 3.6.1.3 Zooming and Panning

Zooming and Panning is a simple approach for navigating the information space (Chittaro 2006). There are multiple ways in which Zooming and Panning have been implemented on mobile devices. Various Zoomable User Interfaces (ZUIs) were developed for mobile devices which support zooming and panning a search space (Burigat, Chittaro and Parlato 2008).

With ZUI the zooming can be done instantaneously or by animation. Figure 3-13 illustrates an example of zooming on a mobile device using the zooming technique. The user draws a rectangle to select the area that needs to be zoomed into.

For panning, conventional approaches used are vertical and horizontal scrollbars (Burigat, Chittaro and Gabrielli 2008). Panning has been found to work well for navigating on small information spaces, but steps need to be in place to ensure that the user does not get lost in the information space.

The existing mobile visualisation techniques discussed in this section provide approaches to support an IV technique on a mobile device. Focus + Context can be problematic on small interfaces if not implemented correctly, as the visibility of the information will be distorted. The Overview + Detail and the Zooming + Panning techniques are well defined approaches for supporting IV on mobile devices. Mobile devices are trending towards touch only interface and therefore the next section will investigate touch interactions supported by mobile devices.

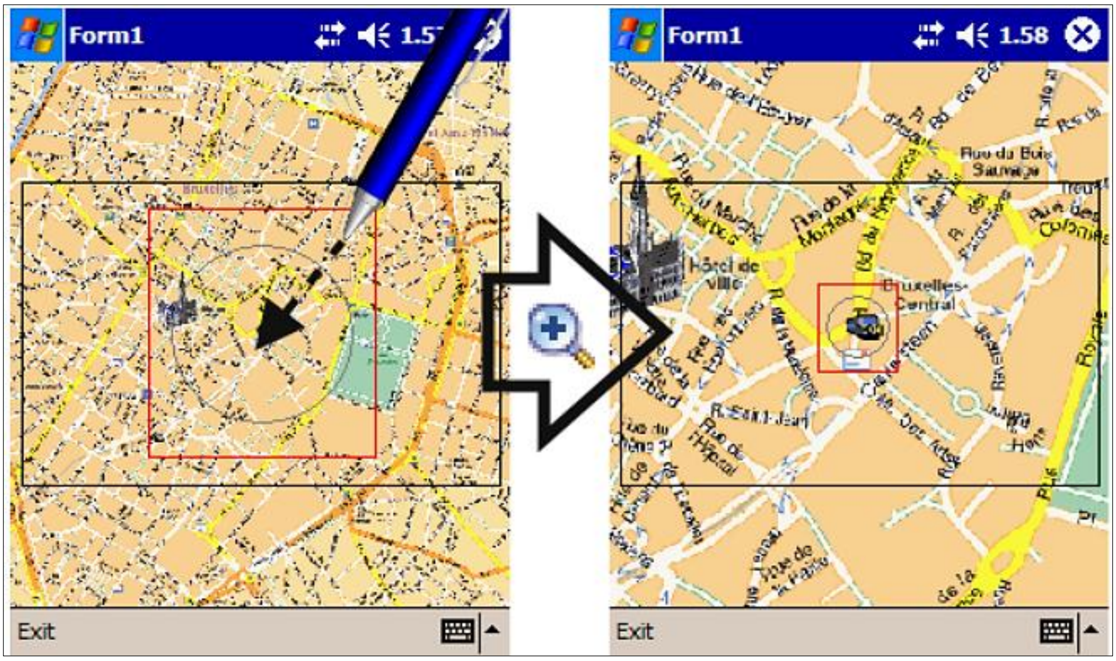



**Figure 3-13: Zooming for Map-Based Visualisation on a Mobile Device using ZUIs (Burigat, Chittaro and Gabrielli 2008)**

### 3.6.2 Touch Interaction

Touchscreens have become customary in mobile devices in recent years, specifically tablet PCs (Lü and Li 2011). The use of finger-based interaction has become popular for mobile user interfaces as it provides an intuitive means of interaction with the device. The ability to directly manipulate on-screen content mimics the idea of spatial manipulations in the physical world (Wigdor *et al.* 2011).

Different touch devices have common and unique touch command gestures. Figure 3-14 illustrates common touch gestures used on touch capable devices. When designing the user interface for touch screens, the gestures that the user will need to use must be taken into account. In highlighting a few of the gestures from Figure 3-14, Tap is used when the user briefly touches the surface, which is similar to a mouse click (Villamor *et al.* 2010). The Drag gesture is when the fingertip is moved across the screen without losing contact, which is commonly used to move or delete objects. Gestures which are normally associated with zooming in and out, are the Pinch and Spread gestures respectively. The Pinch and Spread gestures require the user to move two fingers together (for pinch gesture) or apart (for spread gesture). The press gesture is when the finger is held for a short period of time on an object. This is generally used to select an object. With the Flick gesture, the fingertip quickly brushes the surface and is used to move objects or switch between views.

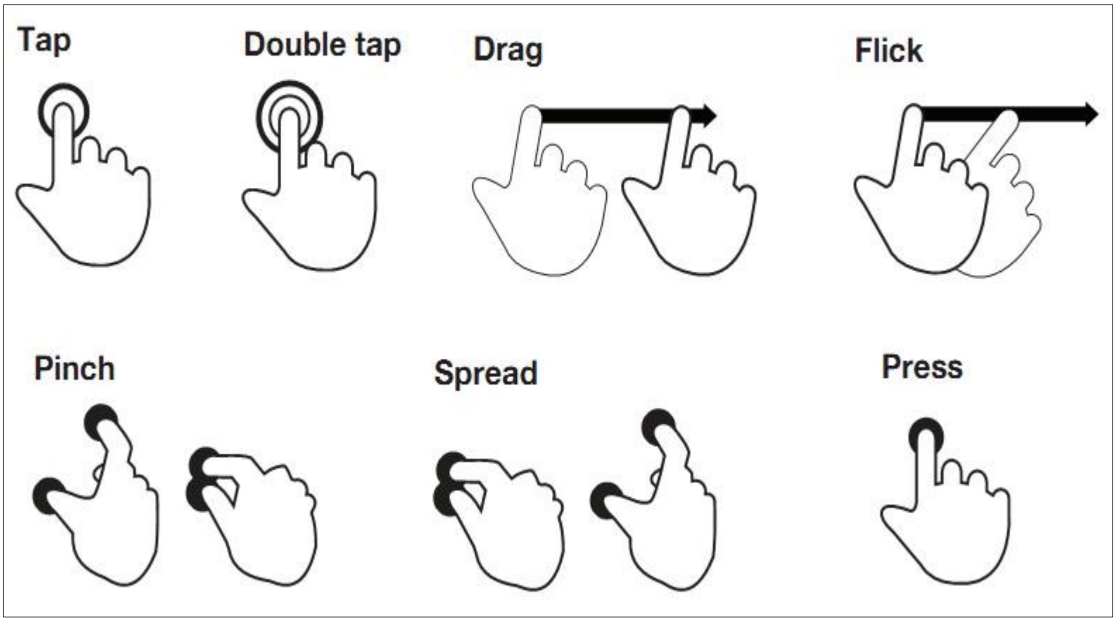



**Figure 3-14: Basic Core Touch Gestures for Most Touch Commands (Villamor *et al.* 2010)**

The use of touch input to control the graphical user interface has many advantages over other input methods such as mouse input (Wigdor *et al.* 2011). The fact that the gestures require physical muscle memory from the user, can improve the user's focus on the task that is being pursued. Touch input can also improve user satisfaction as the user may feel more in control when using the application. Therefore when designing for touch interactive devices, consideration needs to be taken to exploit the potential of the form of interaction. Designing for touch based interfaces should thus avoid the use of windows, icons, menus and pointers (WIMP), which is used on desktop PCs.

Although touchscreen mobile devices have become popular in recent times and provide intuitive interaction, this method of interaction has several shortcomings. Touchscreens suffer from low precision because a finger is larger than a single pixel, whereas a mouse pointer of a desktop PC can select a single pixel (Lü and Li 2011). The second shortcoming is that by touching on the screen, the finger or hand can occlude the user's ability to see certain aspects of the screen.

This section has contributed to an understanding of the gestures that need to be considered when designing MIV techniques. Creating new gestures and addressing the limitations of touchscreens are considered, but are not within the scope of this research. The gestures identified in Figure 3-14 will be sufficient to perform basic interaction for the MIV techniques proposed.

## 3.7 Conclusion

The aim of this chapter was to investigate suitable MIV techniques for visualising TSU data. The analytical reasoning process was investigated to determine how knowledge is gathered to make decisions. Requirements to support the analytical reasoning process were identified and it was discussed that visual analytics can be used to support this process. IV forms part of visual analytics, focusing on how to present and provide interaction with information to support cognitive understanding. MIV is a field of research that is still in its infancy and focuses on how IV should be applied to mobile devices with small screens.

An existing Visualisation Framework for the visualisation of TSU data was identified. Three views for the visualisation of TSU data were identified, namely the Trend, Network and Detail Usage views. The chapter used a detailed literature review for the selection of the visualisation techniques for the different service usage views. Mobile visualisation techniques were investigated that can be used to support IV techniques on a mobile device. Core touch gestures for mobile devices were identified.

For the Trend Usage View, a time series chart will be used to visualise the service usage over time. The Network Usage View will make use of the radar chart visualisation technique to display the service usage on different customer sites. The Detail Usage View will make use of a parallel coordinates visualisation technique to display the service usage measure for a customer's services. The mobile visualisation techniques and touch interaction will be incorporated into the different usage views.

The Visualisation Framework identified for visualising subscriber usage patterns will be extended to support the visualisation of TSU data on a mobile device. The mobile interaction and display techniques will have be incorporated into the Visualisation Framework to support visualising TSU data on a mobile device. Hevner *et al.* (2004) proposed DSR guidelines that a research contribution is made by building on the foundations of existing research. The usage of the existing Visualisation Framework is a research contribution from this chapter.

The next chapter will continue with the design and development phase of the DSR methodology.

# Chapter 4: Design and Implementation

## 4.1 Introduction

Chapter 3 identified an existing Visualisation Framework that describes the components of a visualisation tool for service usage information. This chapter completes the design and development phase of the DSRM by discussing a prototype to support interactive visualisation of TSU on a tablet device. The chapter aims to extend the existing Visualisation Framework, to incorporate the use of touch-based interaction. This chapter addresses the fourth research question by discussing the design decisions for visualising TSU on a tablet device.

The design of the prototype will incorporate the selected visualisation techniques from the existing framework with selected touch interactions. Based on the design, a proposed extension of the framework will be provided, which will be implemented in the form of a prototype. The design of the prototype, discussed in this chapter, was presented at the Southern Africa Telecommunication Network and Applications Conference in 2012 (Twigg, Wesson and Cowley 2012).

To identify potential usability issues, a formative evaluation of the prototype will be conducted using an expert review. The formative evaluation forms part of the demonstration phase of the DSRM, where the solution is initially evaluated to refine the solution. The design changes made, based on the results of the formative evaluation, are presented in this chapter. The deliverable of the design and development phase of the DSRM is the prototype, called MobiTel.

## 4.2 Interaction Design Methodology

The development of the prototype followed an iterative design which allows refined designs to be made based on feedback. A user centred design approach was used in this research which allowed focus to be placed on the users, their tasks and the environment where the users perform their tasks (Sharp, Preece and Rogers 2007). Design for users requires the knowledge about how to assist the users with interacting with the prototype and thus a continuous evaluation of the prototype has to be conducted. There are four phases in the interaction design methodology.

The initial activity is the identification of the user's needs and establishing requirements for the user experience (Sharp, Preece and Rogers 2007). This step involves identification of the target audiences and how an interactive prototype could be useful to the user. Chapter 2 discussed an interview study conducted where requirements were gathered. It was identified that the target users are TSP customer service representatives that consult with customers on their service usage and make decisions regarding the customer service delivery.

After the requirements are gathered, alternative designs need to be considered to meet the requirements (Sharp, Preece and Rogers 2007). Chapter 3 discussed different visualisation techniques and an existing Visualisation Framework that should be considered for visualising TSU. This chapter discusses the design of the prototype for visualising TSU.

The other phases of the interaction design methodology are the implementation and evaluation of the product. This process iterates until a final product is created for release. The rest of this chapter discusses the implementation and initial evaluation of the prototype.

## 4.3 Data Design

Section 2.5.3 discussed the structure of TSU data, where it was identified that the most suitable format for transferring service usage information is by using the IPDR protocol. Service usage data is obtained from multiple sources. The data input received from the various sources is aggregated, correlated and normalised in a mediation layer which serves as a usage collection component. The information gathered, is transformed into the IPDR document, which can more easily be understood by different business systems.

IPDR documents are used to communicate usage information between the network layers (Application services, firewalls etc), mediation layer and the business layer. The IPDR documents sent between the various layers consist of multiple IPDR records of detailed usage information (Broens and Peerlkamp 2003). Figure 4-1 illustrates an outline of an IPDR record format for Voice-over IP (VoIP) and Video on Demand (VoD) services.

In examining the two documents, four common attributes are stored:

- IPDRCreationTime: this is the time when the IPDR document was created;
- seqNum: number provided, based on when the IPDR record was added to the document;

- UserID: unique identifier (ID) assigned to a user using the service; and
- StartTime: This is used to specify when the service has been used.

Each service can also have unique usage measures specific to that service, as shown in Figure 4-1. VoIP has additional usage attributes such as the EndTime (when the user terminated using the service) and Duration (length of time over which a call was made). VoD could capture usage information such as the total number of bytes transferred and the ID of the video that was viewed.

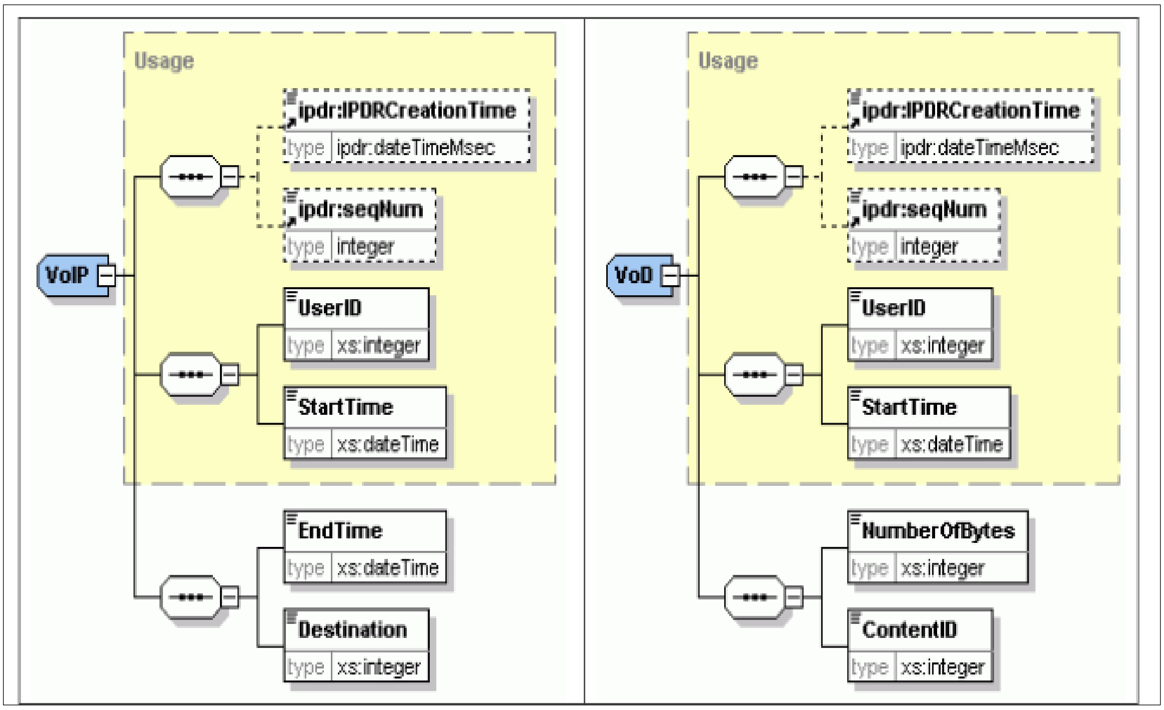



**Figure 4-1: Outline of VoIP and VoD using IPDR Record Format (Broens and Peerlkamp 2003)**

In the IPDR standard, XML is used as the encapsulation technique to store and transmit the service usage information because it is a light-weight storage format (Broens and Peerlkamp 2003). An example of an IPDR document in XML format is illustrated in Figure 4-2, which is a customised version of the document. Each time usage information is collected from the network layer elements, an IPDR document is obtained. The IPDR document format is a standard that can be customised depending on the information that has to be obtained.

```xml
<Usage xmlns="http://wwwhome.cs.utwente.nl/~broens/case">
 <UsageRecord>
        <UserID>Tom</UserID>
        <StartTime>2003-06-15T12:30:58.754</StartTime>
        <VoDRecord>
               <NumberOfBytes>1000</NumberOfBytes>
               <ContentType>1</ContentType>
        </VoDRecord>
 </UsageRecord>
 <UsageRecord>
        <UserID>Arno</UserID>
        <StartTime>2003-06-15T12:31:10.892</StartTime>
        <VoIPRecord>
               <DurationInSeconds>3600</DurationInSeconds>
               <Destination>2</Destination>
        </VoIPRecord>
 </UsageRecord>
```


**Figure 4-2: Example of IPDR Document for VoIP and VoD (Broens and Peerlkamp 2003)**

The services selected for this research are VoIP, email and cloud service to cater for the different service usage data type (Section 2.5.3.1). The usage attributes were identified for each of these services and are shown in Table 4-1. Information is also logged about whether the service is used inbound or outbound. For example, has an email service sent or received an email.

Common information logged for each service is:

- Start Time : When the service was used;
- User Id: User Id of the user that used the service (the customer site can be determined using the User Id);
- Type: Stores whether the service used is inbound or outbound.

**Table 4-1: Additional Usage Measure for Selected Services**

| Service Type | Email | VoIP | Cloud |
|---|---|---|---|
| **Additional Usage Measures** | • Bytes Transferred<br>• Storage Capacity<br>• Storage Duration<br>• Processing Time | • Call Duration<br>• Destination<br>• End Time<br>• Call Type | • Bytes Transferred<br>• File Type<br>• File Size |

The research was restricted by not being able to obtain information from any network elements, but using the usage measures identified in Table 4-1, the data was simulated by using a data generator tool. A year's service utilisation information was generated to allow enough information to be provided to the visualisation tool. The data was generated in a Microsoft Standard Query Language (SQL) Server database, which was exported to a SQLLite database for mobile devices.

## 4.4 User Interface Design

Based on the requirements identified from the literature study, three different views were designed to visualise the different perspectives of the service usage information. The design of the user interfaces is discussed in this section for each of these service usage views. Initial design prototypes were developed, which are discussed in this section. Each of the visualisation views followed Shneiderman's visual-seeking mantra (1996) of "Overview first, zoom and Filter, then Details on demand". The prototype was named "MobiTel", as it is a mobile tool that supports the visualisation of TSU.

### 4.4.1 Trend Usage View

The Trend Usage View visualises the service utilisation over a time period. A time chart is a standard visualisation technique used for presenting temporal data over time. Time chart visualisations have been used on mobile devices as shown in Figure 4-3. Roambi (Figure 4-3) is a mobile business intelligence application used to present data from business intelligent systems into dashboard-style mobile analytics for the iPhone or iPad (Roambi 2012). Roambi has a trend analysis view, which visualises temporal data on a time chart. As shown in Figure 4-3, Roambi makes use of the Overview + Detail technique, where the time chart shows the detail view and the time slider below shows an overview of the search space. A standard slider or range slider can be used for filtering temporal data (Heer and Shneiderman 2012). Standard sliders are used when single values have to be altered, whereas range sliders are used for specifying multiple endpoints. Roambi makes use of a range slider which allows the user to set a start and end date.

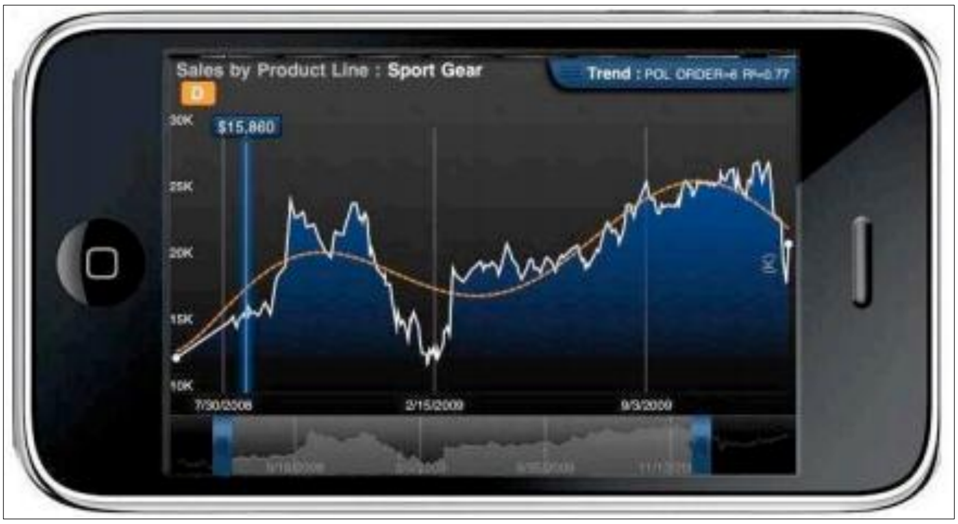



**Figure 4-3: Roambi Trend Analysis View with Overview + Detail (Roambi 2012)**

The Overview + Detail technique for time series charts has been used on existing software and thus can be applied to the Trend Usage View. Figure 4-4 illustrates a screenshot of the Trend Usage View. The current view is underlined in the top tab to show the user where he/she currently is. In Figure 4-4, the label A identifies the time series chart and the label B indicates the graph slider (referred to as range slider in Roambi). The time series chart shows the service usage where the total usage count is on the Y axis and the date range is on the X axis.

Figure 4-4 illustrates the Trend Usage View where the total email service usage for emails sent from a customer's network is displayed. The time series chart contains a threshold horizontal line, which is used to indicate a high level of usage. The threshold line can be altered by the user to a desired level of high usage. The user can obtain the usage value by tapping on a point. The Zooming + Panning technique is used to allow the user to interact with the time series chart to zoom and pan the chart. The graph slider is used to provide the user with an overview of the search space. As the user zooms or pans the graph, a green rectangle is shown on the graph slider to indicate which portion of the search space is shown in the time series chart. This usage view supports interactive and dynamic filtering to allow the user to view a specific time period of service usage.


**Figure 4-4: Trend Usage View of Email Usage**

The following tasks are supported by the Trend Usage View:

- Overview
    - View the entire service usage for the entire time period;
    - Use the graph slider to maintain an overview of the service usage for the search space.
- Zoom and Filter
    - Zoom in or out of the time series chart;
    - Filter the date ranges to view only a specific usage range.
- Details on Demand
    - Tap on a point to obtain the usage view for a specific date.

### 4.4.2 Network Usage View

The information requirements identified that service usage information on the different customer sites needs to be visualised. The *Network Usage View* was designed to use a radar chart to show the total service usage per customer site. The radar chart is an efficient way to graphically present information with a variety of data into a single view (Saary 2008). The radar chart provides the benefit of being able to support additional information without overloading the user, by adding additional spokes to the chart. Figure 4-5 illustrates an example of a radar chart used in the medical domain, which visualises the total number of deaths for males for specific types of treatments. The radar chart can also be applied to service usage information to visualise the total usage for a service for the different customer sites.

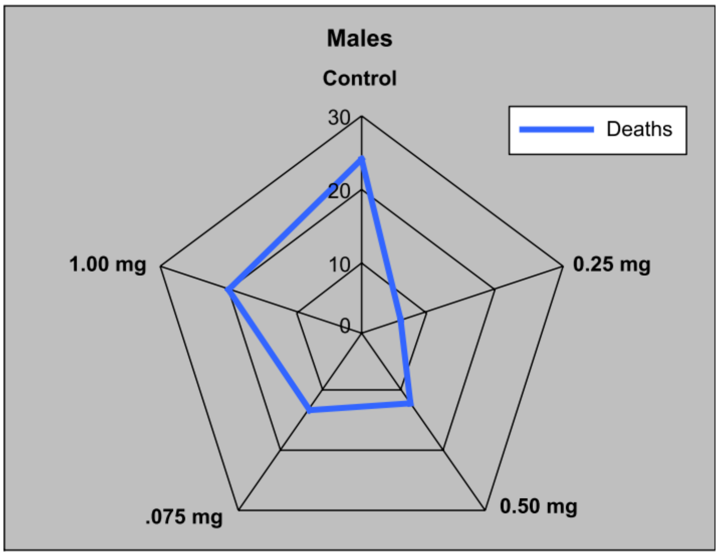



**Figure 4-5 : Radar Chart showing Total Number of Deaths per Medical Treatment (Saary 2008)**

The radar chart represents each variable on an axis, where the axes are equiangular, meaning that the angle between each axes is the same (Chang *et al.* 2012). A data value of a variable is mapped to a data point which is placed on the axis. The data point is placed in such a way that the position of the data point between the origin and endpoint of the axes is proportional to the scale of the data value and the maximum value of the axis. The adjacent axes are connected between the data points to form a polygon which is observed by the user for analysis. The radar chart can contain one or multiple polygons depending on the number of variables that need to be viewed. Figure 4-5 illustrates a radar chart with a single variable for showing the *deaths* variable. Radar charts with single polygons typically assist the analyst in identifying dominant variables for the current visualisation. For example in Figure 4-5, the analyst can identify that the control treatment has the highest number of deaths.

Figure 4-6 illustrates a radar chart with two polygons used to compare additional variables. Figure 4-6 illustrates a radar chart for comparing the quality of service for VoIP service from two different service providers. Multiple polygons allow the analyst to directly compare the dependent variables efficiently.

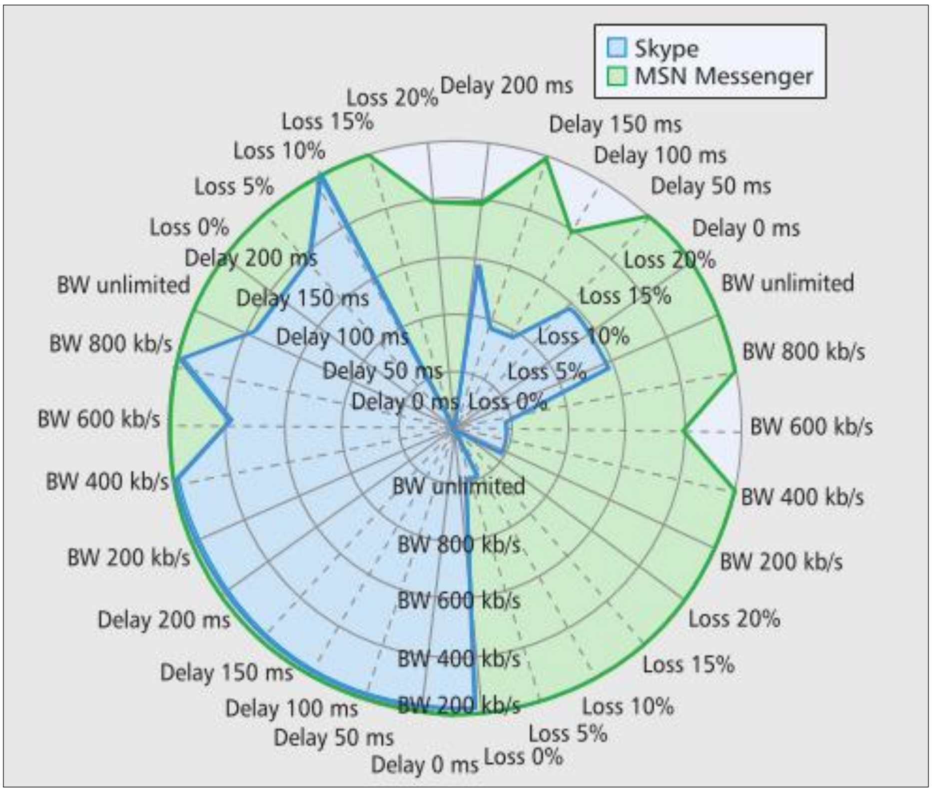



**Figure 4-6: Radar Chart with Two Samples Comparing Multiple Variables (Chang *et al.* 2012)**

For service usage information, the analyst has to be provided with the total service usage for a particular service for the different customer sites. This would require only one polygon, which indicates the total usage value for a service. Figure 4-7 illustrates the Network Usage View for visualising the customer service usage information for the email sent service. The radar chart presents the total number of emails sent on the different customer sites. The analyst can quickly view the customer site has the highest or lowest usage, which could be used to make decisions about resource allocation.

The radar chart is indicated by an A label in Figure 4-7 and B label is the time slider. The time slider is provided to allow the user to specify the time period that the analyst wants to view by specifying the start and end dates. The user can interact with the radar chart by performing actions such as rotating, zooming or dragging on the chart for a desired position. To reduce cluttering of the radar chart, the value for the axis lines is displayed on the axis in the most upright position. If the user rotates the chart, the axes labelling updates to ensure that the labelling for the axis lines is on the most upright axis. To obtain more information about a specific site, a user can tap on the site to display more detailed information.

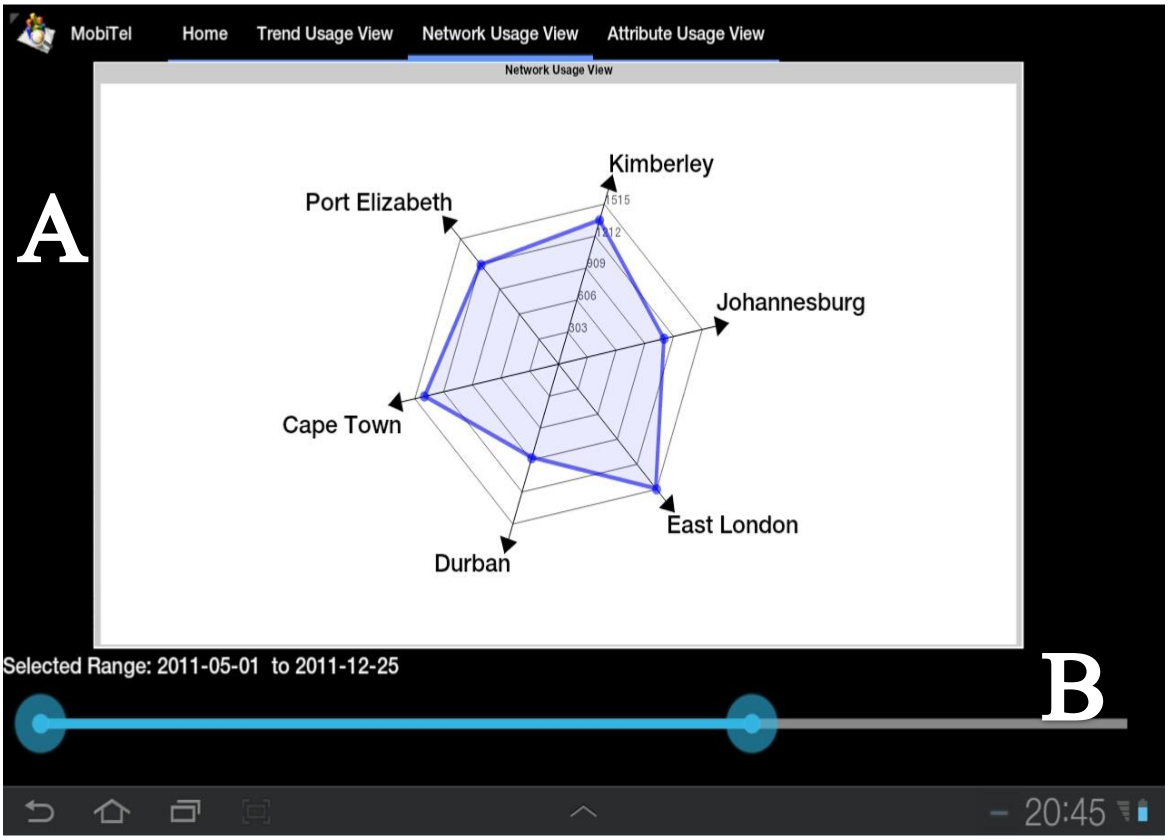



**Figure 4-7: Network Usage View for Different Customer Sites**

The following tasks are supported by the Network usage view:

- Overview
  - View the entire service usage for the entire time period.
- Zoom and Filter
  - Zoom in or out of the radar chart;
  - Filter the date ranges to view only a specific usage range.
- Details on Demand
  - Tap on a site to obtain detailed information about a site.

### 4.4.3 Detail Usage View

The Detail Usage View is used to display the service usage measures and has a multidimensional structure. For example, outbound email service usage would have service usage measured in bytes transferred, storage capacity, storage duration and processing time. VoIP and VoD would have different usage measures. Detailed information can be obtained above the usage measures for the different customer sites for a specific time period. This perspective of the service utilisation is thus multidimensional. Chapter 3 identified that a parallel coordinates chart should be used to visualise the detail service usage information. The parallel coordinates technique was initially developed for n-dimensional geometric computations, but the technique is also widely used for multidimensional data (Siirtola and Räihä 2006). The parallel coordinates chart uses direct manipulation of the visualisation, which means that there are no separate controls for manipulating the visualisation. Therefore, the use of this visualisation is suited for touch-based devices such as mobile devices. The use of scrollbars and buttons is not typically suited for touch-based devices, as these components are not consistent with this form of interaction. Parallel coordinates charts have been used in tasks, such as trend and pattern analysis, exploratory data analysis, geographical visualisation and subset detection. For analysing service utilisation, information can be obtained about the usage behaviour on the customer sites for the various usage measures. For example, the analyst can determine which customer sites have a highest number of high call durations for the VoIP service.

The concept behind the parallel coordinates chart is to have parallel coordinate axes and represent a data point as a connection line between the coordinate values (Siirtola and Räihä 2006). An n-dimensional data point $(x1, x2, .. xn)$ is represented as a line segment connecting the values $x1, x2, .., xn$ between the coordinated parallel axes. A single set of line segments is known as a polyline which connects the values $x1, x2, \dots, xn$ on the parallel axes as shown in Figure 4-8. Using the parallel coordinates chart allows the user to visualise a high number of attributes but is constrained by the horizontal space available. The number of usage measures for the different services varies, but are not high so that the horizontal space is an issue.

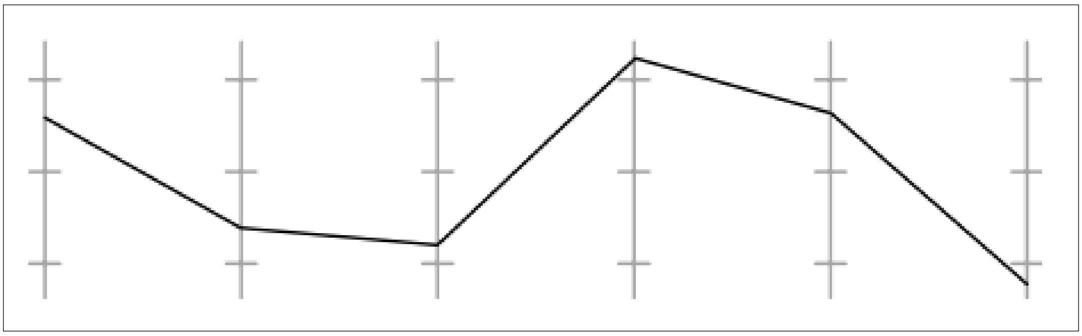


**Figure 4-8: 6D Parallel Coordinates Chart (Siirtola and Räihä 2006)**

Parallel coordinates chart was initially designed to cater only for numerical data but through the years it was identified that it can be used for representing nominal data (Rosario *et al.* 2004). Figure 4-9 illustrates a parallel coordinates chart that supports nominal data. To apply nominal data to the chart, the possible values for an attribute are mapped into small integer values which allow the attribute to be treated as numerical values (Rosario *et al.* 2004; Siirtola and Räihä 2006). This makes the parallel coordinates chart more useful for visualising service usage information. Information, such as customer site and date, can be mapped onto the chart to support in-depth analysis for these attributes.

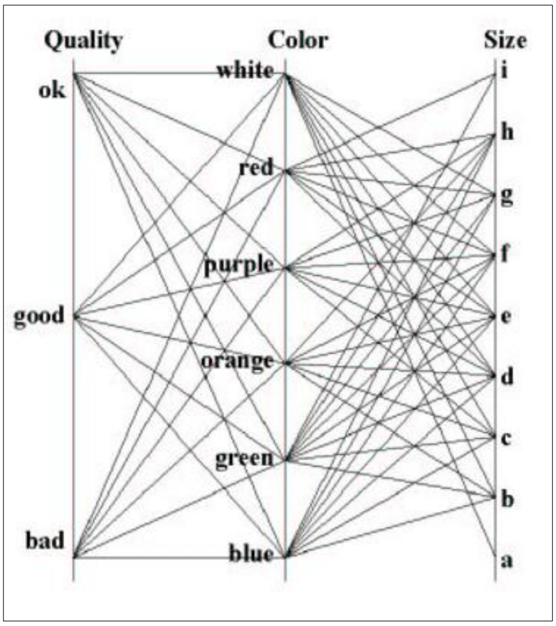



**Figure 4-9: Parallel Coordinates Chart Visualising Nominal Data (Rosario *et al.* 2004)**

Shneiderman's visual seeking mantra of “overview first, zoom and filter, details on demand..” can be applied to the parallel coordinates chart (Siirtola and Räihä 2006). An overview of the visualisation is achieved by providing the entire data set as shown in Figure 4-9. The user can zoom and filter on the visualisation by brushing on an axis, as shown in Figure 4-10. Brushing refers to selecting of polylines, which highlights a set of polylines which can be used to compare against the un-highlighted polylines. Details on demand can also be obtained by selecting a line to get information about the data points for a line on the different axes. A problem that can occur while brushing is that the highlighted polylines may be occluded by the other lines and an intuitive approach to solve this is to introduce a level of transparency with unselected polylines to allow selected polylines to stand out.

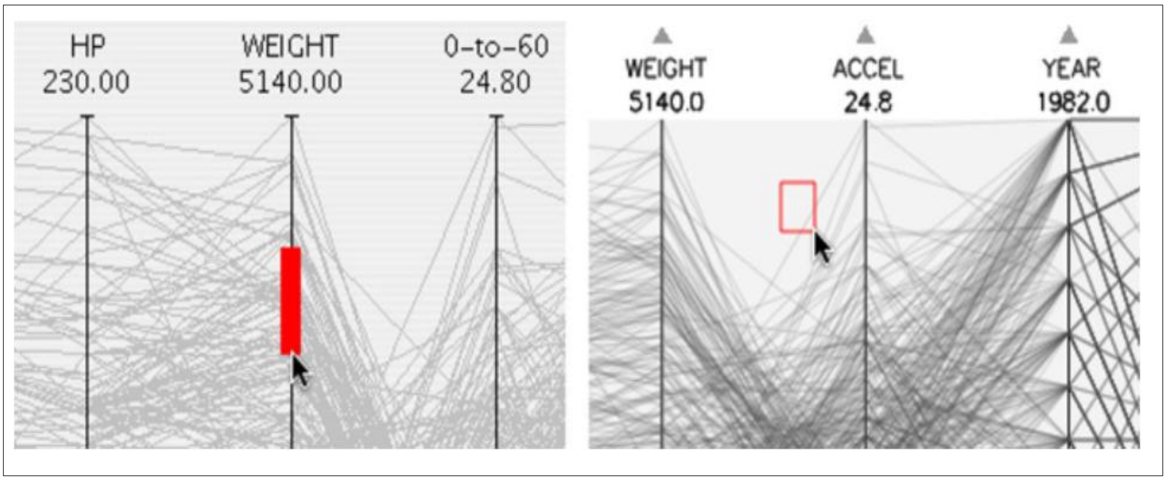



**Figure 4-10: Brushing on Parallel Coordinates Chart (Siirtola and Räihä 2006)**

The Detail Usage View is shown in Figure 4-11, which contains a parallel coordinates chart as this visualisation is focused on direct manipulation as mentioned above. Figure 4-11 illustrates the parallel coordinates chart for email service where the customer site, date and usage attributes are represented on the coordinate axis. The customer sites and date values are mapped to numerical values to allow the attributes to be shown on the visualisation. The user can specify filters on an axis by dragging on the axis which highlights the polylines that meet the specified filters. The user can select specific customer sites to compare the service usage. Each polyline represents the total usage for a day for the various attributes. For example, a line may represent the email services usage at Johannesburg on the 2nd March 2012 with a total bytes transferred of 1800 megabytes. The user can answer questions such as, which customer site has the highest number of days, where the total number of bytes transferred, is greater than a certain value. This visualisation is similar to performing a SQL statement from a database where conditions are specified to retrieve results.

The following tasks are supported by the Detail Usage View:

- Overview
  - View the entire service usage for the different usage measures.
- Zoom and Filter
  - Specify filters on the axis to answer specific user questions.
- Details on Demand
  - Tap on a customer site(s) to compare or view the usage on the specific site.

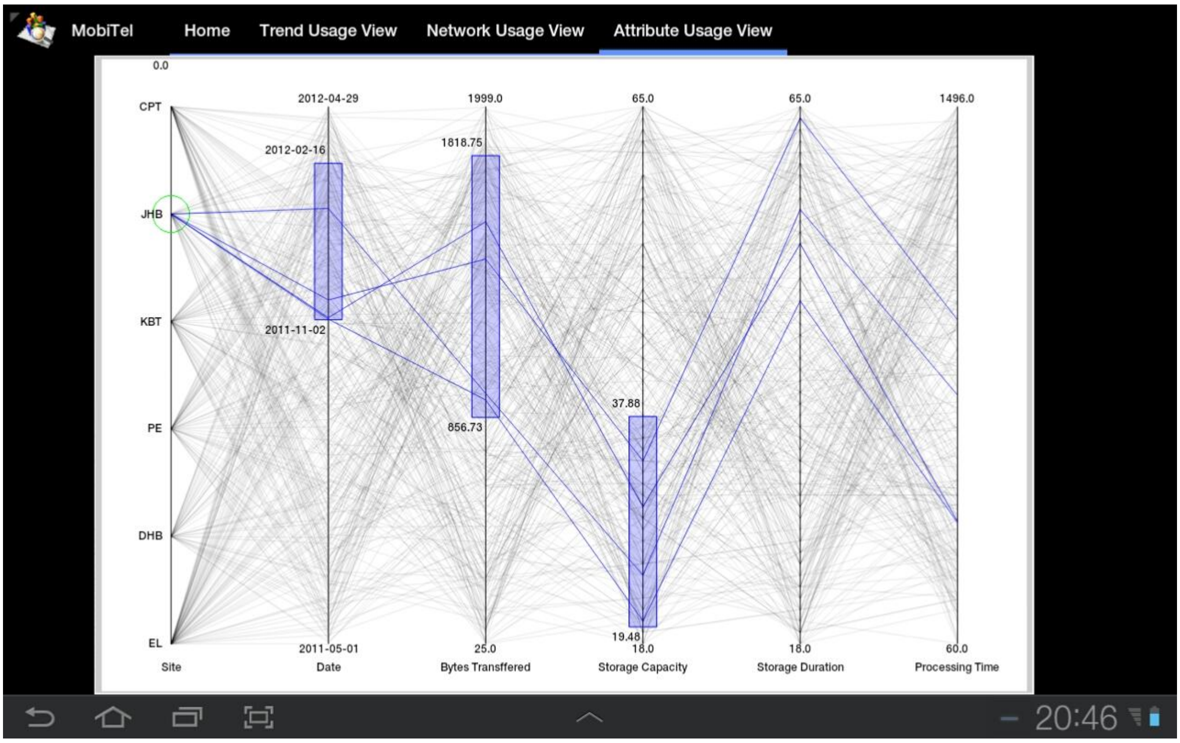



**Figure 4-11: Detail Usage View of Email Service Usage**

## 4.5 Expert Review

The design and implementation of the prototype followed an iterative development process and therefore, an expert review was conducted in order to identify potential usability issues to improve the prototype. The method used and the results of this evaluation are discussed in this section.

### 4.5.1 Evaluation Objectives

The aim of the study was to conduct an expert review in the form of a heuristic evaluation to identify possible usability issues in the early stages of the development cycle. The results of the evaluation will assist in improving the prototype by identifying design recommendations that need to be made. This evaluation focuses on the usability of the visualisation techniques implemented.

### 4.5.2 Heuristic evaluation

A heuristic evaluation is an expert-based evaluation technique, which evaluates the usability of the user interface (Bertini, Gabrielli and Kimani 2006). Heuristic evaluation is a common approach used for evaluating usability because of its efficiency in detecting potential usability issues. To conduct a heuristic evaluation, between three to five evaluators are required. This inspection technique can typically detect about 75% of usability issues, which can save time and human resources costs up-front (Nielsen and Molich 1990). Other benefits of using heuristic evaluations are that the usability can be evaluated early in the development process and that no advance planning is required.

With heuristic evaluation, the experts are given tasks that a typical end user will have to do (Tory and Moller 2005). This technique is best suited for early prototypes where a formative evaluation is conducted (Gabbard, Hix and Swan 1999). Expert reviewers are required to report advantages, disadvantages and evaluate the interface by looking at a set of heuristics. A popular set of usability heuristics are Nielsen's ten heuristics (2010), as follows:

1. Visibility of system status;
2. Match between system and the real world;
3. User control and freedom;
4. Consistency and standards;
5. Error prevention;
6. Recognition rather than recall;
7. Flexibility and efficiency of use;
8. Aesthetic and minimalist design ;
9. Help user recognize, diagnose and recover from errors and
10. Help and documentation.

For the evaluation of the visualisation techniques implemented in the prototype, an expert review was conducted. The heuristics proposed by Nielsen were used except that the "*Help and documentation*" and "*Help user recover from errors*" heuristics were omitted as these heuristics were not applicable at this stage of the prototype development because the evaluation focused on the usability of the visualisation techniques and not the entire tool.

When the experts reviewed the prototype, common usability issues among the different experts were identified. The experts then received the list of the common usability issues and collaboratively assigned agreed severity ratings. The severity rating provides an indication of how severe a usability issue is. The severity rating can be selected from a Likert scale with the values 0-4. The value of each rating is described below:

0. **Not a usability problem**;
1. **Cosmetic problem**: need not be fixed unless extra time is available;
2. **Minor usability problem**: fixing this should be given a low priority;
3. **Major usability problem**: important to fix, should be given a high priority;
4. **Usability catastrophe**: imperative to fix this problem before product can be released.

### 4.5.3 Research Design

An expert review was conducted, as this approach is a cost effective inspection technique that can be used to identify many potential usability issues in the early stages of the prototype development process. A task-based approach was used with an expert review where the experts were given typical user tasks that have to be completed (Appendix C). A persona of the user was also provided to enable the experts to understand the user's context (Appendix D). The experts were given a list of heuristics, which were described in terms of the prototype developed. The heuristics were used to evaluate the usability of visualisation techniques implemented in the prototype. Five experts were selected consisting of two domain experts and three design experts. The domain experts are system engineers who are familiar with telecommunication services and could provide insight on whether the content displayed is correct and can be interpreted correctly. The design experts were selected because of their experience with user interface design. The Think Aloud protocol was used where the expert reviewers were asked to mention what they were thinking while using the prototype. This process was recorded using a dictaphone, which was later transcribed for further analysis. This information was then recorded in terms of the heuristics used for evaluation. The results were analysed and summarised to identify common issues in based on the heuristics. Two of the design experts gathered to collaboratively assign severity ratings to each of the potential usability issues identified. The usability issues identified and severity results were then analysed.

### 4.5.4 Results

Potential usability issues identified from the expert review are summarised in Table 4-2 and Table 4-3 together with the severity ratings. The usability issues identified were the most common issues identified by the five experts. From the results in Table 4-2 and Table 4-3, the issues identified were mostly minor usability issues, which indicate that the system has good usability. Based on Nielsen's heuristics, the prototype needs to improve the visibility of the system status. The experts commented that it was not immediately clear what information is being visualised, e.g. the total emails sent or received. The other issues were minor usability issues such as a missing or small label. Another area of concern was the consistency and standards heuristic as the experts felt that the interaction and controls used on the different views were different. For example, setting the date range on the three views each has a different form of interaction, which could confuse the user. Other areas of concern related to the inaccuracy of the touch interaction on the visualisations. There were a few major usability issues identified that had to be addressed. Some of the experts mentioned that they liked the simplicity of the visualisations and that they could easily interact with the touch gestures. Based on the severity ratings assigned and the comments made by the reviewers, the prototype seemed effective and intuitive to use.

**Table 4-2: General Usability Heuristic Evaluation Results**

| Usability Criteria | Potential Usability Issues | Severity Rating |
|---|---|---|
| ***1. Visibility of system status*** | System does not clearly indicate what information is being visualised | 2 |
| | System does not clearly illustrate the touch interaction | 2 |
| | System does not indicate which parts of the graphs are interactive | 3 |
| | User cannot easily identify the time slider control | 3 |
| | Legends are not clearly visible | 1 |
| | Lack of semantics on the graph | 2 |
| ***2. System and the real world*** | Terminology on the labeling needs to be clearly defined | 2 |
| ***3. User Control and Freedom*** | To zoom or pan certain section of the time slider, multiple steps have to be taken | 2 |
| | System does not provide undo functionality | 3 |
| | Trend Usage View does not allow time range to be specified | 2 |

**Table 4-3: General Usability Heuristic Evaluation Results (Continued..)**

| Usability Criteria | Potential Usability Issues | Severity Rating |
|---|---|---|
| ***4. Consistency and Standards*** | Colour usage is not consistent between the different views | 1 |
| | Interaction is inconsistent between the different graphs | 3 |
| | Date slider is inconsistent between the different views | 3 |
| ***5. Error Prevention*** | System does not allow the user to reset actions as they get lost while navigating | 3 |
| | System does not prevent the user from accidently selecting information | 2 |
| ***6. Recognition rather than recall*** | The selected time range is not remembered for the different views | 2 |
| ***7. Flexibility and efficiency of use*** | Zooming on the graphs is too rigid | 2 |
| | Interaction and visualisation is slow | 2 |
| ***8. Aesthetic and minimalist design*** | Detail Usage View is too cluttered | 2 |
| | There is a lack of spacing on the graphs | 1 |
| | Colours in the attribute usage view are underused | 2 |

### 4.5.5 Discussion

Most of the issues identified in Table 4-2 are minor usability issues, and there were no usability catastrophes, which indicate that the system is usable. Nielsen's heuristics showed that the system needs to improve the visibility of the system status. The experts stated that the system does not immediately indicate what information is being presented to the user. The legends have to be enlarged to be clearly visible to the user. The experts also felt that the system did not provide indication of which touch gestures are supported and where the interaction could be applied. If the user is shown how to interact with the system, then the user can easily perform the action. A feature that should be added to the graphs is to improve the semantics such as selecting a point on the Trend Usage View to obtain more detailed information about a data point. The consistency of the system also needs to be improved. The major concern was that the interaction involved in specifying the date was inconsistent between the different views. The Trend Usage View allows the user to change the date range by using drag or pinch gestures, whereas the other views only make use of the drag gesture for specifying date ranges. The component used to specify the date range is inconsistent with the different views, which could confuse the user.

It was noted that visualising the information on the tablet device is intuitive and encourages users to interact with the information. The next section will address the usability issues identified by discussing the implementation of the prototype, which included the design changes recommended from the heuristic evaluation.

## 4.6 Implementation

The prototype was developed on a Samsung Galaxy Tab 10.1 tablet PC which makes use of the Android operating system and supports ten simultaneous touch points. The prototype was implemented for the Android platform and the implementation tools were selected to support this platform. This section discusses the implementation of the prototype by highlighting the implementation tools selected and presents the prototype developed. The design implications from the formative evaluation are also discussed in this section. The implementation of the prototype was based on the Reference Model (Section 3.3.1).

### 4.6.1 Implementation Tools

Android is an open and free software operating system design for mobile devices such as smartphones and tablet PCs. Various visualisation toolkits for the Android platform were investigated to identify the most suitable toolkits to develop the prototype. A method of comparison is shown in Table 4-4 for available toolkits that could potentially be used for the development of the prototype. The criteria for selecting the implementation toolkits were based on whether the visualisation techniques required can be implemented, the level of customisability and the quality of the visualisation produced. Afreechart (ICOMSYSTECH 2011) and Achartengine (4ViewSoft 2011) are Android libraries, whereas Dojo Mobile (Dojo_Foundation 2012) is a Javascript library that can run on the Android platform as a web-based application. Processing (Fry and Reas 2004) is an open source programming language, which provides support for the Android platform, which contains a rich library to produce high quality visualisations, but does not provide any standard visualisations.

Table 4-4 illustrates that Afreechart and Dojo Mobile were the best candidates for implementing the prototype as both these toolkits can provide times series and radar charts to support the trend and Network Usage Views. These two libraries are also both highly customisable and thus the parallel coordinates chart could have been implemented using the components of these libraries. Afreechart is an Android charting library and thus directly supports the native platform whereas Dojo Mobile produces a web-based application, which is not consistent with the Android platform.

**Table 4-4: Comparison of Implementation Tools to for Visualisation on Android Devices**

| Criteria | Achartengine | AfreeChart (Jfreechart) | Processing | Dojo mobile |
|---|---|---|---|---|
| **Language** | Android (Java) | Android (Java) | Android (Java) | Javascript |
| **Aesthetics** | Medium | Medium | High | High |
| **Chart Drawing Support** | Yes | Yes | No | Yes |
| **Charts Supported** | Time Chart | Time Chart, Radar Chart | N/A | Time Chart, Radar Chart |
| **Extensibility/ Customisability** | Low | High | Custom | Low |
| **Interaction API support** | High | Medium | N/A | Medium |
| **Interaction Customisability** | Low | High | N/A | Low |
| **Scalability** | Low | High | N/A | High |
| **Rendering support** | Low | Medium | High | Medium |

Dojo Mobile was not selected as it produces a web-based application. Developing for the native platform avoids issues such as touch gestures not be efficiently recognised and other issues with processing speed. A large amount of usage data has to be visualised and developing for the native platform better supports intensive processing. Native applications also improve the user experience as the look and feel of the application is consistent with the hardware platform. Afreechart was therefore selected to develop the prototype.

Afreechart is an open-source charting toolkit for Android (ICOMSYSTECH 2011). Afreechart provides basic touch-based gestures such as tap, pinch, spread and drag on the chart. The Afreechart library supports many types of charts such a time series, radar and scatterplot. Afreechart was selected because the library is open source and highly customisable, which allowed the parallel coordinates chart and touch gestures to be implemented. The touch gestures provided by Afreechart were not sufficient for the custom implementation of the visualisation techniques and thus the touch gestures had to be re-implemented. This is discussed in the following section.

### 4.6.2 Touch-based Interactions

There is multiple touch-based gesture support on mobile devices which falls into two categories (Lü and Li 2012). The first category contains those gestures that have some pre-defined shape, such as recognising a handwriting symbol. These types of gestures are suited for applications that require the user to draw and are not suited for manipulating information. The second category comprises of touch gestures such as tapping to activate and pinching to zoom, which are used to directly manipulate an interface. These types of touch-based gestures are typically used for manipulating objects on the screen, mimicking the physical interaction with objects in the real world. Common touch gestures for small screen mobile devices are tap, pinch, spread and drag.

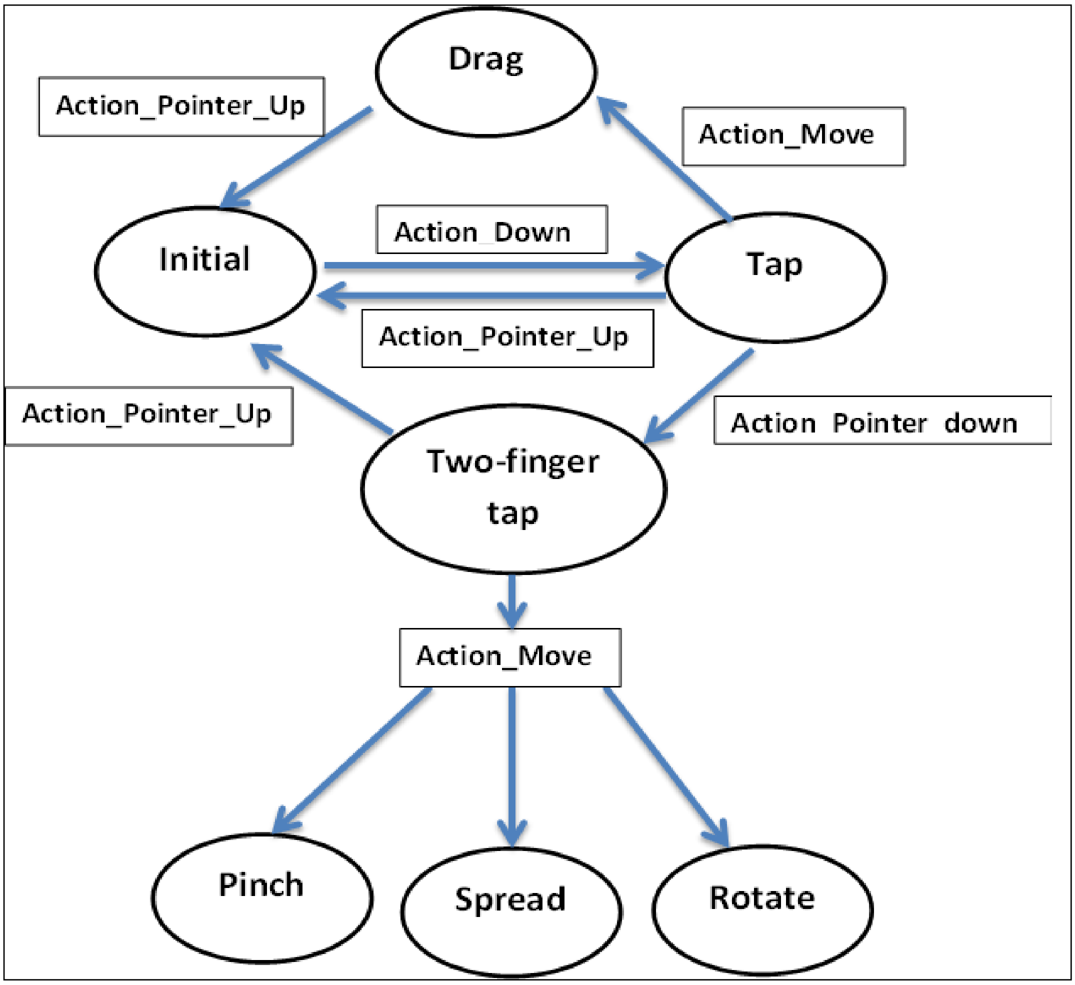



**Figure 4-12: Touch Gesture States in MobiTel**

Programming touch gestures requires the developer to keep track of where the finger(s) land and of movement changes (Lü and Li 2012). For example, if a second finger lands, then the relative movement between the fingers must be analysed to determine if the user is pinching or spreading. The implementation of the touch gestures for MobiTel is illustrated in Figure 4-12. The different states for the touch inputs are shown as ovals and the lines represent the actions performed by the fingers. *Action_Down* indicates that the first finger has touched the surface, which puts the system in the "Tap" state. If the user lifts the finger while in "Tap" mode then the *Action_Pointer_Up* event is triggered, indicating that the user has tapped on the surface. The *Drag* gesture is triggered if the finger moves while the system is in "tap" mode, then the *Action_Move* event is triggered. If a second finger touches the surface then the system will detect that a multi-touch gesture has occurred.

If the *Action_Move* event is called while two fingers are on the surface, then the system will analyse the distance and position of the fingers to detect if a pinch, spread or rotate gesture has occurred. The central point between the fingers is calculated when a pinch or spread gesture is detected to determine where the user is wants to zoom. Once the touch-gesture is determined, the information is sent to the visualisation component to handle the gesture that has occurred. Only one touch-gesture is created during an interaction session to ensure that different touch gesture commands are not executed simultaneously.

### 4.6.3 MobiTel

Section 4.4 discussed the design of the prototype as well as initial prototype implementations. Section 4.5 discussed an expert review of the prototype, which identified potential usability issues. This section discusses the implementation of the prototype, MobiTel, which includes the design changes made based on the expert review. In the design section, it was discussed that each view supports the user tasks of overview, zoom and filter, then details on demand. This section also discusses how the other user tasks of the visual seeking mantra are supported. From the design, the general look and feel of the prototype was implemented to follow Android UI guidelines on interface design (Google 2012). A flexible navigation flow was implemented to allow the user to swipe between the different views which is consistent with the UI design pattern of the Android platform. The use of windows, icons, menus and pointers (WIMP) were omitted as a requirement of the prototype is to effectively support interactive exploration of the data. Other changes made on each of the service usage views were that the size of the labels was improved and the colour scheme was made consistent.

#### 4.6.3.1 Trend Usage View

As discussed in Section 4.4.1, the Trend Usage View makes use of a time series chart to visualise the service usage over a period of time. The time chart in the Trend Usage View was implemented using the time series chart component from Afreechart. The time series chart from Afreechart provides the basic rendering and plotting of the data points. Figure 4-13 illustrates the Trend Usage View, including the touch gestures. The gestures supported on the Trend Usage View are Tap, Pinch, Spread and Drag. The user can zoom in or out of the time chart by using the Pinch and Spread gestures respectively. Zooming can be performed either on the time chart or on the graph slider. The user can also pan the graph by using the drag gesture horizontally on both the time chart and the graph slider.

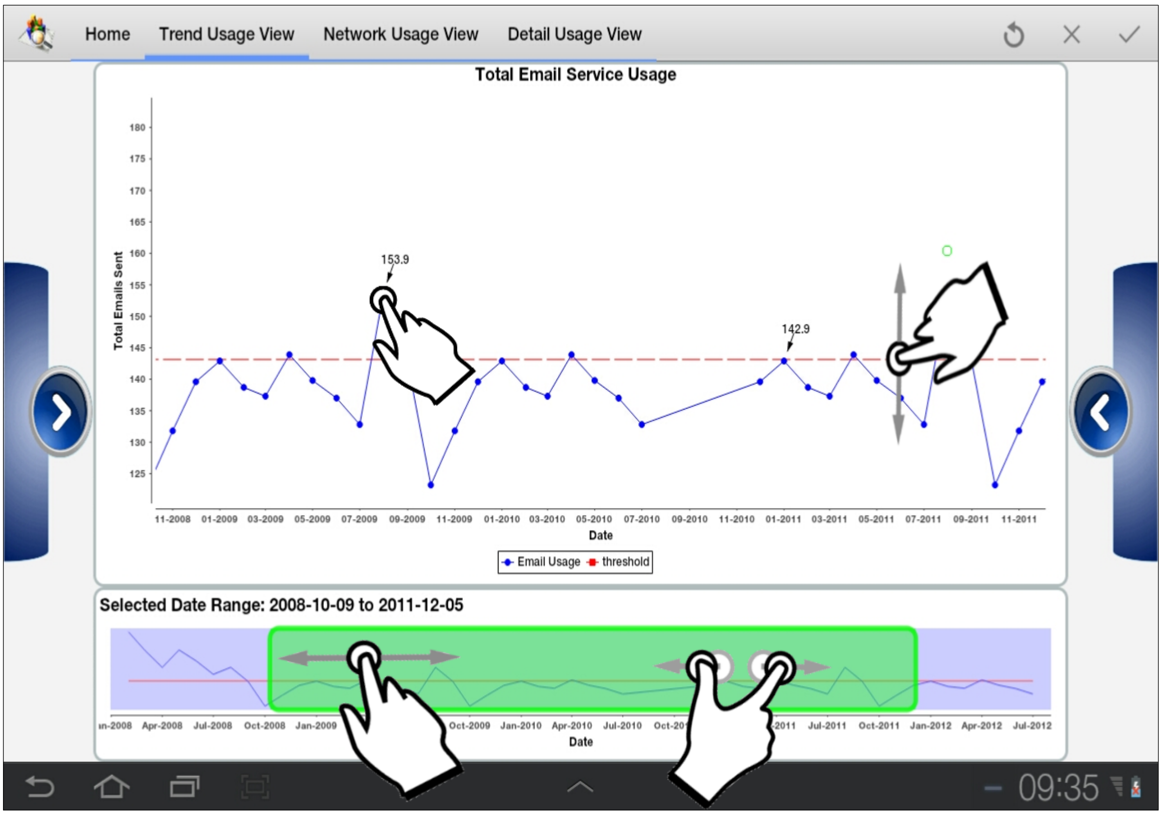



**Figure 4-13: Trend Usage View with Touch Gestures**

A threshold line is displayed on the time chart as a dotted red line which provides an indication of high usage. The user is able to change the threshold line value by selecting the threshold line and dragging in a vertical direction until the desired position is obtained. Values above the threshold line are perceived by the user as high usage points. The user can obtain the value of a data point by tapping on the point as shown in Figure 4-13.

From the expert review, it was identified that the system does not provide sufficient indication that the graph slider is interactive. This was addressed by providing a visual cue when the user touches on the graph slider. The green rectangular block changes from green to red while the user is interacting, then reverts to the green colour when the user does not interact. If the user cannot zoom or pan the graph because the end has been reached, a haptic feedback cue is provided to indicate the end of the search space has been reached. Another issue identified from the expert review was the lack of semantics. The date axis and selected date range is shown on the graph slider to assist the user to more easily identify the time period that is currently being shown. The user tasks supported by the Trend Usage View are interactive filtering and interactive zooming.

#### 4.6.3.2 Network Usage View

The Network Usage View is shown in Figure 4-14. Afreechart was developed from a larger charting library for desktop application called Jfreechart (ICOMSYSTECH 2011). Afreechart contains some of the charts from Jfreechart, but does not have an implementation of the radar chart. Jfreechart and Afreechart are both open source libraries, which allow the coding of the library to be viewed. The radar chart from Jfreechart had to be migrated to Afreechart to use the visualisation. The interactions supported on the Network Usage View are tap, pinch, spread, drag and rotate. The user is able to reorganise the radar chart display by rotating, dragging and zooming in or out of the graph. The zoom gesture was implemented so that the user can zoom, based on where the fingers are positioned on the graph.

The time range can be specified by dragging on the thumb icons on the time sliders. As the user drags on the circular thumb on the time slider, the chart automatically updates. Haptic feedback was implemented to indicate to the user if the minimum or maximum date ranges had been reached. The user can tap on a customer site to obtain more detailed information for the selected site as shown in Figure 4-14. A dialogue is presented to the user which provides more statistical information about the usage on a particular site. Information such as the average usage value and the number of users, using a particular service is displayed. The view supports dynamic filtering by automatically updating the visualisation while the user interacts with the range slider. From the expert review it was mentioned that the experts felt that the manner of changing the date range was inconsistent between the Trend Usage View and the Network Usage View. This is due to the nature of the visualisation, as the radar chart has a different search space to the time series chart. The Network Usage View also supports interactive zooming and filtering. The MIV technique used on the Network Usage View is the radar chart and Zooming and Panning.

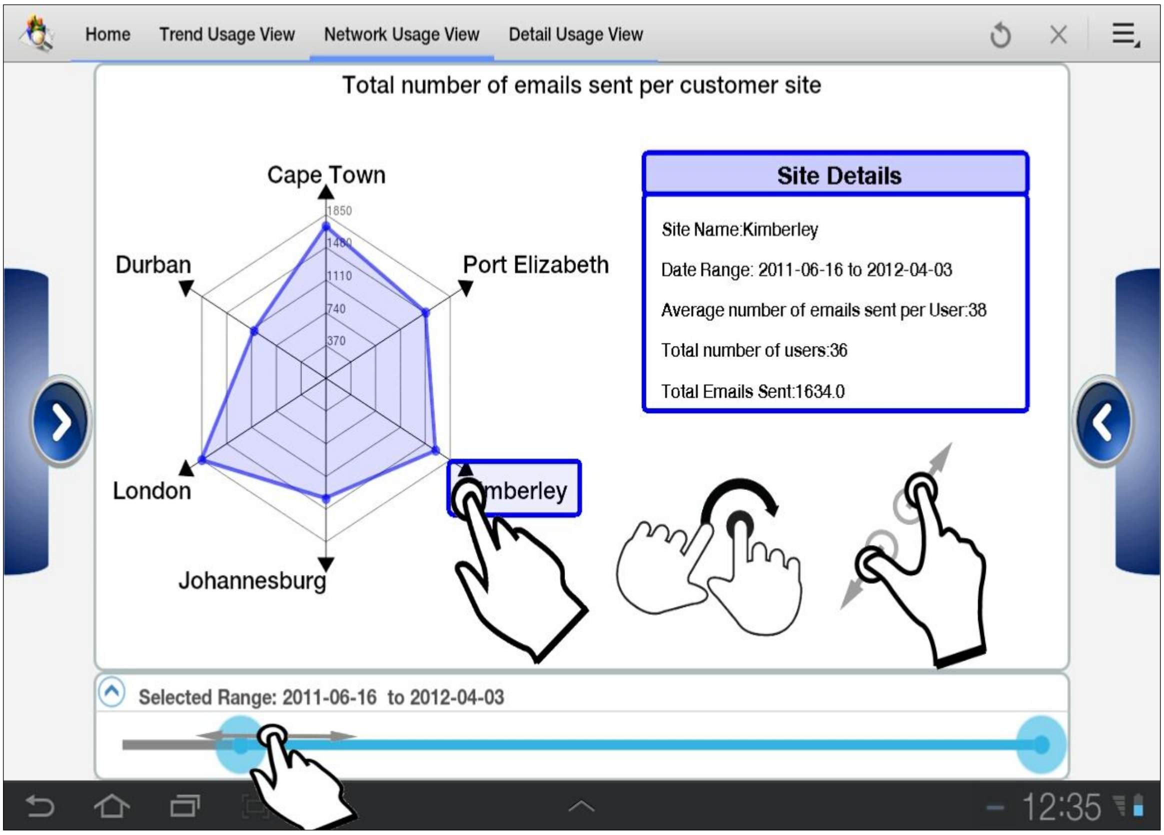



**Figure 4-14: Network Usage View with Touch Gestures**

### 4.6.3.3 Detail Usage View

Figure 4-15 illustrates the Detail Usage View with the touch gestures. The Detail Usage View provides detailed information about the usage measures for a service, which assists the analyst with decision making. Afreechart does not provide support for the parallel coordinates chart, which implied that the visualisation had to be implemented into the Afreechart library. The user is provided with an initial overview of all the information by displaying all the polylines.

The axes of the parallel coordinates chart were implemented to cater for the customer sites values, which are nominal values. Each customer site is mapped to a number value based on the order in which the site's name was read into the system. Axes that contain nominal data have different touch interaction from axes that cater for numerical data. Axes that contain nominal data support the Tap gesture where the user can select a nominal value. In Figure 4-15, the user can select customer sites to show only the information relevant to those sites by tapping on the value. The polylines originating from the customer site will be highlighted.

The user can specify filters for axis with numerical data. As the user drags on the axis, a filter is generated and shown with a vertical rectangular block. The upper and lower values are displayed next to the filter to show the user the filter value. As filters are specified on the parallel coordinates chart, the polylines that pass through the filters are highlighted and the other polylines are made partially transparent. This is referred to as a “brush tunnel”, where colour and highlighting are used to select specific data (Liang and Huang 2010). The user can reposition a specified filter on an axis by selecting on the filter and dragging in a vertical motion. The user can increase or decrease the upper or lower part of the filters by dragging on the bottom or top part of the filters.

The expert review identified that the manner in which the date range is specified in the Detail Usage View was different from the other views. The date axis was removed from the parallel coordinates chart and a range slider was added to the bottom of the Detail Usage View to allow the user to specify the time period. This also provides consistency between the different views where the time period is specified at the bottom of the service usage view.

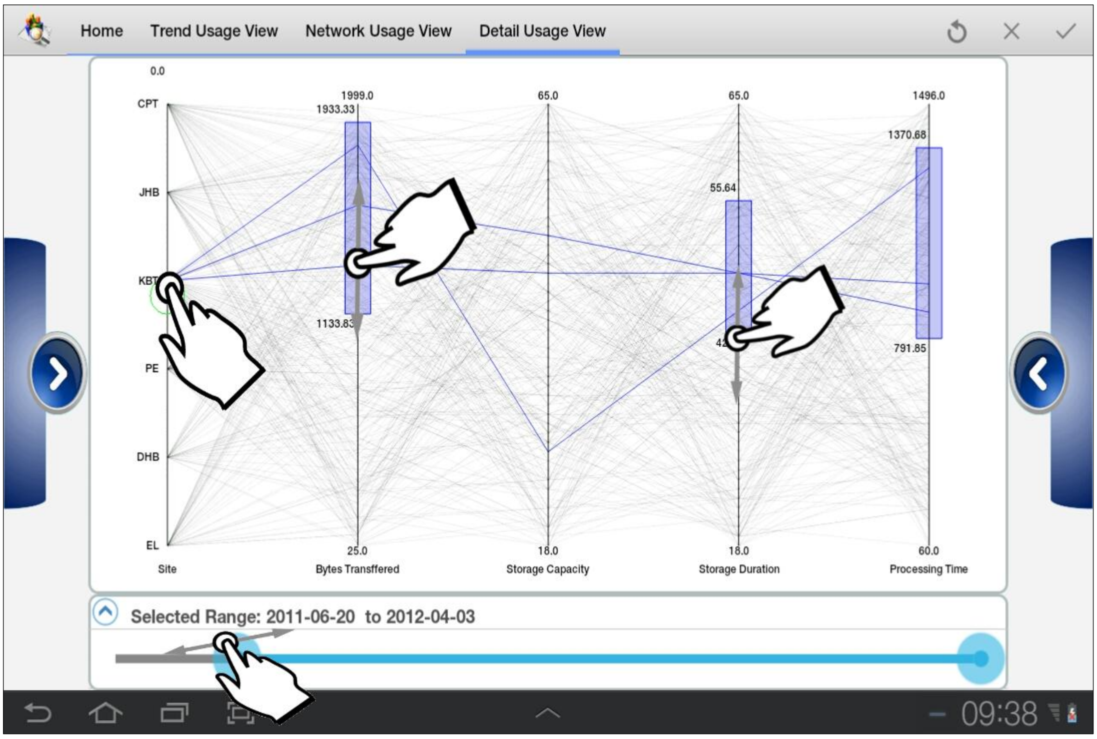



**Figure 4-15: Detail Usage View with Touch Gestures**

A usability issue identified from the expert review was that the system did not allow the user to undo any action. One of the user interaction tasks from Shneiderman’s visual seeking mantra (1996) is history, which allows the user to undo actions. On the Trend, Network and Detail Usage Views, a Clear (✕) icon and a Reset (↻) icon is provided on the top right hand corner of each graph. The Clear icon removes any filters or annotations that have been displayed on the graphs based on the user's interaction. The Reset icon is used to reset the state of a graph to remove all interactions performed by the user, including resetting the time periods.

#### 4.6.3.4 Dashboard View

Analysis tools need to be able to support multiple views where selection and filtering operations, applied to various displays, can be organised into a resulting dashboard (Heer and Shneiderman 2012). One of the objectives of the solution identified in Chapter 2 is that a solution for reporting on TSU should provide a dashboard of the customer service usage. A Dashboard View was therefore implemented in MobiTel to provide an overview of the different service usage views.

The three service usage views support four of the six tasks of Shneiderman's visual seeking mantra. The *Relate* and *Extract* tasks are supported through the use of a dashboard view. Figure 4-16 illustrates the Dashboard view, which is the home screen of the application. The Dashboard View provides a read-only view that presents a screenshot of the interactions performed on the various service usage views. The Dashboard view thus serves as a quick reference view to the different usage views.

Section B in Figure 4-16, shows a series of thumbnail screenshots of the different usage views, which can be navigated by using the drag touch gesture. The user can view a thumbnail screenshot by positioning the thumbnail in the middle of the component in Section B. Section A presents an enlarged version of the thumbnail. This allows the user to quickly navigate between the different service usage views to analyse the graphs based on how they interacted with the different views. The user can also specify which service he/she wants to view by selecting a service from the list in Section C in Figure 4-16. The user can click on the image in Section A to navigate to a usage view. This improves the flexibility of the navigation of the application, which allows a smoother flowing and interactive prototype.

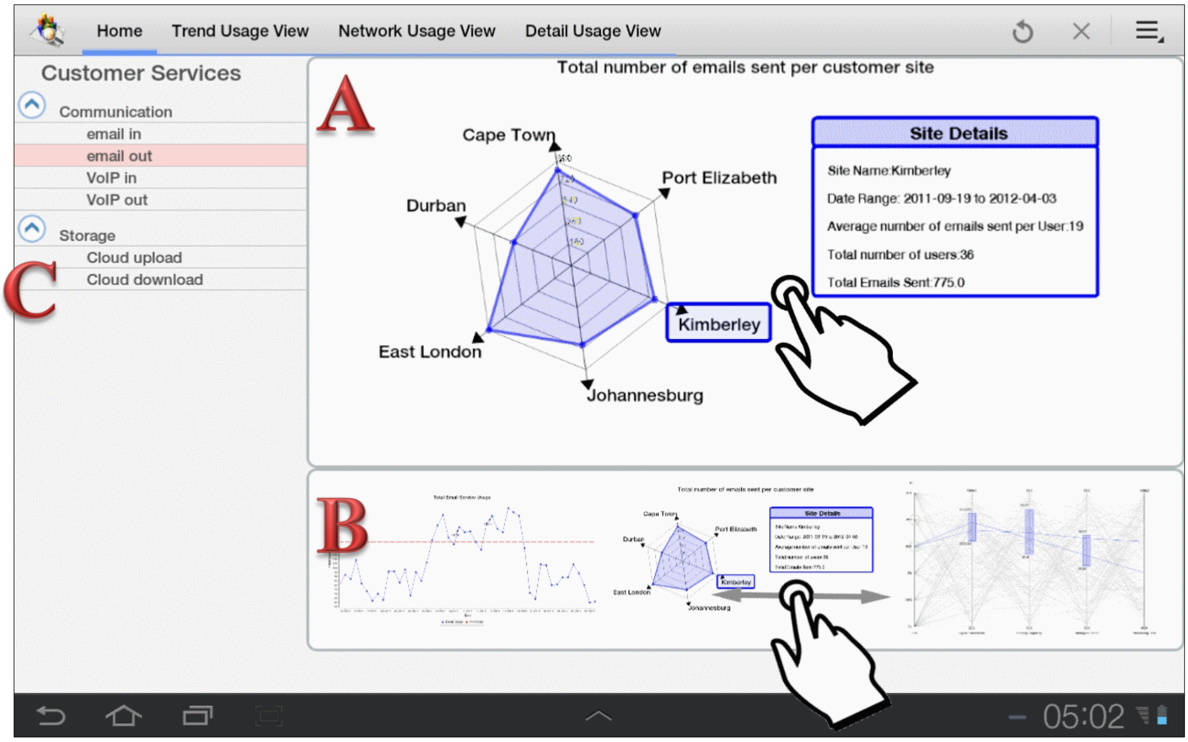



**Figure 4-16: Dashboard View supporting Relate and Extract Tasks**

The *Relate* task is supported in this view, as the user is able to quickly compare the information on the different visualisations, efficiently supporting decision making. The *Extract* task is also supported as the interactions on the visualisation are saved and presented on the dashboard view. If the user navigates back to a particular view, the state will remain unchanged from the last time the user interacted with the view.

## 4.7 Extended Visualisation Framework

Section 3.4 identified an existing framework for visualising service usage information. From the Visualisation Framework and the requirements from Chapter 2 and Chapter 3, it was determined that three views are required for the visualisation of TSU data, namely Trend Usage View, Network Usage View and Detail Usage View. Chapter 3 identified suitable visualisation techniques for service usage information as well as suitable touch gestures. Touch gestures were incorporated with visualisation to cater for mobile devices. Figure 4-17 contains an extended framework that describes the components that a mobile visualisation tool should contain in order to visualise service usage information. Figure 4-17 illustrates the IV techniques, MIV techniques as well as the touch gestures that a visualisation tool should contain in order to visualise service usage information on a mobile tablet device.

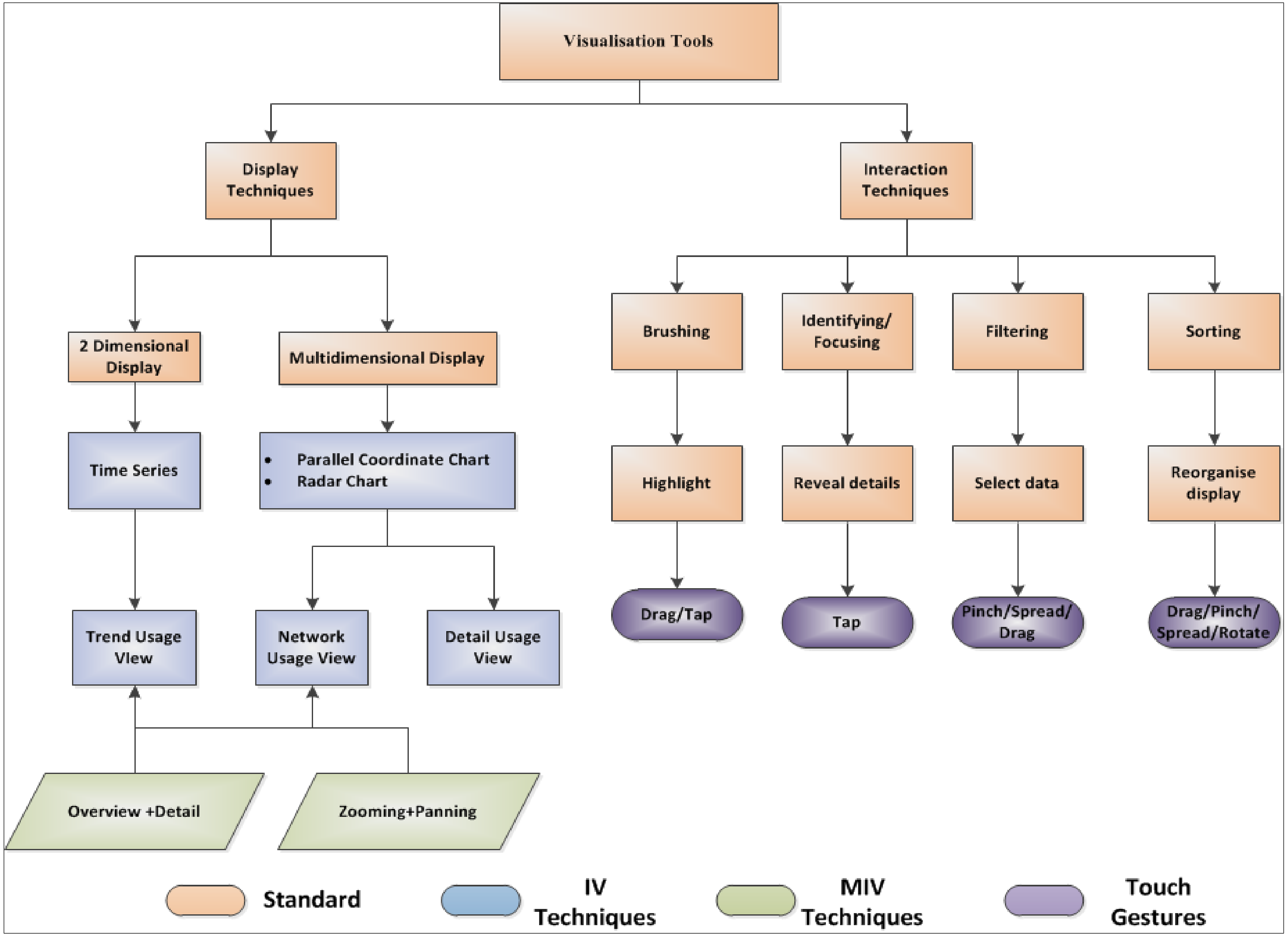



**Figure 4-17: Extended Framework for Visualising TSU Data on a Tablet Device**

The visualisation tool consists of display and interaction techniques. For two dimensional display of service usage information, a time chart is used to visualise the usage of the time period and is implemented in a Trend Usage View. The multidimensional data of the service usage information is visualised by using a radar and parallel coordinates chart, which should be viewed in a Network and Detail Usage View respectively. To support the space constraints of mobile devices the Trend Usage View should make use of the Overview + Detail as well as the Zooming + Panning technique. The Network Usage View also makes use of the Zooming + Panning technique to allow the user to navigate the search space and rearrange the visualisation.

The touch interactions were incorporated into the framework to support the interaction techniques. On the parallel coordinates chart, brushing is performed where the user can drag or tap on an axis to specify filters and thus the drag and tap gestures are assigned to the brushing technique. Obtaining detailed information in MobiTel is done by tapping on an object of interest on a visualisation. The Drag gesture is used on each view to change filters such as the date range or axis filters in the Detail Usage View. The pinch and spread gestures are used on the Trend Usage View to allow the user to filter a date range and thus the Pinch, Spread and Drag gestures can be selected when designing the filtering interaction technique.

On the Trend and Network Usage Views, the user can interact with the graphs by zooming, rotating and dragging on the visualisation. The Drag, Pinch, Spread and Rotate gestures can thus be used for sorting the display.

## 4.8 Conclusion

This chapter discussed the design and implementation of a MIV tool for service usage information. An existing Visualisation Framework, describing the components that should be in a visualisation tool for service usage information, was identified in Chapter 3. The design and implementation followed an interaction design methodology to iteratively improve the prototype. This chapter completed the design and development phase and the demonstration phase of the DSRM. Hevner *et al.* (2004) sixth design guideline was met which states that the design of the solution should be conducted as a search process for an effective artefact. Chapter 3 investigated MIV techniques as the solution and in Chapter 4, a prototype design was created. The prototype design was demonstrated to refine the solution.

The Visualisation Framework and visualisation techniques identified from Chapter 3 were used to design the prototype. Three usage views were designed, namely Trend, Network and

Detail Usage Views, to visualise the service usage information. A time series chart, a radar chart and a parallel coordinate chart were used in the three usage views. The Overview + Detail technique was applied to the Trend Usage View as existing systems currently make use of the same technique. An initial prototype was developed as part of the iterative development process.

A expert review was conducted to identify potential usability issues. The evaluation was conducted in the form of an expert review, consisting of two domain experts and three usability experts. The expert review was performed by using a heuristic evaluation where the experts were asked to rate the usability issues identified. The results of the expert review indicated that there were no usability catastrophes and the usability issues identified were addressed in the implementation of the prototype. A Dashboard Usage View was also developed during the final development phase of the prototype to provide the user with a query history of the different views.

The next phase of the DSRM is the evaluation of the solution developed, which is discussed in Chapter 5.

# Chapter 5: Evaluation

## 5.1 Introduction

Chapter 4 discussed the design and implementation of MobiTel, a prototype, to support in-field investigation of TSU. Chapter 4 completed the design and development phase and conducted the demonstration phase of the DSRM. The solution discussed in Chapter 4 was iteratively developed to produce a usable solution. The next phase of the DSRM is the evaluation of the solution to rigorously demonstrate the utility, quality and efficacy of the solution. This chapter discusses the evaluation phase of the DSRM by addressing the fifth research question, which is to determine the usefulness and user satisfaction of the prototype. A user study was conducted with domain expert participants to evaluate the prototype and identify any usability problems. The results of the user study are used to rigorously demonstrate the solution and validate the design decisions of the prototype developed. Chapter 5 also addresses part of the communication phase of the DSRM as the results were analysed to extract design recommendations for developing similar solutions.

The chapter begins with a discussion of evaluation methods for IV tools to determine how to evaluate the prototype. The evaluation of MobiTel is discussed, which includes the objectives, instruments, participants and user tasks. The results and discussion are presented along with design implications and recommendations.

## 5.2 Evaluating IV Techniques

There are a variety of IV evaluation methods that exist which include empirical methods such as controlled experiments, usability testing and longitudinal studies and analytical methods such as heuristic evaluation and cognitive walk-throughs (North 2006). There is a general evaluation challenge in selecting suitable evaluation questions, methods and by correctly executing the evaluation as it can be difficult to capture and quantify knowledge gained from using a visual analytical tool (Lam *et al.* 2011). Metrics need to be defined to determine if the rationale for the development of a IV tool supports the intended environment (Scholtz 2006). Consideration needs to be taken into defining metrics that can be used to measure the success of an IV tool to support user tasks. The metrics should be based on the aspects of the IV tool that should be evaluated. Scholtz (2006) identifies contributing evaluation area(s) based on the purpose of the IV tool. The intended use of

MobiTel is that it should assist the customer service representative by presenting information to support analysis and decision making regarding a customer's service utilisation. Based on this, Scholtz (2006) recommends that the contributing evaluation area for MobiTel should focus on the interaction, usability and utility of the prototype.

A key feature of IV tools is that the users are able to dynamically interact and explore the data. The interaction supported by the tool should be evaluated. Interaction can be evaluated through the use of a user study (Scholtz 2006). This requires that the users perform suitable tasks with the visualisation tool such as being able to conduct tasks such as select, locate, identify, distinguish etc. A user study should be conducted in order to determine if the user can interpret the information presented and interact with the IV tool. User studies of IV tools should focus on three main issues: how the data is presented; the interaction with the data and usability of the data itself (Freitas *et al.* 2002). Evaluating how the data is presented, focuses on the visual display of the visualisation to enhance the user experience, whereas evaluating interaction focuses on how well the visualisation tasks are supported through human interaction. The usability of the data refers to whether the data representation is understandable by the user to assist the user to make decisions.

Performance and self-reported metrics are typically used to measure the interaction between the user and the IV tool in usability evaluations. The goal of the user study is to evaluate the usefulness and user satisfaction of MobiTel and thus a usability evaluation should be conducted. Evaluating user satisfaction can provide information such as perceived efficiency, correctness, satisfaction and other user-based opinions. Therefore a usability evaluation was selected to evaluate MobiTel in terms of the interaction, usability and utility.

## 5.3 Evaluation Design

A user study was conducted to evaluate the prototype, called MobiTel. Purposive sampling was used based on selection criteria and ten participants were obtained for the evaluation. Performance and self-reported metrics were captured during the user study to evaluate the interaction, usability and utility of the prototype. Each participant was required to complete a set of tasks for each of the service usage views and questionnaires were used to capture and analyse the usefulness and user satisfaction of MobiTel. The evaluation was also used to provide design recommendations and suggestions for future work.

### 5.3.1 Evaluation Objectives

Three service usage views were proposed to visualise TSU which were implemented in the MobiTel prototype. The aim of this evaluation was to evaluate the interaction, usability and utility of MobiTel. The secondary objective of the research was to identify usability problems with MobiTel and recommendations for future work. A user study was used to evaluate these aspects of MobiTel. The results of the evaluation will provide insight into the design decisions made for the development of the prototype.

### 5.3.2 Evaluation Metrics

The purpose of the development of MobiTel was to support in-field investigation of TSU by providing an interactive prototype for visualising TSU. Section 5.2 identified that the interaction, utility and usability should be evaluated by using a user study. Visualisations should not only provide insight into the information to the user, but do so within a suitable time and with a reasonable amount of satisfaction (Santos 2005). The evaluation of visualisation techniques is a multidimensional problem, which involves dimensions such as effectiveness, efficiency and satisfaction in the usability evaluation. Interaction and usability can be evaluated by providing the users with a set of tasks and by evaluating to what extent the prototype can support the user in completing these tasks. Metrics for evaluating the utility of the prototype involved determining the user’s perspective of the prototype. User perceived metrics for utility include (Scholtz 2006):

- Ease of use of the prototype;
- Buy-in to use the prototype;
- Satisfaction with the solutions provided;
- Quality of the solutions provided;
- Time to obtain results.

Performance, perceived satisfaction and perceived usefulness metrics were captured for the evaluation of the interaction, usability and utility of MobiTel. For performance metrics, the following were measured for each task:

- *Effectiveness*: Task success, i.e. whether the participant could fully, partially or not complete a task. This metric will provide insight into the extent to which the prototype is usable and whether the selected interaction techniques can support the user in completing the tasks.

- *Learnability*: determining how the efficiency metric changes over time, i.e. the difference between the first and second attempt of performing a task.

### 5.3.3 Participants

Selecting random participants is acceptable for situations where the usability evaluation focuses solely on interaction or perception (e.g. checking the colour or size of objects) and the participant requires little knowledge about the visualisation domain (Ellis and Dix 2006). Usability evaluations involving more realistic tasks require the participants to have a clear understanding of the data itself as well as the problem that the visualisation tool is attempting to solve. Ellis and Dix (2006) suggest that more valuable information can be obtained by using a small number of domain experts than with a large number of random participants. To support evaluating the usefulness of MobiTel, participants were required to have experience in the telecommunication service domain so that their feedback could validate the possible usefulness of the tool. Therefore ten domain expert participants were recruited for the usability evaluation.

Purposive sampling approach was used to obtain participants, who could provide the most valuable information about the prototype. Purposive sampling involves selecting participants based on the objectives that need to be achieved (Palys 2008). Expert sampling is a type of purposive sampling where individuals that have a particular expertise are sampled.

For the user study of MobiTel, ten domain experts were recruited who had knowledge about the telecommunication service domain. Seven of the participants were recruited from a well-known TSP and three of the participants from the ICT staff at the NMMU. The demographic details of the two groups of participants were similar and thus a within-subjects design approach was used. The jobs roles of the participants ranged from solution architects to senior system engineers. The criteria for recruiting participants were that the participants had to have experience with service management and consulting with customers. Participants that meet these criteria can provide more realistic feedback on the usefulness on the prototype.

Figure 5-1 illustrates the demographics of the participants used in the evaluation. All the participants had experience with TSM as well as with consulting with customers. These two attributes are important for the evaluation as they support the perceived usefulness of the participants. Nine of the ten participants have worked with TSU data. The participants were also asked to report on their mobile tablet skill level, although it was not a prerequisite for the evaluation, and Figure 5-1 shows that ninety percent of the participants had experience with tablet devices.

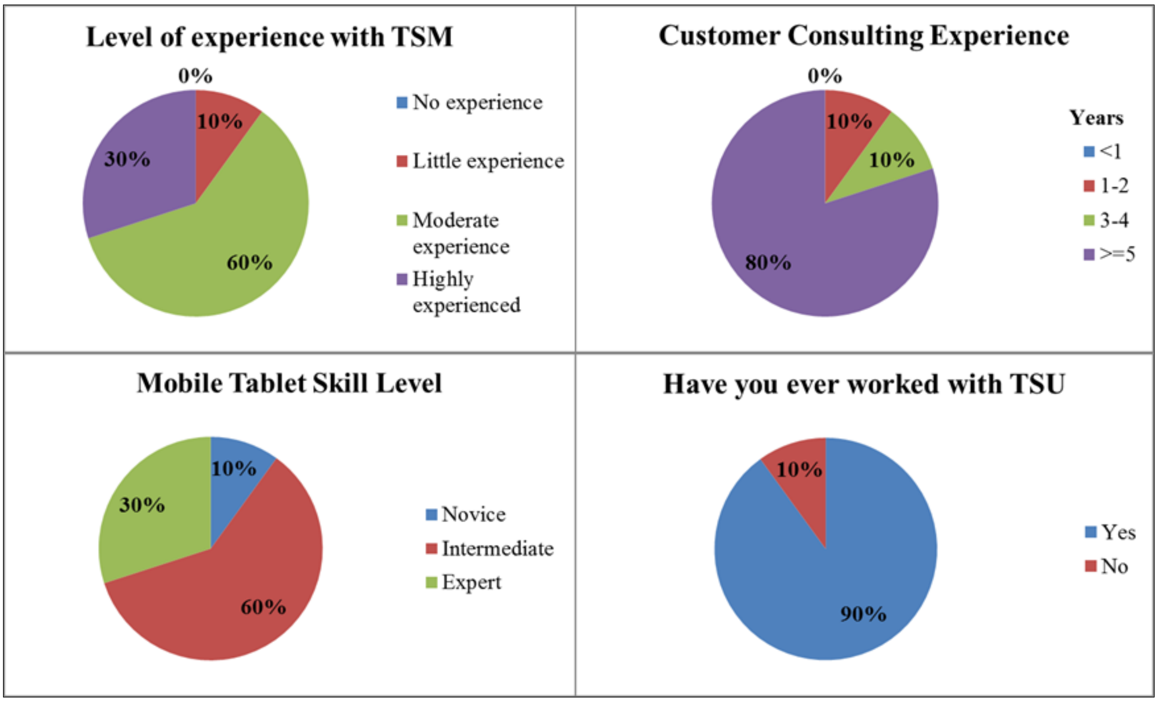



**Figure 5-1: Demographics of Participants (n=10)**

### 5.3.4 Evaluation Instruments

Each participant was provided with a background questionnaire at the start of the evaluation (Appendix F). The background questionnaire was used to collect demographic and experience details for each participant to support the analysis of performance and satisfaction results.

Effectiveness was determined, based on the extent to which the user could complete the tasks provided. Each participant was provided with a task list document (Appendix I) which contained questions where the participants were required to write down an answer. The answers provided by the participant were used to determine the task success rate.

A post-task questionnaire was provided to the participant after the completion of a set of tasks for each service usage view (Appendix G). The post-task questionnaire was adapted from the After-Scenario Questionnaire (ASQ) to provide insight into the perceived effectiveness, perceived efficiency and satisfaction for each service usage view (Tullis and Albert 2008). The post-task questionnaire was used to evaluate each service usage view.

A post-test questionnaire was provided at the end of the evaluation to evaluate the user satisfaction of the prototype. The post-test questionnaire was adapted from the Usefulness, Satisfaction and Ease of Use (USE) (Tullis and Albert 2008) questionnaire to capture the participants' overall perception of the system. The questionnaire was modified to better support the evaluation of MobiTel (Appendix H). The USE questionnaire groups the questions into four categories: Usefulness, Ease of Use, Ease of Learning and Satisfaction. All the questionnaires made use of a seven-point Likert Scale.

### 5.3.5 User Tasks

Each participant was provided with six tasks distributed evenly among the three service usage views (Appendix I). The participants completed two sets of tasks for each service usage view to determine if the prototype had a positive learnability factor. The tasks were selected, based on Shneiderman's visual seeking mantra (1996) of overview first, then zoom and filter, then details-on-demand. For each view the participant was provided with an overview of the search when navigating for the first time to a service usage view. Table 5-1 illustrates the tasks selected and how the tasks map onto Shneiderman's principles.

**Table 5-1: Mapping of Evaluation Tasks to IV Tasks**

| | **Trend Usage View** | **Network Usage View** | **Detail Usage View** |
|---|---|---|---|
| **Overview First** | Show the entire usage for a time period | Aggregated usage information for a time period | Show each day's usage for a time period |
| **Zoom and Filter** | Zoom and pan the search space; Change the threshold value. | Specify date range; Zoom, pan and rotate the chart. | Specify date range; Set filters for usage measures. |
| **Details On Demand** | Select highest point to obtain value | Select a site to obtain descriptive details of the service usage | Select a customer site(s) to obtain usage information for the specific site(s) |

The task list also supports the *History*, *Relate* and *Extract* tasks. The participants were required to reset or clear the visualisation at the end of each task, which supports the *History* task. The task list also required the participants to navigate back to the dashboard screen at the end of a task so that the participant could view how the Dashboard View is updated with the interactions on the service usage view. The *Relate* task is supported as the user can view the usage on the different views in a single view. The interaction is captured and displayed on the dashboard which supports the *Extract* task.

### 5.3.6 Evaluation Procedure

The first seven user evaluations were conducted at the headquarters of a TSP in Johannesburg. The seven participants were scheduled for specific time periods for the user study on the day of the evaluation. The three remaining participants were evaluated at NMMU in Port Elizabeth. The evaluation began by explaining to the participant the purpose and procedure of the evaluation. The participant was then asked to provide informed consent to take part in the evaluation by completing the consent form (Appendix E). The participant then completed a background questionnaire (Appendix F) before an explanation of the prototype was given. The participants were provided with the task list to be performed on the prototype (Appendix I). The participant was required to complete a post-task questionnaire (Appendix G) after completing the tasks for each of the service usage views. After all the tasks were completed, the participant was required to complete a post-test questionnaire (Appendix H) to evaluate the entire prototype.

The participants were encouraged to provide comments after completing a task or at the end of the evaluation. The participants were observed by the test administrator while completing the task and user comments and observations were recorded. The data was captured from the questionnaires and notes taken were captured and analysed and the results are discussed in the next section.

## 5.4 Evaluation Results

The results from the user evaluation were captured by using Microsoft Excel 2010. Section 5.4.1-5.4.2 presents the results and Section 5.4.3 provides a discussion and interpretation of the results. The post-task and post-test questionnaire both produced quantitative results where the measure of central tendency was calculated using descriptive statistics, which included the mean, standard deviation, median and mode. The questionnaire made use of a seven-point Likert scale and therefore a median score of 5 and above is considered favourable and a score of 3 and below as unfavourable. The mean was used if the result of the median is 4. If the mean is above 3.58 then the result is considered favourable but if the mean is below 2.72 then the result is unfavourable. These values were determined by using the Likert scale range and deriving an interpretation interval. The range between 1

(Strongly Disagree) and 7 (Strongly Agree) is 6 and therefore the interpretation interval is 0.86 (6 divided by 7).

The values obtained for the mean were based on the following:

- A score of 1-1.86 is Strongly Negative;
- A score of 1.86-2.72 is Negative;
- A score of 2.72-3.58 is Slightly Negative;
- A score of 3.58-4.44 is Neutral;
- A score of 4.44-5.3 is Slightly Positive;
- A score of 5.3-6.16 is Positive;
- A score of 6.16-7 is Strongly Positive.

Qualitative results were also captured from the post-test questionnaire and notes made from observing the participants during the evaluations.

### 5.4.1 Performance Results

This section discusses the performance results in terms of the effectiveness and learnability of the prototype based on the tasks performed by the participants. Each participant was required to complete two sets of tasks for each service usage view. One of the participants was unable to complete the second set of tasks for each service usage view due to time constraints and was omitted from the performance results.

#### 5.4.1.1 Effectiveness

For each of the tasks for the three usage views, the participants were required to answer a question(s) based on the information displayed to the user. Effectiveness was determined based on the task success of the participants. The task success was determined by capturing and evaluating the answers provided by the participants for the questions in the task list. Levels of accuracy were specified to determine to what extent the participants' answers were correct. The levels of accuracy were correct, partially correct and incorrect. These levels of accuracy were assigned a scoring value to rate the answers provided by the participants. The following weight values were assigned to the three levels of accuracy:

- Correct = 1.0
- Partially Correct = 0.75
- Incorrect = 0

Table 5-2 contains the coding scheme for the answers to the questions in the user task list. Partially correct values were interpreted as values that are close to the correct answer and the absolute difference with the correct answer is less than three.

**Table 5-2: Coding Scheme for Answers to Tasks**

| Service Usage View | Task No. | Correct Value | Partially Correct Values |
|---|---|---|---|
| **Trend Usage View** | 1.5b | 8 | 5-11 |
| | 1.6b | 9 | 6-12 |
| | 1.7 | 168 | 165-171 |
| | 1.13 | 14 | 11-17 |
| | 1.15 | 17 | 14-20 |
| | 1.16 | 64 | 61-67 |
| **Network Usage View** | 2.4 | East London | N/A |
| | 2.6 | 12 | N/A |
| | 2.11 | Durban | N/A |
| | 2.13 | 175 | N/A |
| **Detail Usage View** | 3.7 | Johannesburg | N/A |
| | 3.15 | Durban | N/A |

When the participants' answers were scored, the total score value for each service usage view was determined. The total score was then categorised into three levels: Complete Success; Partial Success and Failure. Complete Success was assigned if the participant had all the answers correct for the tasks on a service usage view. Partial Success was determined as follows:

- For Trend Usage View tasks, if the score was greater than 3 out of 6;
- For Network Usage View tasks, if the score was 3 out of 4;
- For Detail Usage View tasks, if the score was 1 out of 2.

Any other scores obtained were marked as a Failure. Figure 5-2 illustrates the task success for the different service usage views. Five out of nine (55.6%) participants were partially successful in completing the tasks for the Trend Usage View. Analyses of the results indicated that participants correctly performed some the tasks but provided the incorrect answer. For example, participants wrote down the total number of points shown instead of the total number of points above the threshold and thus received an incorrect answer. Three participants had complete success and five participants had partial success for the tasks on the Network Usage View. Most of the participants who obtained partial success answered incorrectly but performed the correct steps to obtain the answers. The Detail Usage View obtained the highest number of participants for complete success with six out of nine participants (66.7%). Two of the participants had partial success and one participant failed with the tasks on the Detail Usage View.

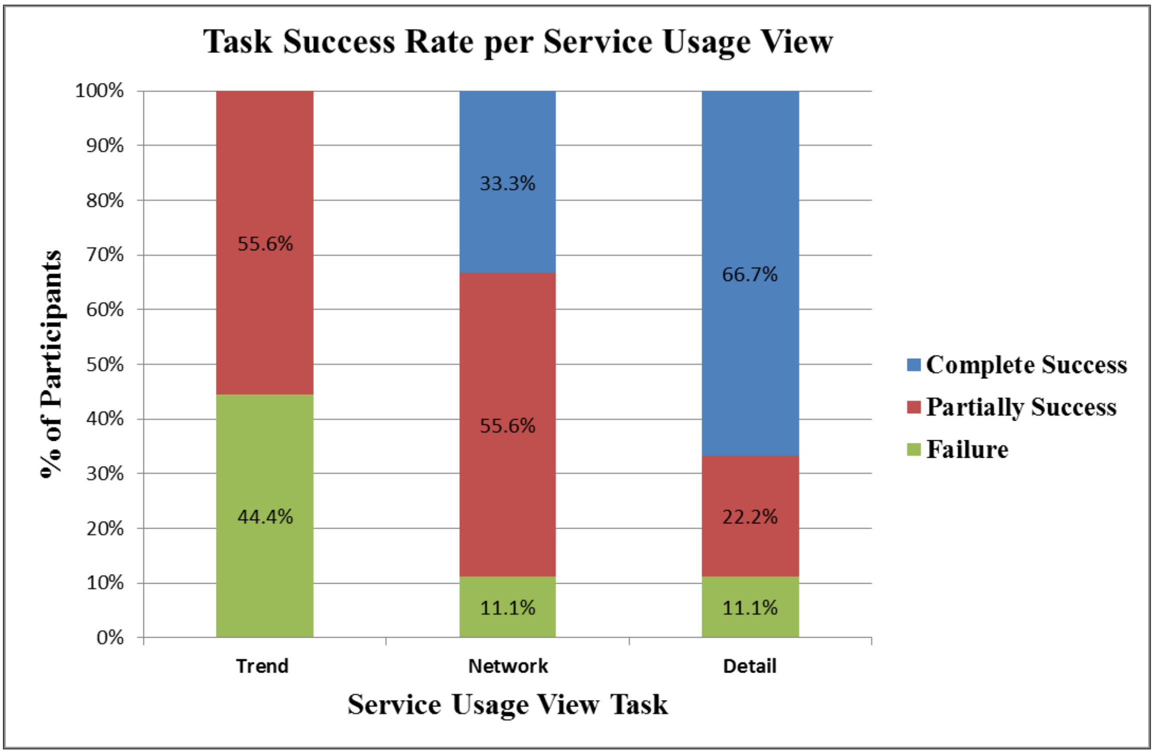



**Figure 5-2: Levels of Success Based on Answers provided by Participants (n=9)**

For the Trend Usage View, some of the participants had difficulty in identifying the highest point, as the points were very close to each other and thus led to fewer correct answers. Possible reasons for incorrect answers provided by the participants could be due to unclear questions in the task list and by not highlighting in a question what answer was required from the participant. For example, in the first task of the Trend Usage View, the participants were required to select the highest point and in the second task, the lowest point. Some of the participants would select the highest point for both tasks and would then be scored as incorrect. This became evident from investigating the answers.

### 5.4.1.2 Learnability

A Start and End Task menu option was included in the toolbar of the prototype for the user study. The participants were required to start each task from the Dashboard view (home) and select the Start Task menu option at the beginning of each task. Once the participants completed a task, they were required to select the End Task menu option and return to the dashboard view. When the participants selected the Start and End Task menu options, the time was captured and the time taken was calculated by using the two time values. The time taken to complete a task includes the participants answering the questions and reviewing the task instructions. The participants were asked to leave any comments until they had completed the task or the entire test, to avoid affecting the time on task value. Figure 5-3 illustrates the time on tasks for the user study which is grouped according to the service usage view.

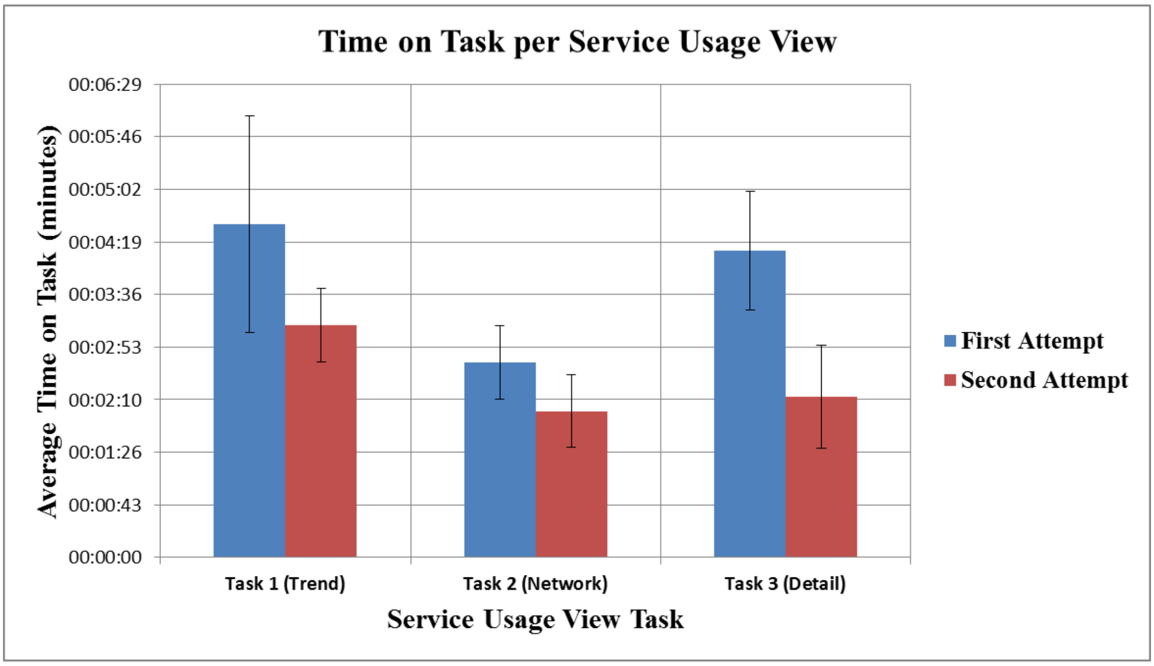



**Figure 5-3: Average Time on Task (n=9)**

The geometric mean was calculated for the time on task, which is less biased as time data is typically skewed and thus the geometric mean is more appropriate. The results indicate that the time taken on the second attempt at completing the task was less than the first attempt for each view. This indicates that the participants became more familiar with the prototype in terms of how to interact with and query service usage information. The error range for the task times was larger for the Trend Usage View as Participant One took twice as long to complete the task. Participant One was the only participant who had a novice mobile tablet skill level, which could be the reason for the participant taking longer to complete the task.

The time for the Network Usage View from the first to the second attempt was lower than the other views. This could indicate that the participants could more efficiently query information on the Network Usage View. The participants mentioned that while interacting with the Network Usage View, that they could easily interact, which explains the time on task being lower for the Network Usage View. There was a marginally significant difference for the time-on-task for the two tasks on the Detail Usage View as the error bars do not intercept. This indicates that although the parallel coordinates chart is not familiar to the participants, the design of the Detail Usage View helps the user to learn how to use the visualisation technique employed.

### 5.4.2 User Satisfaction Results

Post-task questionnaires and the post-test questionnaire were used to capture the user satisfaction results (Appendix G and Appendix H). The post-task questionnaire captured perceived ease of use; perceived efficiency and the perceived satisfaction for the information presentation and interaction of each service usage view. The post-test questionnaire captured the overall perceived usefulness; perceived ease of use; perceived satisfaction and perceived ease of learning of MobiTel. The post-test questionnaire also contained an open-ended section to capture qualitative data for participants' comments. The rest of this section discusses the user satisfaction results.

#### 5.4.2.1 Post-Task Satisfaction Results

Each participant was required to complete a post-task questionnaire for each service usage view, including the dashboard view. The post-task questionnaire was adapted from the ASQ to evaluate each of the views in MobiTel. The standard ASQ was adapted to contain four questions to capture the perceived user satisfaction with the interaction and presentation of each view.

Figure 5-4 illustrates the overall satisfaction for the post-task questionnaire for each of the service usage views in MobiTel. The median and mean was plotted for each view and were all above five indicating a high-level of user satisfaction. The results indicate that the participants were generally satisfied with the interaction and presentation of the different service usage views.

The Dashboard View received the highest overall rating (median = 6.1). The interaction on the Dashboard View made use of two touch gestures (Tap and Drag) for selecting and panning between the different usage views. The participants commented that they liked being able to view the interaction history on the Dashboard View and that it provided a quick reference to the other views. The high rating for the Dashboard View motivates the use of a simple design for the interaction and presentation for the home screen of a visualisation tool for TSU.

The Detail Usage View received the lowest mean rating among the different views but was still rated favourably (median=5.1). The participants might have experienced slight difficulty with specifying the thresholds in the Detail Usage View and this might have reduced the rating response. The participants may have perceived the usability issues on the Detail Usage View as a minor concern as the view was rated favourably.

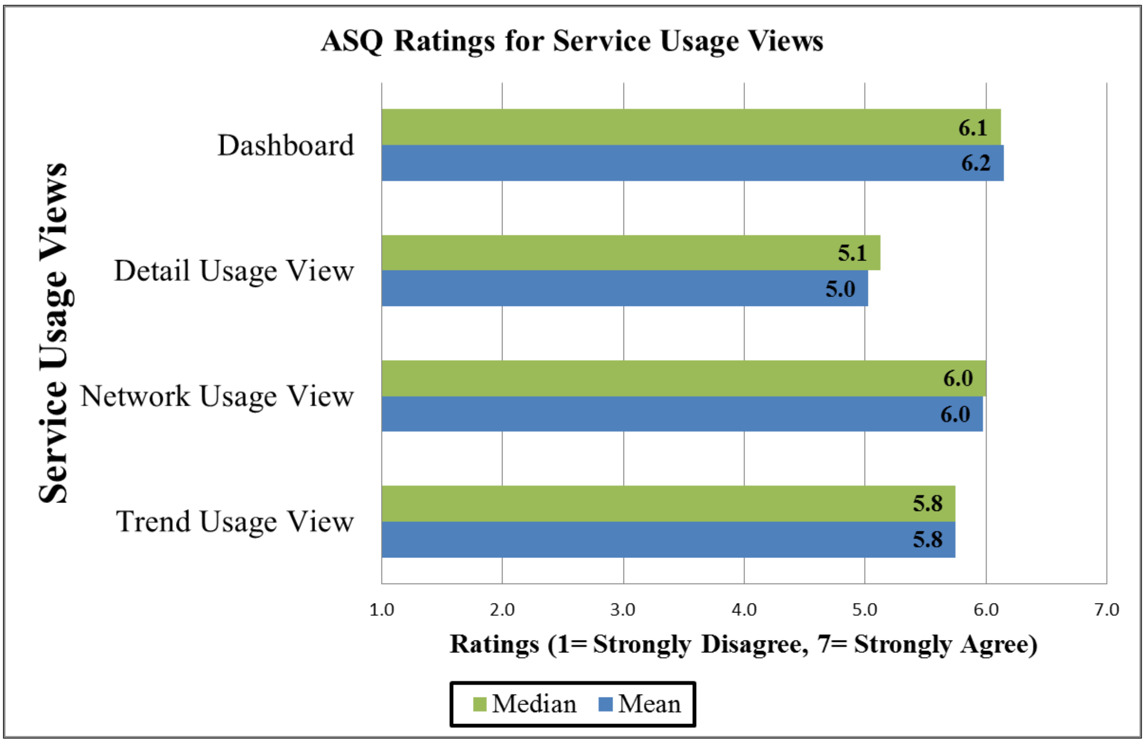



**Figure 5-4: Ratings for ASQ Ratings per Service Usage View (n=10)**

Figure 5-5 illustrates the results for each question of the post-task questionnaire for the different service usage views. The median values are presented for each of the questions of the ASQ for the different views in Figure 5-5. All the results for the questions in the post-task questionnaire were at least positive except for the interaction and satisfaction for the Detail Usage View which was neutral.

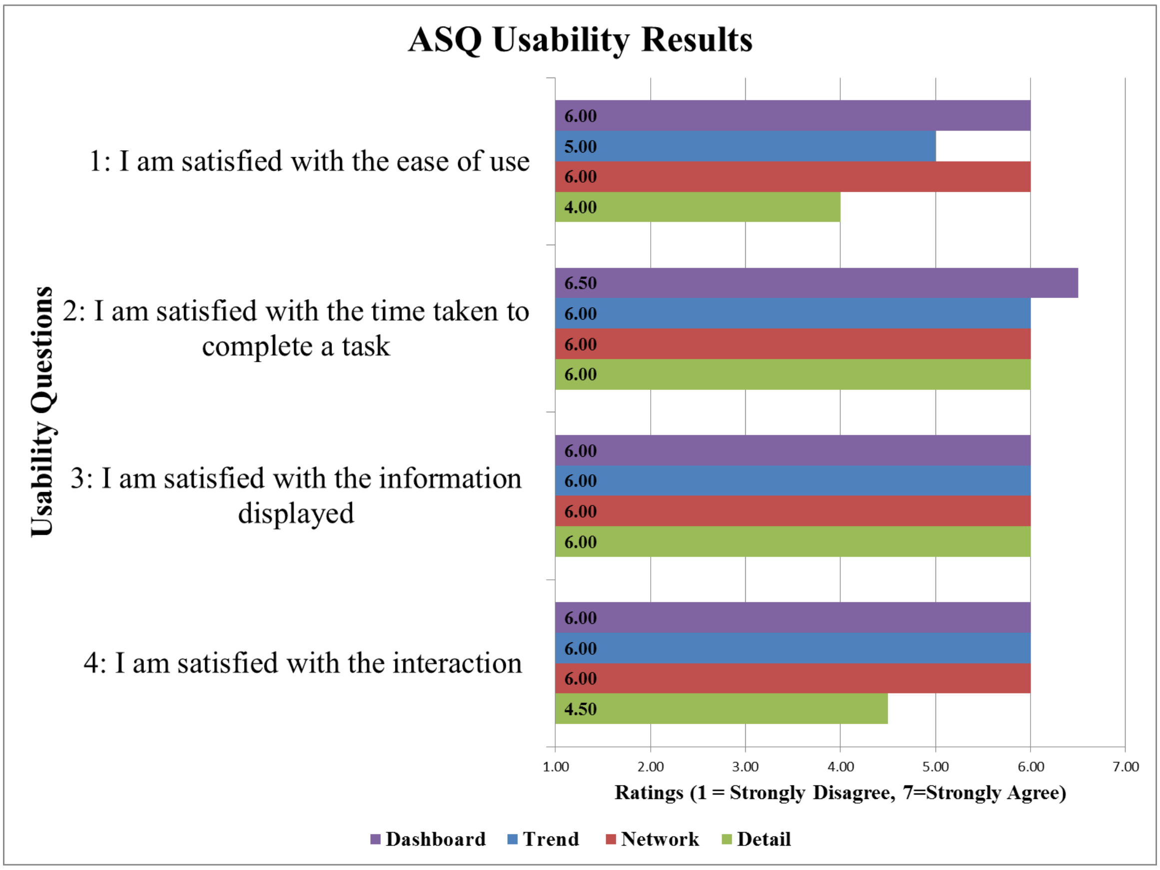



**Figure 5-5: ASQ Ratings for Usability Questions (n=10)**

The first question of the ASQ related to the perceived ease of use for the tasks of each view. The results for the perceived ease of use for the dashboard view (median=6), trend (median=5) and the network usage (median=6) view were favourable. The Detail Usage View received a neutral median rating (median=4), but the mean rating was slightly positive (mean=4.7). The participants had slight difficulty with manipulating the filter component for the Detail Usage View. The lower rating for the ease of use for the detail usage could be attributed to the participants initially having slight difficulty with using the view.

The second question referred to the perceived efficiency in completing a task on a service usage view. The perceived efficiency was favourable as the results for each view were positive. The participants may have felt that the time taken to complete the tasks was fairly quick as they may be accustomed to waiting longer to access service usage information. It was identified from the interview study in Chapter 2 that solution architects use large amounts of documentation when consulting with customers, which is inefficient. The results confirm that the participants perceived using the service usage view to obtain service usage information as efficient.

The last two questions of the ASQ were satisfaction metrics which related to the information presentation and interaction with the views. The participants were satisfied with the way in which the information was presented on the different usage views as results for information presentation were all positive. This supports the design decisions to use the selected IV techniques to visualise the service usage information. One of the participants commented that he thought that the visualisation techniques used such as the parallel coordinates chart was a “powerful” way to present the information.

The participants were satisfied with the interaction on the Dashboard, Trend Usage and Network Usage Views. The results for these views were positive, which indicates that the participants favoured the interaction used to on these views. The perceived satisfaction for the interaction on the Detail Usage View was neutral (mean=4.3). The parallel coordinates chart used in the Detail Usage View is not commonly used in business applications and thus the participants may not have been familiar with the interaction of the visualisation technique.

Some of the participants had slight difficulty with specifying the filters on the parallel coordinates chart in the Detail Usage View using the touch interaction. It was observed that some of the participants initially tapped first on an axis and then dragged on the axis to expand/shrink a filter where it is actually required that the participant should initially just drag on an axis and not tap. This observation will be used to recommend the interaction that should be provided with the parallel coordinates chart so that user expectations of the interaction can be better met.

It was also observed that once the participants determined how to specify the filter they could continue easily. This was evident as there was a significant difference between the task times for the first and second attempts on the Detail Usage View. The interaction for the Detail Usage View may have been slightly difficult, initially, for the participants, but it was determined that the participant could easily learn how to understand and interact with the view. Therefore the interaction design was perceived overall as positive by the user and thus supports the design decisions for selection of the interactions used.

#### 5.4.2.2 Post-Test Satisfaction Results

The post-test questionnaire was a modified version of the standard USE questionnaire (Tullis and Albert 2008), which was used to capture perceived usefulness, perceived satisfaction, perceived ease of learning and perceived ease of use. Figure 5-6 illustrates the results captured from the post-test questionnaire in a radar chart. The chart shows that perceived usefulness and ease of learning were higher than the perceived satisfaction and ease of use.

The perceived ease of learning was the highest with a mean score of 91.4%, which indicates that the participants perceived that they were able to learn how to use the prototype after being provided with a demonstration. The performance data identified that the prototype was learnable and the post-test results confirmed that the prototype was easy to learn.

The perceived usefulness had a mean score of 82.1%, which indicates that the participants generally think that the prototype can be used to support decision making for TSU data. The satisfaction obtained a mean score of 81.6%, which indicates that MobiTel provides a positive user experience which can affect the users' interaction and the extent to which they can complete the task. The ease of use received the lowest score of 80.6%, but still indicates that overall the prototype is easy to use. The ease of use was slightly lower due to slight difficulties that participants had with setting the filters on the Trend and Detail Usage Views.

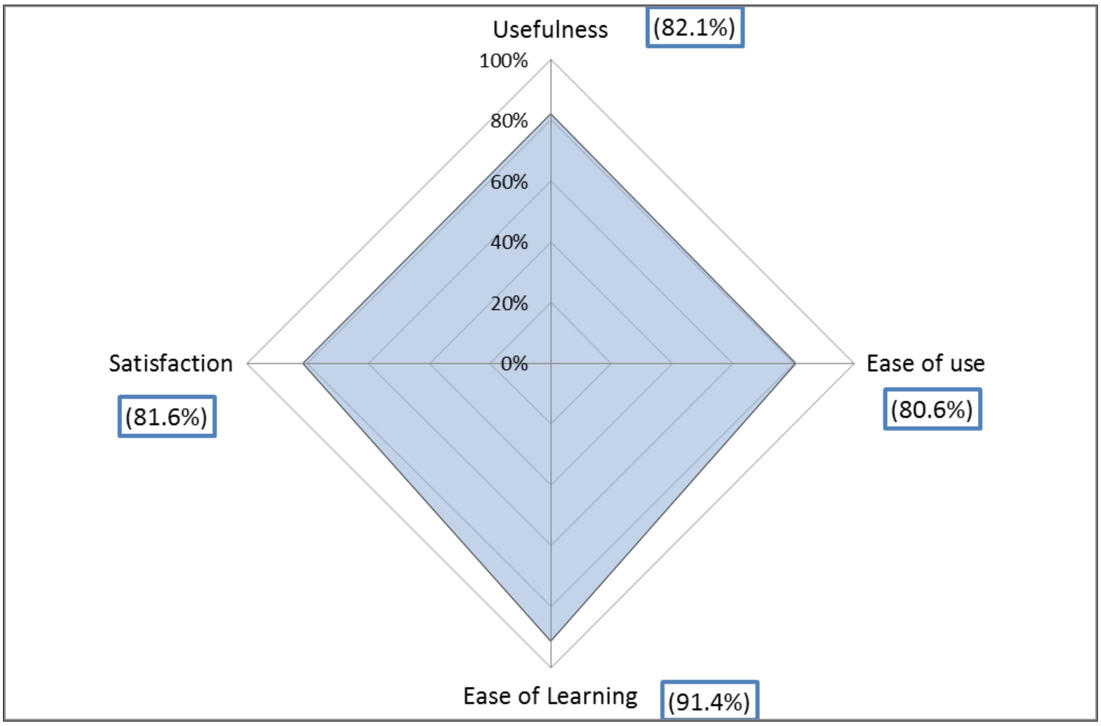



**Figure 5-6: Ease of Use, Usefulness, Ease of Learning and Satisfaction (n=10)**

Figure 5-7 illustrates selected questions from the post-test questionnaire. Question A4 had a positive result as to whether the system provides more control over decision making. The results indicate that the participants perceived the prototype as being useful as it can assist the decision making process which indicates that the usability of the data is positive. MobiTel was also perceived as useful because MobiTel supports the needs of the user. This is indicated in question A7 (median=6). The results were in favour of participants being able to easily interact with the prototype as the result for question B11 was somewhat positive (median=5). This supports the design decisions for the selection of the touch-based interaction, but to obtain a more strongly positive result design modifications need to be made, based on the feedback from the user evaluation. The participants were satisfied with using the prototype to visualise the service usage information as the results from question D1 was positive.

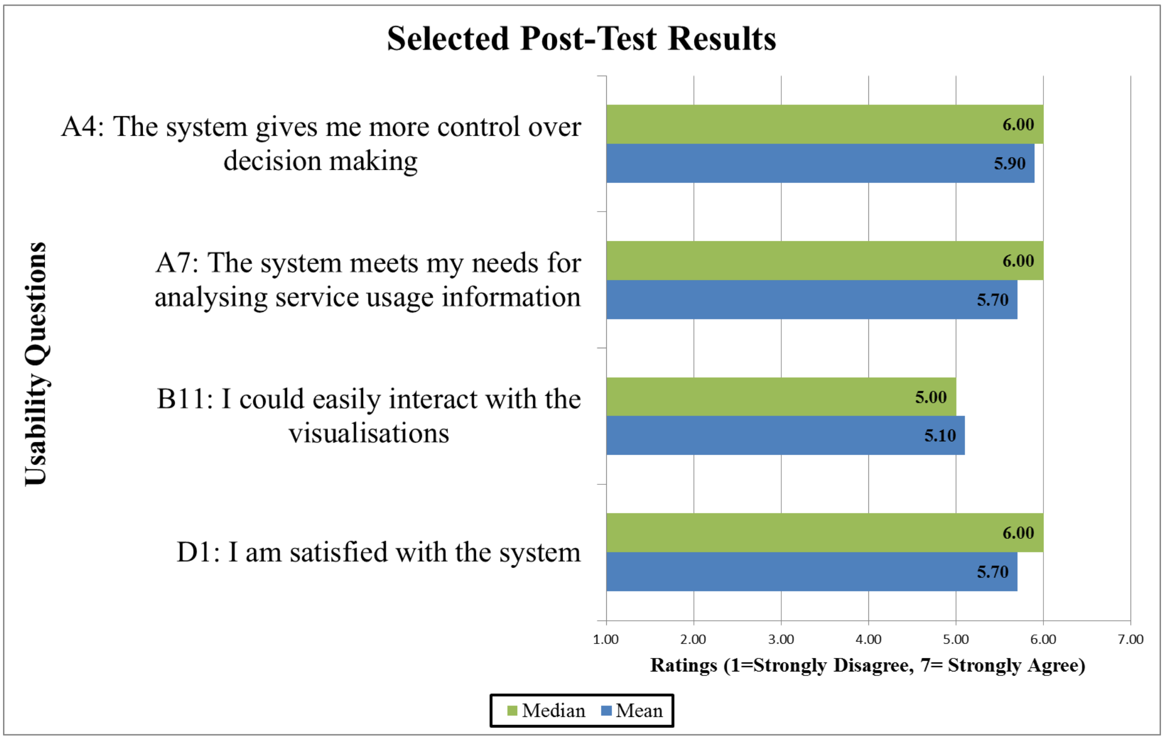



**Figure 5-7: Selected Post-Test Results (n=10)**

#### 5.4.2.3 Qualitative Feedback Results

Qualitative data was captured from open-ended questions in the post-test questionnaire as well as from comments made by the participants during the evaluation. The feedback was categorised into presentation and interaction comments. The feedback on the prototype was generally positive. The comments regarding the positive aspects of the presentation aspect of MobiTel are illustrated in Table 5-3 where n is the frequency of participants that made similar comments. Four of the participants indicated that the prototype had a simple interface that was easy to read and three participants liked the dashboard view that provides the interaction history.

**Table 5-3: Most Positive Comments for the Presentation of MobiTel**

| Description | n |
|---|---|
| 1. Simple interface and easy to read | 4 |
| 2. I liked the Dashboard View which shows the query history of the other views | 3 |
| 3. Quick accessibility to data | 3 |
| 4. Excellent use of visualisations for complex data | 2 |
| 5. Portability, flexibility and innovative | 2 |
| 6. Trend Usage View is very useful for decision making | 1 |
| 7. Detail Usage View is very useful and powerful | 1 |

There were a few negative comments regarding the presentation of MobiTel as shown in Table 5-4. One of the participants mentioned that the graph slider does not visually indicate the slider’s functionality and thus he did not immediately know that it could be used to alter the date range. This problem is more a learnability issue, where a demonstration is first required. Section 5.4.1 identified that the prototype is learnable. Another participant commented that it was somewhat difficult to identify the highest point on the Trend Usage View when there are points that are close to each other. Negative comments relating to the presentation aspect of MobiTel are addressed in Section 5.5.

**Table 5-4: Most Negative Comments for Presentation of MobiTel**

| Description | n |
|---|---|
| 1. Graph slider not clear on Trend Usage View | 1 |
| 2. Difficulty in distinguishing highest points above in Trend Usage View | 1 |

General comments for the presentation of MobiTel are shown in Table 5-5, which provides suggestions for improvement. Three of the participants suggested that colour coding should be used so that the user can quickly identify high and low usage. These suggestions are further discussed in Section 5.5.

**Table 5-5: General Comments for the Presentation of MobiTel**

| Description | n |
|---|---|
| 1. Use a colour pallet to indicate different levels of usage | 3 |
| 2. Use a drop down option for selecting date | 2 |
| 3. Use more realistic attributes for graphs | 1 |
| 4. Show all point values on Trend Usage View | 1 |
| 5. Combine graphs to show email sent and received | 1 |
| 6. Need to consider scalability factor for parallel coordinates chart for large number of customer sites | 1 |
| 7. Use "magnifying glass" effect to show occluded information | 1 |

The interaction on MobiTel received mixed comments. The positive comments relating to the interaction are shown in Table 5-6. Four of the participants commented that they liked the prototype as it was easy to use and two of the participants liked that the data could be interacted with by using accepted standard touch-based gestures. The prototype avoided making use of buttons and windows that are typically used in a desktop environment. The participants generally liked using the date slider to specify the date range and one participant felt that it was very accurate.

**Table 5-6: Most Positive Comments Relating to the Interaction on MobiTel**

| Description | n |
|---|---|
| 1. Ease of Use | 4 |
| 2. Supports standard/well accepted gestures and interaction with the data | 2 |
| 3. I liked interacting with the Network Usage View | 1 |
| 4. I liked the date Slider which is easier to use and more accurate | 1 |
| 5. Easy to grasp interaction simply from a demo | 1 |

The negative comments relating to the interaction on MobiTel are shown in Table 5-7. Six of the participants felt that setting the date range on the Trend Usage View was a bit "tricky" as they felt that the interaction was cumbersome to complete a task. For example, some of the participants had to zoom, then drag, then zoom again to set the date range. Six participants also felt that the system response was slightly delayed with interaction such as the Tap gesture. A number of the participants mentioned that they make use of iPads/iPhones, which have a different feedback to the Android device used in the evaluation. The participants may have not been experienced with the Android type of interaction and this may have impacted their experience. Four of the participants felt that setting the filters on the Detail Usage View was somewhat difficult but were still able to complete the task. These issues are addressed in Section 5.5.

**Table 5-7: Most Negative Comments Relating to the Interaction on MobiTel**

| Description | n |
|---|---|
| 1. Setting the date range is quite “tricky” on Trend Usage View | 6 |
| 2. Slight sensitivity and responsiveness issues with touch | 6 |
| 3. It was slightly difficult to alter the filters on the Detail Usage View | 4 |
| 4. Accuracy of certain graphs was difficult to get | 2 |

General comments relating to the interaction on MobiTel are shown in Table 5-8, which contains suggestion for improvement. Three of the participants commented that that they liked the date slider used on the Network Usage and Detail Usage View. This supports the design decision for using date sliders with touch interaction to specify the date range. They mentioned that the same slider should be used on the Trend Usage View. The results indicate that the graph slider used on the Trend Usage View is not an effective visualisation technique and that the date sliders should rather be used.

**Table 5-8: General Comments Relating to the Interaction on MobiTel**

| Description | n |
|---|---|
| 1. Change trend usage view data range mechanism to that of Network Usage View | 3 |
| 2. Pinch gestures should be inverted on Trend Usage View | 2 |
| 3. Use “anchor” on the graph slider to allow the gesture to be dragged | 1 |
| 4. Threshold needs an automated timer to deselect | 1 |

### 5.4.3 Discussion

The aim of the evaluation was to evaluate the interaction, usability and utility of MobiTel by investigating the usefulness and user satisfaction of the prototype. The secondary objective of the evaluation was to identify usability problems of MobiTel and recommendations for future work. The evaluation focused on the presentation of the service usage information and how the participants interacted with the visualisations techniques. Performance and self-reported metrics were captured and analysed to meet the evaluation objectives.

The performance metrics evaluated were effectiveness and learnability. Positive task success for the Network and Detail Usage View was obtained but the Trend Usage View obtained a lower task success. It was determined that the low result obtained for task success on the Trend Usage View was largely attributed to usability issues with specifying date ranges, which led to some participants providing incorrect answers. The task list may also not have been clear enough, which could also have led to participants providing incorrect answers. The perceived ease of use was favourable with the mean value of 80.6%. Therefore the prototype was perceived as effective in supporting the visualisation of TSU. The participants generally felt that they could easily use the prototype, which supports the design decisions for the selection of the touch-based interactions. The learnability provided positive results as the second attempt was always lower than the first attempt on the different views. The perceived ease of learning also supports the performance metric as the mean value was 91.4%. This indicates that the prototype was easy to learn.

The perceived usefulness was positive as the results indicated a mean score of 82.1%, which means that generally the participants felt that the prototype could be useful in a real-world environment. All the participants had experience with telecommunication service management as well as with consulting with customers. This better motivates the perceived usefulness results from this usability evaluation. The high result for usefulness indicates that the participants feel the information, which the prototype provides, was reliable and can be used to assist the user in a real-world environment. The overall satisfaction for the prototype was 81.6% which indicates that MobiTel provides a positive user experience.

Participants commented that the prototype made excellent use of the visualisation to present TSU. Some of the participants felt that the visualisations selected were suitable for visualising complex data. The participants also liked some of the interactions used in the prototype, but slight responsiveness and usability issues limited the extent to which the participant could smoothly interact. The participants still perceived that the prototype is easy to use and understand. This supports that the usability of the data (Freitas *et al.* 2002) is positive as the participants are able to understand the information that is presented.

The Dashboard View received the highest mean rating as the participants liked being able to have a quick reference view that showed the queries made on different views. The participants were generally satisfied with the interaction and presentation of the Dashboard View. The dashboard is thus a good design decision as the view can be used to quickly support decision making instead of having to switch between different views.

The Trend Usage View contains a time chart and uses the Overview + Detail technique to show the service usage over time. The participants were generally satisfied with the interaction and presentation of the Trend Usage View. The participants were also impressed with the Network and Detail Usage View. The participants liked the Network Usage View as they felt it had a simple and easy-to-use interface. The Detail Usage View received a slightly lower but positive feedback. This could be due to the participants' unfamiliarity with the parallel coordinates chart. The participants were still able to complete the tasks and the view was easy to learn. The date slider used on the network and Detail Usage View were preferred by the participants over the graph slider used on the Trend Usage View.

The results have provided insight into the interaction, usability and utility of MobiTel, which were all positive. Based on the results of the evaluation the following design recommendations were identified:

- Design of the interface of an MIV tool for service usage information should utilise touch-based interaction.
- A Dashboard View should be used to show an overview of the prototype. The Dashboard View should show the results of the queries that the user made on the different service usage views. The Dashboard View should support quick navigation to different views. Thumbnails and a larger view should be shown to the user as read-only on the dashboard and more interaction is available in different service usage views. The Dashboard View should support the Tap and Drag touch gestures.
- A Trend Usage View should be used to show the service utilisation over time. The Trend Usage View should make use of a time chart and a graph slider to show the

overall search space. The user should be able to change the threshold on the time chart using the Tap and Drag gesture. To support navigation of the search space, the Drag and Pinch gesture should be used. Points can be selected on the time chart by using the Tap gesture to show point values.

- A Network Usage View should be used to show the service usage on the different customer sites. A radar chart is suitable for visualising each of the customer sites as each of these sites can be represented on the axis of the radar chart. Details-on-demand should be provided when the user selects a customer site using a pop-up annotation which contains more data. The touch gestures that should be supported are Tap, Zoom, Drag and Rotate. To alter the time period, a date range slider should be used that supports the Drag gesture.
- A Detail Usage View that makes use of a parallel coordinates chart should be used to visualise the service usage measures. Each axis on the parallel coordinates chart should represent a usage measure for a service and the axis should support the Drag gesture to specify the thresholds. If the axis contains nominal data such as a customer site, then the axis should support the Tap touch gesture. A data range slider should also be used to set the time period and should support the Drag gesture.

## 5.5 Design Implications

From the comments on the post-test questionnaire and user feedback provided, a few issues were identified with regard to the presentation and interaction of the prototype. Each of the problems identified were characterised. The following issues were identified based on the results from the usability evaluation. Recommendations along with future work that could be investigated to address the issues are discussed below.

**a) Indicating levels of usage**

The participants want to be able to quickly view where there is high service usage. On the Trend Usage View, some of the participants had difficulty in distinguishing between the top points. The same applied to the Network Usage View, where it was not directly visible to the user which site had the highest usage. One of the participants commented that for the Detail Usage View it was a bit unclear which polylines link with which sites.

**Recommendation:** One of the participants recommended the use of a colour palette to indicate the different levels of usage, where green could be low usage and red indicates high usage. On the Trend Usage View, the highest point could be indicated by a red colour or circled to direct the user's attention to quickly determine the high points. For the Network and Detail Usage View*s*, the different customer sites should be assigned a colour, based on the level of usage compared to the other sites. This would allow the user to quickly determine which customer sites should be focused on and could possibly make the decision making process more efficient.

**b) Detail Usage View Analysis**

One of the participants identified that the site axis on the parallel coordinates chart needed to be modified to cater for a high cardinality of customer sites. It was mentioned that as many as 250 customer sites can exist for large customers. Another issue identified when specifying the filters is that the user's fingers occlude values under the finger.

**Recommendation:** An investigation needs to be conducted into handling a high cardinality of nominal data, such as the customer sites. Techniques such as binning or defining a hierarchy for the customer sites could possibly be used. The use of map-based visualisation should also be investigated to visualise the service usage on the customer site geographically.

**c) Accuracy on the filters**

The participants had slight difficulties with the rectangular filters on the Trend Usage View and those used on the Detail Usage View. On the Trend Usage View, the filter could only be enlarged or reduced by using the spread or pinch gesture respectively. On the Detail Usage View it was observed, during some of the evaluations, that the user was uncertain how the filter could be enlarged on either side by dragging on the end points of the filters.

**Recommendation:** The filters used should indicate to the user which part of the component can be manipulated. The graph slider on the Trend Usage View should have an extra block at either end which allows the users to drag one side at a time and thus improve the accuracy of the time period. On the Detail Usage View, a handle should be placed on the top and bottom of the filter, which the user can learn will drag to increase or decrease the size of the filter.

The results indicate that the use of touch-based interaction and visualisation techniques for presenting TSU data is feasible. Future research could therefore be conducted into the use of other visualisation techniques and touch gestures to further enhance the user experience for MobiTel.

## 5.6 Conclusion

The research follows a DSRM, which requires iterative design and evaluation of the solution developed, which was conducted in Chapter 3 and 4. This chapter has addressed the evaluation phase of the DSRM through the use of a user study. The evaluation focused on the interaction and presentation of the solution by evaluating the usability, interaction and utility of MobiTel. Hevner *et al.* (2004) provides research rigour guidelines for evaluation where appropriate subject selection should be used for recruiting participants. Purposive sampling was used where ten domain expert participants were recruited.

The results revealed that the participants perceived the prototype as being useful which supports the rationale for the development of the prototype. The task success for the Network and Detail Usage Views were positive, whereas the task success for the Trend Usage View was about neutral. The perceived ease of use for the task, on the Trend Usage View, was however positive as the participants were satisfied with the use of the prototype. The evaluation also evaluated each of the service usage views of MobiTel and identified that the participants generally preferred the use of a Dashboard View for providing a query history and quick reference view.

The results support the design decisions for the solution as the user satisfaction and usefulness of the prototype were positive. Some minor issues were identified, based on results of the evaluation, and recommendations for future improvement and future work were identified. This chapter also forms part of the communication phase of the DSRM as the findings of the results were communicated in Sections 5.4.3 and 5.5.

The next chapter communicates the findings and concludes the research.

# Chapter 6: Conclusions and Recommendations

## 6.1 Introduction

The primary objective of the research was to develop a solution for the visualisation of TSU data to support in-field investigation. This chapter addresses the last research question by communicating the contributions of the research and recommendations for future work. This chapter forms part of the final phase of the DSRM, which is the communication phase.

This chapter concludes the research by discussing the achievements of the research by addressing the research objectives defined in Chapter 1. The theoretical and practical contributions of the research are discussed, which is followed by limitations and problems encountered during the research. The chapter concludes with suggestions for future work.

## 6.2 Achievements of Research Objectives

The research identified that there is a lack of tools to effectively support in-field investigation and visualisation of TSU. The main research objective of this research was to design and evaluate an interactive mobile tool to support the visualisation of TSU. The sub-objectives of the research used to address the main research objective were as follows:

1. To investigate TSU and identify shortcomings of current software tools for TSU;
2. To determine the nature of TSU data and derive requirements for reporting on TSU;
3. To identify suitable IV techniques for TSU data and determine how to use MIV techniques to support visualising TSU data on a tablet device;
4. To propose and implement design decisions based on the selected visualisation techniques to visualise TSU data on a tablet device;
5. To evaluate the solution for visualising TSU data on a tablet device;
6. To communicate the findings of the research and design recommendations as well as suggestions for future work.

DSR was used to design and evaluate a solution to address the problem identified. The DSRM used was proposed by Peffers *et al.* (2007), which consisted of six phases to support the creation of a solution to the problem identified. The six phases were used to address each of the research objectives identified above to design and evaluate a solution to the problem.

The first phase of the DSRM is the identification and motivation of the problem. In Chapter 2 a literature review and an interview study was conducted. The interview study was conducted with domain experts from a well-known TSP and ICT engineers from NMMU using semi-structured interviews (Appendix A). The purpose of the interview study was to investigate problems in the telecommunication industry regarding TSU and to identify requirements for reporting on TSU. It was identified that providing information about customer service utilisation could provide useful information, which could be used to improve customer service delivery.

There are several reasons for obtaining service usage information, such as having the information available to make decisions regarding customer solutions to provide recommendations for customer package upgrades (Section 2.5.1). When TSP customer service representative engages with customers, they require service usage information to assist with the decision making process. From the interview study it was identified that during the customer engagement process, a customer service representative needs to compile a large amount of documentation (Section 2.6.1). The documentation is static and inefficient to work with while engaging with a customer.

Existing systems for visualising TSU were investigated and it was determined that these tools cannot be used to support in-field investigation and dynamic interaction (Section 2.5.4). The problem was identified that there is a lack of suitable tools to support the visualisation of TSU when customer service representatives engage with customers.

The nature of TSU data was investigated to determine the information that must be presented for decision making during in-field investigation of TSU. There are three types of service usage information, namely, volume-based, event-based and duration-based usage data and, accordingly, a common format for storing the information is required. In Chapter 2, the IPDR, which is a data format protocol, was identified to be a suitable format for storing and transferring service usage information that can be used for the different types of service usage data (Section 2.5.3.1).

The second phase of the DSRM is the identification of objectives for the solutions. Based on the literature review and on an interview study discussed in Chapter 2, requirements for reporting on TSU data were derived, which were categorised as functional, user and information requirements. These requirements served as objectives that the developed solution should meet. The second research question was addressed during this phase.

The third and fourth research questions were addressed in the design and development phase of the DSRM. Various IV and MIV techniques for visualising TSU data were investigated. An existing visualisation framework for usage data was used to describe the components that a visualisation tool should have to visualise usage data. This framework highlighted that the tool should consist of display and interaction techniques (Section 3.4).

There are various views of the service usage data that are required for decision making and thus, more than one visualisation technique was selected. It was identified that three views for visualising TSU data were required, namely a Trend, Network and Detail usage view (Section 3.4). The Trend Usage View displays service usage information over a specified period of time by using a time chart. The Network Usage View provides ranking patterns such as high and low service usage at different customer sites. The Detail Usage View provides information of the usage measures for a service that is linked to the customer site.

The Network and Detail Usage Views make use of multivariate data and thus multidimensional visualisation techniques were investigated. It was identified that a radar chart and a parallel coordinates chart be used for the Network and Detail Usage Views respectively. MIV techniques were investigated to determine how the identified IV techniques can be applied to tablet devices (Section 3.6).

Chapter 3 focused on investigating visualisation techniques for TSU data on a tablet device. Chapter 4 focused on the physical design and development of the solution. To support iterative development for the DSRM, the iterative prototyping design methodology was used to develop the prototype. The Trend Usage View made use of the Overview + Detail technique to support navigation of the information space on a tablet device. The Trend Usage View supported the Tap, Drag and Zoom gestures (Section 4.4.1). The Network Usage View was designed to make use of a date slider to change the date range. The Tap, Drag, Zoom and Rotate gestures were also supported (Section 4.4.2). The Detail Usage View supports the Tap and Drag gestures and also makes use of a date slider to dynamically update the visualisation when changing the date range (Section 4.4.3).

The Zooming + Panning technique was applied to each view to allow the user to explore the search space. One of the goals of the interface design was to omit the use of windows, icons, menus and pointers, which are commonly used on large screens where keyboard and mouse inputs are used. The reason for omitting a WIMP interface was to explore the full potential of touch-based interaction, which was identified as an intuitive form of interaction. A prototype called MobiTel was developed using the design decisions from Chapter 3 and 4.

The fourth phase of the DSRM is the demonstration phase where the solution is initially evaluated in order to refine the solution. Chapter 4 discusses an expert review, which was conducted with three usability experts and two domain experts (Section 4.5). Each expert was required to interact with the prototype and make recommendations. The usability experts provided severity ratings for the usability of the prototype. The severity ratings were analysed and no major usability issues were identified. The comments made by the experts were used to refine the prototype. The framework identified in Chapter 3 was extended to incorporate the use of touch-based interaction to support visualisation of TSU data on tablet devices.

The fifth research question was answered during the evaluation phase of the DSRM, which was discussed in Chapter 5. A user study was conducted with ten domain expert participants (Section 5.3.3). The goal of the evaluation was to determine the usefulness and the usability of MobiTel. Purposive sampling was used to obtain participants who understood the domain. The participants were required to have an understanding of the data presented on the visualisation tool. Participants were asked to complete a set of tasks, post-task and post-test questionnaires. The participants were asked to complete tasks using each of the service usage views and to evaluate their experience while using the prototype. Qualitative and quantitative data were collected from the post-test questionnaires. The questionnaires captured perceived ease of use, satisfaction, usefulness and learnability. Performance data was also collected to determine the effectiveness and learnability of the prototype.

The results from the user study yielded positive results as the participants felt that the prototype was useful (mean=82.1%) and easy to learn (mean=91.4%). The results also indicate that there was a high level of satisfaction (mean=81.6%) and perceived ease of use (mean=80.6%) with MobiTel. Each of the service usage views was evaluated by the participants and the results were generally positive for all the views. The results show that the participants were satisfied with the visualisations used to present the information as the mean rating for each view was above 5.7 on a 7-point Likert scale. The interaction for all the views received a rating of 5.8 and above except for the Detail Usage View, which received a rating of 4.3 on a 7-point Likert scale. The results indicate a significant learnability issue for the Detail Usage View, which could have resulted in the low rating for interaction. The participants were impressed with the dashboard view, which provided a quick reference view and navigation for the other service usage views. The results from the evaluation were used to identify recommendations for improvement and to propose design recommendations, which are discussed in the next section.

## 6.3 Research Contributions

The research contribution is discussed in terms of the theoretical and practical contributions. The theoretical contributions focus on using visualisation techniques to support visualising TSU. The practical contributions relate to the implementation of the visualisation techniques to support in-field investigation of TSU.

### 6.3.1 Theoretical Contributions

The research has made several theoretical contributions. Chapter 2 focused on the problem domain where an interview study was conducted with domain experts. Through this interview, requirements were gathered and analysed to produce a set of requirements for reporting on TSU and to better identify the problem domain. User, information and functionality requirements were extracted from the interview study, which represent a contribution towards identifying objectives for a solution to solve to the problem identified (Section 2.7). The objectives served as design criteria for a solution to support reporting on TSU.

An existing visualisation framework was identified, which describes the components the visualisation tool should contain in order to visualise customer service usage data (Section 3.4). The visualisation framework illustrates the display and interaction techniques that a visualisation tool should contain for service usage data. The display techniques selected consisted of two-dimensional and multidimensional visualisation techniques that could be used to visualise TSU. The interaction techniques in the framework described general tasks that the tool should support to interact with the visualisation. The visualisation framework was extended to provide support for the visualisation of TSU data on a tablet device (Section 4.7). Figure 6-1 is repeated here for ease of reference.

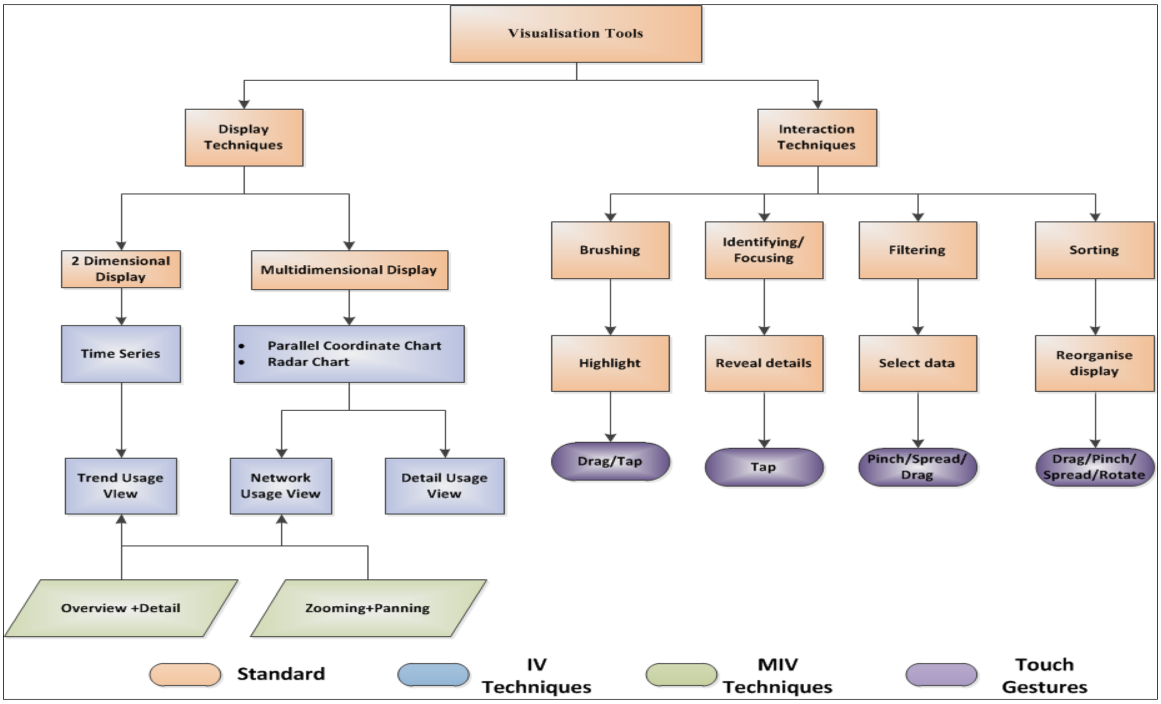



**Figure 6-1: Extended Framework for Visualising TSU Data on a Tablet Device**

Areas of the visualisation framework that needed to be modified were the IV techniques selected, the MIV techniques and touch-based gestures that were used to support interaction of TSU data on a tablet device. Based on the requirements identified in Chapter 2, three IV techniques were selected and the three usage views were identified, namely, a Trend, Network and Detail Usage View. For the Trend, Network and Detail Usage Views, the research determined that a time series chart, radar chart and parallel coordinates chart should be used respectively. The time series chart was used for viewing two dimensional service usage data and the radar and parallel coordinates chart were used to visualise multidimensional data. Chapter 3 identified suitable MIV techniques to visualise TSU data on a tablet device. The Overview + Detail technique was used on the Trend Usage View to support the user in navigating the time series chart. The Zooming + Panning technique was applied to the Trend and Network usage view. These MIV techniques are included in the extended framework.

The third component added to the framework was the touch gestures that should be supported for the various possible tasks on the visualisation tool. To support the brushing interaction technique, which is used in the Detail Usage View, the Drag and Tap touch gestures needed to be implemented to allow the user to specify filters on the axis of the parallel coordinates chart. To provide more detailed information, the Tap gesture is used to support the identification task. Selection of the data for the Trend, Network and Detail

Usage Views refers to changing the filters for the date range by using a graph or date slider. The Pinch, Spread and Drag touch gestures should be implemented for selecting the date ranges and supporting selecting data. To reorganise the display on the Network Usage View, the Pinch, Spread, Drag and Rotate gestures were implemented.

Another research contribution is a set of general design recommendations that were proposed for interactive visualisation of TSU data on a tablet device (Section 5.4.3). The design recommendations could be used by developers when developing similar systems or by researchers investigating the use of IV techniques on tablet devices. The design recommendations are based on the results from the user study. The results of the participants' perception of MobiTel were positive and based on these results, the design recommendations were proposed.

### 6.3.2 Practical Contributions

The practical contribution of the research includes the MobiTel prototype as well as the visualisation and interaction techniques developed and implemented in MobiTel. The extended visualisation framework was used to make design decisions for the prototype. The design decisions were implemented into the MobiTel prototype. Three service usage views were implemented into MobiTel to support interactive visualisation of TSU data on a mobile device. A Dashboard View was also implemented on MobiTel to provide the user with a quick navigational reference view of the other views, which includes the user interactions on each view.

Mobile visualisation toolkits for the development of MobiTel were investigated and compared to select the most suitable toolkit. The visualisation toolkits were compared using a defined set of criteria, which includes the IV techniques and touch gestures supported by the toolkit. Afreechart was selected as the most appropriate tool based on the criteria. Afreechart provided support for the time chart and radar chart. The parallel coordinates chart had to be implemented into the toolkit. The implementation of the prototype using the selected toolkit is a practical contribution as the prototype was evaluated as being usable. The research has identified the use of Afreechart as a suitable visualisation toolkit for MIV.

Another practical contribution of the research is the results of the user study which can be used by researchers for investigating similar research. The participants used were domain experts and the perceived usefulness of MobiTel was highly positive, which indicated that the participants were willing to adopt the use of the prototype in a real-world setting. The results of the evaluation indicated that the participants were satisfied with MobiTel and perceived the prototype as easy to use and learn. A number of the participants liked the use of a Dashboard View to provide a quick reference to the other views as well as being able to show the query history on each view.

## 6.4 Limitations and Problems Encountered

Several problems and limitations were encountered during the implementation and evaluation of MobiTel. Realistic data could not be obtained due to the unavailability of the data. The data had to be simulated using a data generator tool by specifying possible values and attributes of the data, which were obtained from examples by using the IPDR format. This problem was identified during the evaluation as one of the participants mentioned that some of the service usage attributes were not directly applicable to service utilisation. The participant then recommended altering selected attributes for the different types of data. These recommendations did not have an impact on the selection of the visualisation techniques as the data structure remains the same.

For the evaluation of MobiTel, purposive sampling was used, where ten domain participants were recruited. Seven of the participants were evaluated at the company's office in Johannesburg. Each participant was allocated a slot, based on their availability. One of the participants was constrained by time and thus was not able to complete the tasks on each of the service usage views twice. The data captured about this participant's interaction was excluded for performance data but was included in the user satisfaction results, as the participant did interact with the prototype and could provide an opinion of MobiTel.

Problems were encountered with visualising the TSU data in Afreechart. The Afreechart was selected as the most suitable tool as it had built-in support for two of the visualisations. The parallel coordinates chart had to be implemented with Afreechart.

## 6.5 Future Research

Several recommendations for improvement of MobiTel were identified from the user study (Section 5.5). One of the issues, which was identified by one of the participants, was that the Detail Usage View did not have the ability to handle a large number of customer sites, which would increase the cardinality on the parallel coordinates chart in the view. Future work is proposed to investigate the management of high cardinality data in the parallel coordinates chart for tablet devices to support a large number of customer sites. The customer sites have geographical coordinates and thus the use of map-based visualisation could be investigated as an alternative to addressing the cardinality issues for the Detail Usage View. A comparative study could also be conducted, which compares the IV techniques, a map-based visualisation and a hybrid approach for visualising TSU data on a mobile device.

Results of the user study were generally positive for the interaction of MobiTel. Basic touch-based gestures were implemented in MobiTel, namely Tap, Drag, Pinch, Spread and Rotate. Future work could be done to investigate other touch gestures that can be used with MobiTel to potentially improve the interaction.

Participants provided some suggestions for improvement to the prototype. Future work could be conducted to implement the recommended improvements. The research outlined the use of projection analysis of customer service usage. Projection analysis within MobiTel could be investigated and implemented to determine if in-field investigation could be better supported. The research was limited to a controlled user study for the evaluation in order to determine the perceived usefulness. A longitudinal study could be conducted to determine the usefulness of the prototype in a real-world environment.

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# Appendix A    Interview Study Survey

Nelson Mandela Metropolitan University

*for tomorrow*

Mobile Information Visualisation to Support the Analysis of Telecommunication Service Utilisation

**Interview Questions**

## A. Introduction

Dear Sir / Madam.

The growth of the telecommunication industry has led to the telecommunication environment becoming very competitive. A trend for telecommunication service providers is to become more service-oriented to obtain a competitive advantage. Telecommunication service utilisation focuses on who uses a service and how services are being used. The telecommunication industry has a large amount of data and effectively visualizing the information can assist the decision making process. The purpose of this field study is to identify any problems with visualisation of telecommunication service utilisation in practice and the requirements for mobile visualisation.

It would be appreciated if you could review the following short questionnaire for a structured interview survey on how the management of telecommunication service utilisation is currently done in your company. You will be required to answer the questions during the interview which will be recorded by the interviewer. The questionnaire has been provided to you before the interview so that you know exactly what you will be asked.

Although your response is of the utmost importance to us, your participation in this interview survey is entirely voluntary. Information provided by you remains confidential and will be reported in summary format only in a dissertation and scientific articles.

Your participation in this study is highly appreciated.

Yours Sincerely
Gianni Twigg
MSc Student (Computing Sciences)
Nelson Mandela Metropolitan University

## A. Biographical Information

This section of the survey relates to background or biographical information.

| | | |
|---|---|---|
| 1 | Gender | Male / Female |
| 2 | Age Range (in Years) | 18-29 / 30-39 / 40-49 / 50+ |
| 3. | Position held at company? | |
| 4 | Experience (in Years) in service Management? | ____ years |
| 5. | What specific roles to you have in the company? | |

**B. General Questions**

1. Please explain the classification scheme used for services in your company?

2. Customers can be categorised on multiple criteria such as size or business type. How are customers categorised in your company?

3. Are mobile technologies being used internally for management purposes within the company? If yes, please explain. (Mobile technologies are defined as small portable devices that allow easy portability, information processing and retrieval capabilities. For Example, smart phones, tablet pc and PDA's)

**C. Telecommunication Service Management**

1. Please explain your understanding of telecommunication service utilisation?

2. How important is information on service utilisation to you in assisting with decision making?

3. What system(s) are currently in place to support management of service utilisation and what is the purpose of these system(s)?

4. What information about how a customer uses a service is of interest to you?

5. Are there any difficulties with interpreting reports on telecommunication service utilisation?

6. What decisions are you required to make using information on service utilisation?

**D. Information Visualization of Telecommunication Service Utilisation**

1. Explain the current format of the reporting on service utilisation.

2. Are any components of the service level agreement included in the reporting of service utilisation, specifically relating to the resources the customers are allocated?

3. How frequently is information about service utilisation reported on?

| Daily | Weekly | Monthly | Quarterly | Yearly |
|---|---|---|---|---|

Further comments:

4. Are any information visualisation techniques applied when reporting on service utilisation?

**E. General Comments**

Please include any other general information on telecommunication service utilisation that you see as useful

# Appendix B NMMU ICT Interview Questions

**Questions**

1. What system monitoring tools are applicable for monitor service usage?
   a. What information about the service usage gets retrieved by the monitoring tools?
2. What information is included in the service usage reports?
3. How is information about the service usage collected?
   a. What data collection protocols (SNMP, IPDR and RADIUS) are used to collect service usage data on the networks?
4. What decisions would be made from using the service usage data? (E.g. A high email usage in a department could require, more storage capacity be allocated)
5. What views on service usage information are applicable? (E.g the total number of emails sent per a department or the average number of emails sent per department )
6. What level of detail/granularity is required from service usage information? (E.g. Would the reports need to include service usage for a specific computer/lab or higher levels such as campus or departments)

# Appendix C Expert Review Task List

## Tasks Description

This expert review will be conducted using three categories of tasks relating to the different service usage views. As you use the application feel free to speak out loud about any concerns that you may have. You are provided with a set of heuristics which will be used to evaluate the prototype. The goal of conducting these tasks is to identify any usability issues and rate the severity of the issues identified. All the tasks below will focus on the visualisation of email service usage information

## Task 1: Trend Usage View

Description: The trend usage view provides information about the service usage over a period of time. The goal of this view is to allow the user to observe how the service usage varies over time.

| **1.** | **Task** |
|---|---|
| 1.1 | Select the "*Trend Usage View"* tab on the actionbar |
| 1.2 | Familiarise yourself with the TimeSlider |
| 1.2.1 | Zoom in and out by pinching and spreading two fingers on the TimeSlider |
| 1.2.2 | Pan the graph by dragging on the TimeSlider using one finger |
| 1.3 | Determine the period when the total email usage was mostly used |
| 1.4 | Determine the period when the total email usage was the lowest |

## Task 2: Network Usage View

Description: The Network Usage View provides information about the total email usage per customer site. The goal of this view is to determine which sites have the highest service usage for a specified period of time

| **2.** | **Task** |
|---|---|
| 2.1 | Select the "*Nework Usage View"* tab on the actionbar |
| 2.2 | Familiarise yourself with the TimeSlider by dragging on the control |
| 2.2.1 | Set the range between 11 October 2011 to 14 November 2011 |
| 2.2.2 | Set the range to show the total usage per customer site on the 1 September 2011 |
| 2.3 | Determine which site has the highest usage for the full period of the time range |
| 2.4 | Rotate the radar chart by placing two fingers on the graph and rotating in a circular motion |

## Task 3: Detail Usage View

Description: The Details Usage View provides detailed information about the service usage attributes. The goal of this view is to allow the user to specify filter and view the distribution to make comparison or decisions such as high or low usage of an attribute.

| **3.** | **Task** |
|---|---|
| 3.1 | Select the "*Detail Usage View*" tab on the actionbar |
| 3.2 | Scan the parallel chart to familiarise yourself with the labels |
| 3.2.1 | Drag on the date axis to specify a time range |
| 3.2.2 | Tap on site axis next to KBT to select a site |
| 3.3 | Filter the bytes transferred to about 50% of the axis |
| 3.4 | Filter the storage duration |

## Task 4: Completion

1. Select the other tabs and check if previous states are as you left it.
2. Close the program by tapping on the back button.

# Appendix D Expert Review Evaluation Form

MobiTel: An Interactive Tool for the Visualisation of Telecommunication Service Utilisation

Expert Review: May 2012

**B. Introduction**

Dear Sir / Madam

The analysis of how customers make use of telecommunication services can provide valuable information that telecommunication service providers can use to improve the service quality. We are undertaking a research project to determine whether using Mobile Information Visualisation can be used to effectively support the visualisation of telecommunication service utilisaiton. From literature and a field study it was determined that there is currently a lack of support to effectively support the visualisation of service utilisation. The use of mobile devices provides an intuitive means of interaction which can encourage exploration of information and allow information to be access anywhere. An existing framework for the visualisation of service utilization has been extended to incorporate the touch interactions support on mobile devices.

The purpose of conducting this expert review is to evaluate MobiTel as part of a formative evaluation. This expert review will identify any usability issues and any improvements that can be made to the prototype. Although your response is of the utmost importance to us, your participation in this expert review is entirely voluntary. Information provided by you remains confidential and will be reported in summary format only.

Should you have any queries or comments regarding this expert review, you are welcome to contact us telephonically at 073 379 4218 or e-mail us at Gianni.Twigg@nmmu.ac.za.

Your participation in this expert review is greatly appreciated.

Yours Sincerely
Gianni Twigg
MSc Student (Computer Science)
Nelson Mandela Metropolitan University

**A. Scenario of typical user in MobiTel**

This section highlights a scenario of the tasks a typical user will conduct in MobiTel.

John is a solutions architect who is responsible for consulting with customers about using a solution that the company has to offer, or discuss about possible upgrades. When John goes out to meet with an existing customer, he has to compile a large volume of paper work which is used as a communication tool. The documents compiled, contain information about the services the customer has; the SLA documentation; service quality and service utilisation information. The problem that John is experiencing is that once the documentation has been compiled, the information remains in a static form and thus cannot be manipulated when being presented to the customer. He also does not have an overall perspective of the customer provided in a single view. John decides to make use of MobiTel to communicate how the customer usage the services.

### B. Heuristic Evaluation

This section presents heuristics which you need to evaluate MobiTel against. The heuristics focuses on the User Interface design and functionality of MobiTel. The heuristics will evaluate the three visualisation views for the service usage information (Trend, Network and Detail Usage View)

| Heuristic | Severity Rating |
|---|---|
| **1. <u>Visibility of system status</u>**<br>The system should always keep user informed about what is going on, through appropriate feedback within reasonable time.<br>• MobiTel clearly states what information is being visualised.<br>• MobiTel clearly identifies which view of the data is being used<br>Filtered information is clearly displayed | |
| **Comments/Reasons:** | |
| | |
| | |
| | |
| | |
| | |
| | |
| **2. <u>Match between system and the real world</u>**<br>The system should speak the user's language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.<br>• The information display on service usage matches that in the real world<br>• The visualisations used in each view are easily understandable and match real world data analysis tools.<br>• The three views used for visualising service utilisation are applicable to the service usage information<br>The touch interactions are effectively and efficiently applied on the three views | |
| **Comments/Reasons:** | |
| | |
| | |
| | |
| | |
| **3. <u>User control and freedom</u>**<br>Users should be free to select and sequence tasks (when appropriate), rather than having the system does this for them. Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Users should make their own decisions (with clear information) regarding the costs of exiting current work.<br>• The user can easily control the touch gestures on the different views<br>• The user can easily navigate between the different views | |
| **Comments/Reasons:** | |
| | |
| | |
| | |
| | |

| | |
|---|---|
| | |
| | |
| | |

4. **<u>Consistency and standards</u>**

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- MobiTel provides clear and valuable information
- MobiTel caters for touch based interaction by allowing easy interaction
- The user can easily distinguish which touch interaction to use on the different views.
- The three views have a consistent layout

| | |
|---|---|
| **Comments/Reasons:** | |
| | |
| | |

5. **<u>Error prevention</u>**

   Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error prone conditions or check for them and present users with a confirmation option before they commit to the action.

| | |
|---|---|
| **Comments/Reasons:** | |
| | |
| | |

6. **<u>Recognition rather than recall</u>**

Make objects (images, buttons, etc.), actions, and options visible. The user should not have to remember information from one part of the dialogue to another.

- The state of the view is saved after user interaction
- All the necessary information is provided to understand the service utilisation

| | |
|---|---|
| **Comments/Reasons:** | |
| | |
| | |
| | |

7. **<u>Flexibility and efficiency of use</u>**

Accelerators-unseen by the novice user-may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions. Provide alternative means of access and operation for users who differ from the "average" user (e.g., physical or cognitive ability, culture, language, etc.)

- Touch based interaction allows fast interaction and manipulation of the service usage information.
- Shortcut gestures to move between the different views are provided.
  Touch gestures effectively allow the information to be filtered to the user's criteria.

| | |
|---|---|
| **Comments/Reasons:** | |
| | |
| | |
| | |

<table>
<tr><td colspan="2">8. <u>Aesthetic and minimalist design</u><br>Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.<br>• Relevant information is provided on the different visualisation views.<br>• The screen is not cluttered with information<br>The size of the visualisations are large enough and visible</td></tr>
<tr><td>Comments/Reasons:</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

# Appendix E Informed Consent Form

## NELSON MANDELA METROPOLITAN UNIVERSITY

## INFORMATION AND INFORMED CONSENT FORM

| RESEARCHER'S DETAILS | |
|---|---|
| **Title of the research project** | **Using Mobile Information Visualisation (MIV) to support Telecommunication Service Utilisation Management** |
| **Reference number** | |
| **Principal investigator** | **Gianni Twigg** |
| **Contact telephone number** (private numbers not advisable) | **041 504 2094** |

| **A. DECLARATION BY OR ON BEHALF OF THE PARTICIPANT** | | **Initial** |
|---|---|---|
| **I, the participant and the undersigned** | (full names) | |

| **A.1. HEREBY CONFIRM AS FOLLOW** | | **Initial** |
|---|---|---|
| **I, the participant was invited to participate in the above-mentioned research project** | | |
| **that is being undertaken by** | Gianni Twigg | |
| **from** | Department of Computing Sciences | |
| **Of the Nelson Mandela Metropolitan University** | | |

| **A.2 THE FOLLOWING ASPECTS HAVE BEEN EXPLAINED TO ME, THE PARTICIPANT** | | | | | | **Initial** |
|---|---|---|---|---|---|---|
| | **Aim** | The investigators are studying how MIV techniques can be used to support the visualisation of telecommunication service utilisation<br><br>The information will be used to/for research purposes | | | | |
| | **Procedures** | I understand that I am required to use a system to evaluate the MIV techniques to visualise service usage information. | | | | |
| | **Risks** | I understand that there are no risks involved in participating in this process | | | | |
| | **Confidentiality** | My identity will not be revealed in any discussion, description or scientific publications by the investigators | | | | |
| | **Access to findings** | Any new information or benefit that develops during the course of the study will be shared as follows: | | | | |
| | **Voluntary participation / refusal / discontinuation** | My participation is voluntary | YES | NO | | |
| | | My decision whether or not to participate will in no way affect my present or future career/employment/lifestyle | TRUE | FALSE | | |

| | | |
|---|---|---|
| | No pressure was exerted on me to consent to participate and I understand that I may withdraw at any stage without penalisation | |

| | | |
|---|---|---|
| | Participation in this study will not result in any additional cost to myself | |

<table>
<tr><th colspan="3">I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT:</th></tr>
<tr><td colspan="3">Signed/confirmed at on 20</td></tr>
<tr><td rowspan="2">Signature</td><td colspan="2">Signature of the witness:</td></tr>
<tr><td colspan="2">Full name of witness:</td></tr>
</table>

# Appendix F Background Questionnaire

| | | | | | |
|---|---|---|---|---|---|
| 1. | Gender | Male | Female | | |
| 1. | Age | 18-29 years | 30-39 years | 40-49 years | >=50 years |
| 2. | Occupation | | | | |
| 3. | Industry domain | Telecommunication | Academic | Other | |
| | | Other, please specify: | | | |
| 4. | Experience in consulting with customers | < 1 year | 1 - 2 years | 3 - 4 years | >= 5 years |
| 5. | How often do you consult with customers | Never | Rarely (Appr. Once a year) | Seldom (Appr. once a month) | Frequently (Appr. Once a week) |
| 6. | Level of experience with telecommunication service management | No experience | Little experience | Moderate experience | Highly experienced |
| 7. | Have you ever worked with service usage information | Yes | No | | |
| 8. | Mobile tablet skill level | Novice | Intermediate | Expert | |
| 9. | To what extent do you use mobile devices in your organisation | Never | Rarely | Occasionally | Frequently |
| | | Specify that tasks of mobile devices if used: | | | |
| 10. | Have you ever used any mobile analytics software | Yes | No | | |
| | | If yes, please specify: | | | |

# Appendix G Post-Task Questionnaire

| B1 | **Trend Usage View** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Overall I am satisfied with the **ease** of determine the service usage using this view | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 2. | Overall, I am satisfied with the **amount of time** it took to determine the service usage for the time period | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 3. | Overall, I am satisfied with the **information provided** about the service usage | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 4. | Overall, I am satisfied with the **interaction provided** with the trend usage view | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |

| B2 | **Network Usage View** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Overall I am satisfied with the **ease** of determine the service usage using this view | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 2. | Overall, I am satisfied with the **amount of time** it took to determine the service usage for a customer site | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 3. | Overall, I am satisfied with the **information provided** about the service usage | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 4. | Overall, I am satisfied with the **interaction provided** used with the network usage view | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |

| B3 | **Detail Usage View** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Overall I am satisfied with the **ease** of determine the service usage using this view | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 2. | Overall, I am satisfied with the **amount of time** it took to determine the customer site that meets the filters specified | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 3. | Overall, I am satisfied with the **information provided** about the service usage | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 4. | Overall, I am satisfied with the **interaction provided** used with the detail usage view | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |

| B4 | **Dashboard View** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Overall I am satisfied with the **ease** of using the dashboard to view obtain a quick view of the different usage views | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 2. | Overall, I am satisfied with the **amount of time** it took to navigate from the dashboard to another view | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 3. | Overall, I am satisfied with the **information displayed** on the dashboard | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
| 4. | Overall, I am satisfied with the **interaction provided** used with the dashboard | | | | | | | | | |
| | | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |

# Appendix H Post-Test Questionnaire

| MobiTel - Post-Test Questionnaire | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **A. Usefulness** | | | | | | | | | |
| **1.** The system helps me be more effective | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| **2.** The system helps me be more productive | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| **3.** The system is useful | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| **4.** The system gives me more control over decision making | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| **5.** The system makes the things I want to accomplish easier to get done | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 6. The system saves me time when I use it | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 7. The system meets my needs for analysing service usage information | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 8. The system does everything I would expect it to do. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |

| **B. Ease of Use** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. The system is easy to use. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 2. The system is simple to use. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 3. The system requires the fewest steps possible to accomplish what I want to do with it. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 4. The system is flexible | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5. Using the system is requires minimal effort. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 6. I can use the system without written instructions. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 7. I did not notice any inconsistencies as I use the system. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 8. Both occasional and frequent users would like the system. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 9. I can recover from mistakes quickly and easily. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 10. I can use the system successfully every time | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 11. I could easily interact with the visualisations | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| **C. Ease of Learning** | | | | | | | | | |
| 1. I learned to use the system quickly. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 2. I easily remember how to use the system | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 3. It is easy to learn to use the system. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| **4.** I quickly became skilful with the system. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| **D. Satisfaction** | | | | | | | | | |
| 1. I am satisfied with the system. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 2. I would recommend it to a fellow employee. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 3. The system is fun to use | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4. The system works the way I want it to work. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 5. The system is wonderful. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 6. I feel I need to have the system. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |
| 7. The system is pleasant to use. | | | | | | | | | |
| | Strongly disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly agree |

General:

1) Best features of the system

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

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2) Worst features of the system

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

3) What did you like about the interaction in MobiTel

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

____________________________________

4) What did you not like about the interaction in MobiTel

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

5) Recommendations for future improvement

______________________________________________________________________

______________________________________________________________________

__________________________________________________________________

# Appendix I User Study Task List

## Task 1: Trend Usage View

Description: The trend usage view provides information about the service usage over a period of time. The goal of this view is to allow the user to observe how the service usage varies over time.

1. Start *MobiTel* by selecting the *MobiTel* icon on the home screen.
2. Select Start Task from the options menu
3. Select the "*Trend Usage View"* tab on the actionbar
4. Change the threshold to 145 by dragging on the threshold
5. Navigate using the Graphslider
   a. Zoom and Pan on the graph slider so that the date range is between October 2011 to December 2011
   b. How many points are above the threshold line:
   ______________________________________________
6. Navigate using the Time chart
   a. Zoom and Pan on the graph slider so that the date range is between September 2011 and January 2012
   b. How many points are above the threshold line:
   ______________________________________________
7. Tap on the highest point to obtain the usage value and write down the value displayed.
   ______________________________________________
8. Select End Task from the options menu

---

9. Select Start Task from the options menu
10. Click on the trend usage view image from the dashboard
11. Change the threshold value to 100
12. Change the date range to show between the July 2011 and the December 2011 using the Graphslider.
13. How many points are above the threshold:
    ______________________________________________
14. Change the date range to show between September 2011 and January 2012 using the Times chart.
15. How many points are above the threshold:
    ______________________________________________
16. Tap on the lowest point to obtain the usage value and write down the value displayed.
    ______________________________________________
17. Select End Task from the options menu.

Complete Section B1 of the questionnaire before moving on to the next task.

## Task 2: Network Usage View

Description: The Network Usage View provides information about the total email usage per customer site. The goal of this view is to determine which sites have the highest service usage for a specified period of time.

1. Select Start Task from the options menu
2. Select the "*Network Usage View"* tab on the actionbar
3. Using the Time Slider set the date range to be between 1/08/2011 and 10/10/2011 by dragging on the control
4. Which customer site has the highest usage for the selected time period:

   ______________________________________________

5. Rotate the chart by placing two fingers on the graph and rotating in a circular motion so that Kimberley is on top.
6. Tap on the site name with the highest usage and record the average number of emails sent (Zoom or drag to centre the annotation):

   ______________________________________________

7. Select End Task from the options menu

---

8. Select Start Task from the options menu
9. Go to the Network Usage view by select the radar chart on the dashboard
10. Set the date range to be between 1/10/2011-10/12/2011
11. Which customer site has the lowest usage for the selected time period:

    ______________________________________________

12. Rotate the graph so that Johannesburg is on top.
13. What is the total email usage value for the site with the lowest usage:

    ______________________________________________

14. Select End Task from the options menu

Complete Section B2 of the post-task questionnaire

## Task 3: Detail Usage View

Description: The Details Usage View provides detailed information about the service usage attributes. The goal of this view is to allow the user to specify filter and view the distribution to make comparison or decisions such as high or low usage of an attribute.

1. Select Start Task from the options menu
2. Select the "*Detail Usage View"* tab on the actionbar
3. Using the Time Slider set the date range to be between 1/08/2011 and 10/10/2011 by dragging on the control
4. Select "JHB", "PE" and "DHB" on the site axis by tapping on the site name
5. Change the filter for **storage capacity** so that it is approximately between 40 and 60.
6. Change the filter for **Bytes Transferred** so that it is approximately between 1100 and 1800
7. Which site has the most number of events that meet the filters specified (Total number of lines from a site)

   __________________________________________
8. Clear the filters by selecting the reset icon on the actionbar
9. Select End Task from the options menu

---

10. Select Start Task from the options menu
11. Go to the "*Detail Usage View"* by selecting the parallel chart on the dashboard
12. Set the date range to be between 1/10/2011-10/12/2011
13. Change the filter of the **Storage Duration** so that it is between 40 and 60.
14. Change the filter of the **Processing Time** so that it is between 1000 and 1400.
15. Which site has the highest number of occurrences based on the filters specified?

    __________________________________________
16. Click on the Home tab to view changes made from interactions
17. Select End Task from the options menu

Complete Section B3 of the post-task questionnaire