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USING INFORMATION AND COMMUNICATIONS TECHNOLOGY TO IMPROVE THE EFFICIENCY AND ACCURACY OF A UTILITY'S NETWORK DATA COLLECTION BUSINESS PROCESS

Rex van Olst

A Dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements of the degree of Master of Science in Engineering.

Johannesburg 2005

Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science (Engineering) in the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.



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Rex van Olst

__1st_____ day of ___AUGUST_____(year)__2006_____

Abstract:

"You can see the computer age everywhere except in the productivity statistics". This offhand remark by Robert Solow, the Nobel prize-winning economist [1] has stimulated many other economists to conduct more rigorous analyses on the impact of information technology on productivity.

The research presented in this dissertation has been conducted on a large telecommunications utility. An important business process of the utility, that of collecting information on its geographically dispersed network assets, was automated using mobile computing and wireless technologies. The research compared this newly developed automated process with the current, manual, process of sourcing the field network asset data using paper-based templates, and capturing the data manually from the templates. The results of the pilot for this automated business process were encouraging and demonstrated an improvement of over 50% in the productivity of the data collection process, and its integrity. An important aspect of the research outlined in this dissertation was to design and implement the mobile computer-based electronic data collection prototype to minimise user obstruction to the technology deployed. The prototype was tested for technology acceptance by the targeted field workers. This test also proved successful.

The research demonstrated that an improvement in productivity of over 50% was achievable from a well-considered investment in information technology. The results from the research also pointed the way for the deployment of this data collection solution in other utilities, e.g. electricity distribution, water reticulation, and municipalities. Through user prototype tests and a cultural intervention process on the targeted users (field workers), the research also demonstrated how the automated business process can be geared for use by low-skilled field workers, so important to improve productivity in developing economies such as those in Africa.

ACKNOWLEDGEMENTS

Thanks are expressed to Prof. Barry Dwolatzky of the School of Electrical & Information Engineering at Wits University for his guidance throughout the research project, and to Dr. Ian Kennedy for editorial help on this document and with papers published on this research. Thanks are also expressed to the two post-graduate students, Kyaw Moe and Dan Hurwitz, who assisted with the design of the electronic data collection prototype. The author would also like to acknowledge the support from Telkom's management and field staff, without their co-operation this research study could not have taken place.

GLOSSARY OF TERMS

Term	Definition
GIS	Geographical (or Geospatial) Information System
PDA	Personal Digital Assistant
Data Collection	The business process of sourcing information about a field object/asset directly in the field and then capturing this information into a computer database.
Data Sourcing	The business process of writing down information on a paper template about a field object/asset directly where that asset is located.
Data Capturing	The business process of manually entering data written on paper templates about a field object/asset into a computer database.

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1. INTRODUCTION

1.1 New Information Technologies and Productivity improvements

Large telecommunications utilities have many assets both as inside and outside network equipment. These assets must be managed in order for the telecom business to operate at optimum efficiency. Thus a key requirement is for the telecom company to collect information about these network assets and store it in an easily retrievable form. The mobile field personnel in the telecom utility normally carry out this data collection process.

The research question presented in this dissertation is to prove the productivity gains for a mobile workforce using new technologies to improve the methodology and accuracy of collected field asset data. For this to occur, these new technologies must be accepted and used by employees in organisations. According to the Mobile Field Service Benchmark Report: 'Bridging the Chasm between the Field and Back Office' [19], no measure of technology can sustain long-term performance gains unless accompanied by improved and sound business processes. Thus the review of the business processes for data collection, and user acceptance of these new technologies were important research areas for this project [4]. The verification of productivity gains and user acceptance of the technologies was accomplished through the development and testing of mobile computer prototypes that encompass the critical Human Computer Interaction (HCI) aspects of perceived usefulness and ease-of-use [5]. As an example of the use of these new technologies for productivity enhancement, the research focussed upon the needs of a large utility corporation with its assets distributed geographically throughout a nation.

Almost all utilities have to face the challenge of capturing and maintaining field asset records, which are required in an "as-built" format to supply accurate information to work teams in the field. With geospatial information content becoming more easily available, it is possible to source, verify, capture, maintain and access data about field assets using mobile computers, for example, personal digital assistants (PDAs) and wireless communications technology. In this way the productivity of the field workforce can be greatly enhanced. The dramatic growth in business demand for mobile computing,

used for example for the collection of outside plant asset data (described above), is a direct result of the natural synergy between PDAs, wireless technology, and data-driven workstyles.

To deal with the key challenge of network data collection the School of Electrical and Information Engineering at the University of the Witwatersrand commenced research in 2003 to develop appropriate software solutions for a mobile computer prototype to be used for collecting data on a utility's network elements more productively. It also investigated whether any changes to the current data collection business processes had to be introduced [2] when using this device. A team consisting of research staff and post-graduate students was established to investigate various aspects of this challenge. The research covered in this paper investigated the business process changes and the technology acceptability of the prototype designed and developed. It also involved a broad survey of the existing network data collection productivity within South Africa's telecommunications company, Telkom. Using this data as a base, the quantitative and qualitative productivity gains that can be attained by using an electronic data collection process were assessed.

1.2 The Telkom NetData project

Telkom has rolled-out an extensive Geospatial Information System (GIS)-based network asset management and planning system (NetPlan). The utility's management identified serious deficiencies in its existing network data. For this reason Telkom initiated a new project, NetData, which intended to provide NetPlan with the data it requires for providing a holistic view of the telecommunication network. Telkom anticipates that the NetData project will provide the means to source, migrate and capture the data in a single network inventory repository. [14]. In the NetData project, Telkom is currently collecting network inventory data using paper sourcing sheets. The main purpose of the NetData project is to source and capture data for the provisioning of NetPlan's network inventory repository. NetPlan will operate on this data repository, using the repository as the master source of data. The data repository will be the master inventory of all network infrastructures, both the existing as well as those planned, and other planning related

information. All envisaged planning tools will also use this repository as their master source of data, notwithstanding their use of local data copies.

NetData is also critical for the success of other initiatives in Telkom's Operating Support Services (OSS)[14]. Some examples of these initiatives are:

- Correlated Fault Management
- Network Inventory replicated to the Customer Billing System
- Service Assignment
- Customer Relationship Management
- Trouble Management

The scope of the NetData project [14] can ultimately be summarised as:

- The sourcing and capturing of data into an integrated holistic network inventory repository.
- The migration of data from current sources into the new repository.

1.3 Current (manual) workflows for data sourcing and electronic capturing.

The current manual NetData collection process at Telkom is shown in Figure 1. The data collection consists of two tasks: first, field workers source the information about an outside network element using paper sourcing sheets. These sheets have evolved over many years of refinement and were used as a basis by the research team to design the user interface for the PDA. Next, after the field workers have sourced the data in the field, and recorded it on the paper sourcing sheets, these sheets are sent to the regional depot office where data capture clerks enter the information manually into the NetPlan GIS repository.

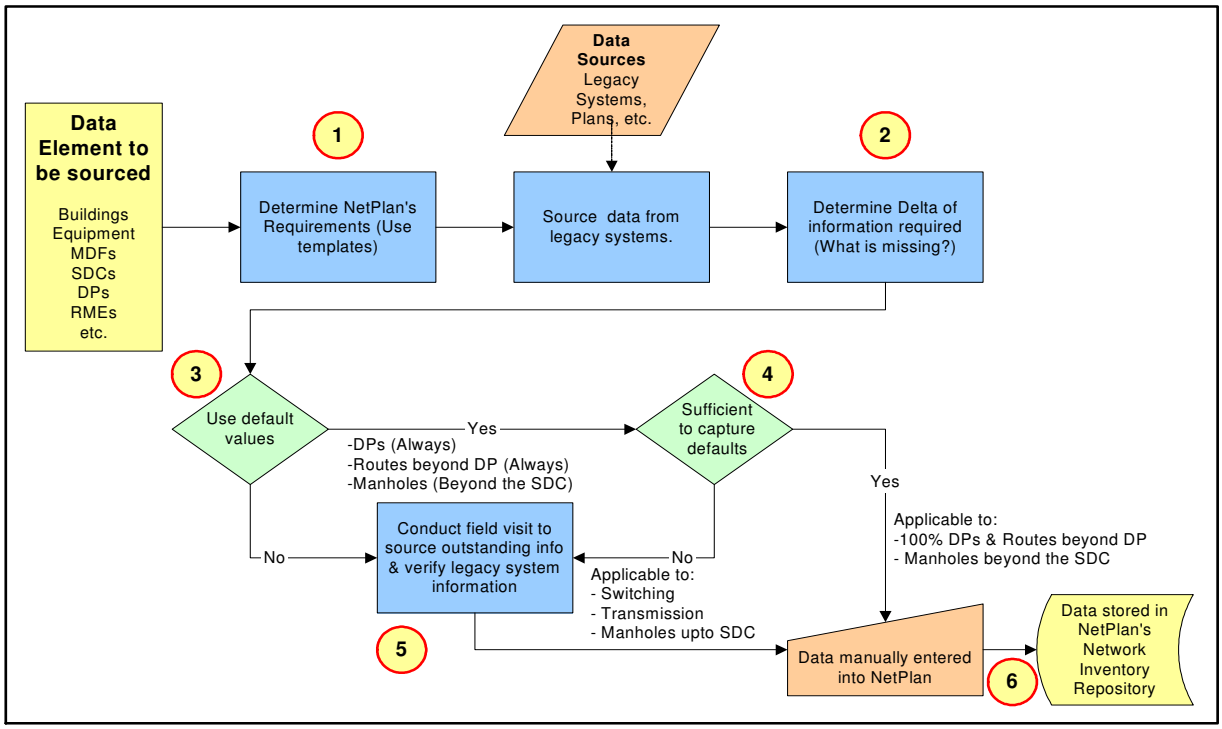


Figure 1: Flow diagram of Manual Data Collection Process [14]

The method outlined below is used to collect the data pertaining to Telkom's Network Elements (NE) which are geographically dispersed throughout the nationwide telecommunications network. A Network Element is defined as a pertinent item of electronic equipment, wire/fibre distribution tie-blocks (or ' Main Distribution Frames' (MDFs), 'Street Distribution Cabinets' (SDCs) and 'Distribution Points' (DPs)), cables (= routes), cable joints, and manholes.

1. The requirement of NetPlan for the capturing of the Network Element is determined (i.e. can it be captured from data in the depot/office, or must it be sourced directly in the field). This requirement is based on the mandatory attributes required by the Smallworld GIS database for NetPlan. The information is sourced using paper-based templates. An example of one such template is provided in Appendix 1.

2. Data can be sourced from existing legacy IT systems/databases and compared against the requirements of the NetPlan software solution. The required data, or

metadata (i.e. information describing when, and by whom, the network data was captured), that is still outstanding is thus identified.

3. A decision is taken regarding the use of default values for the Network Elements (NEs). The 'default value' of a network element is usually the information that can be derived from a schematic diagram, plan, etc. and thus the use of default values is only applicable to Distribution Points (DP's), routes beyond the DP, and manholes. With all other NEs, the use of defaults is not permitted as it could impact on the functionality of the NetPlan system.

4. If the use of defaults is deemed desirable it has to be determined if sufficient information is available to capture default values. If there is sufficient information on the NE to make use of defaults then it is captured in NetPlan.

5. In the event of a field visit being required, the outstanding information will be sourced and the information in the legacy system will be verified.

6. The final step is to manually capture the data in NetPlan's GIS Network inventory repository via NetPlan's graphical user interface.

In summary, "data collection" is defined as the business process of collecting the data pertaining to a Network Element into its electronic format consistent with the GIS inventory repository requirement. "Data sourcing" is defined as the business process of visiting the geographical site of the network element and writing down information pertinent to the NE. "Data capturing" is defined as the business process of transforming the 'sourced' information on the NE into an electronic form.

Dependencies between the network elements are identified and specified as they are sourced (in the field) and captured electronically. Telkom's NetPlan provides for a data inventory for the captured details of the physical, logical, and service layer for the nationwide telecommunications network.

The system also has a technical dependency as depicted in Figure 2 [14]. This means that information on the higher layers is dependent on information on the lower levels. The method of data collection and migration is determined by these technical dependencies, and needs to be captured in a predetermined manner, i.e. for the physical layer, then the logical layer and then the service layer.

The researchers chose to review the manual workflows for sourcing the field data and the subsequent capture, at the depot, of this data for a typical urban Underground Utility Closure (UUC); also known as a 'manhole'. The field sourcing process took almost an entire workshift (i.e., from 9am until 3pm), whilst the data capture process also took a proficient data capture clerk the entire day. This did include entering the complex connectivity information for the cables within the UUC.

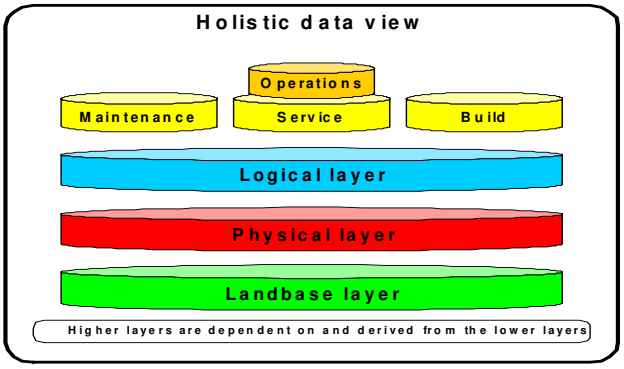


Figure 2: Telkom's NetPlan Holistic data view – technical dependencies

1.4 Problems with manual data collection process, and their impact on data integrity.

As has been described in section 1.3, the manual data collection process consists of two sub-processes. Firstly the network information is *sourced* by Telkom Sourcing Teams within its Access Networks Operations (ANO) organisation. The sourcing entails field visits to gather information on the network elements using "Sourcing Sheets" for each of the main items sourced. These are:

i. Street Distribution Cabinets (SDCs)

ii. Underground Utility Closures (UUCs), or “manholes”
iii. Distribution Points (DPs); and
iv. Overhead routes and specialised resources.

Sourcing sheets are completed in the field, typically on a daily shift (approx. 7.5 hours), and these sheets are returned to the office where the second process, that of *data capture*, is performed. The data capture entails “interpreting” the data on the sourcing sheets and entering it into the Telkom NetPlan database using prepared schemas.

1.5. The Research Project summarised

The theme of this research is to ensure “ease-of-use” of the information and communication technologies proposed for the electronic collection of the field network information, and the synergy between these technologies; i.e. wireless, location-based services and handheld computers. The research project described in this dissertation has focussed on using the technologies as a tool-box for providing this data collection for Telkom, using currently available, (inaccurate) Head-Office (HO) information, and providing updates directly from the field to the Operational Support Systems' HO staff. In this way, i.e. by comparing the manual field data sourcing process combined with its manual data capture process, to that of the electronic data collection process directly in the field, the researchers proved that productivity of the electronic business process increased substantially (over 50%), whilst the accuracy of the data collected was also greatly enhanced.

A team of three researchers, including the author of this dissertation, worked together on this project to develop an electronic data collection prototype, based upon an industry standard PDA, and to field test the prototype. The field tests covered both functionality of the prototype and its technology acceptability to the Telkom field workers. All researchers worked on the requirements elicitation, including the analysis of the manual sourcing process; and the broad design of the prototype data collection mobile application. Kyaw Moe’s work [17] was primarily focussed upon the Usability Engineering aspects of the field data collection application. Dan Hurwitz’s work [26] looked at how the mobile application could be enhanced by introducing context-

awareness into the prototype solution. The author's work was primarily focussed upon the improvement in the productivity of the business process through the introduction of the mobile field data collection prototype. This was achieved by comparing its use with the estimates of performing the work manually as comprehensively analysed in Telkom's NetData business case document [14]. The manual data collection process was analysed by the author and is reported in more detail in Chapter 3 (3.1.1).

Another important aspect of the author's research was to ensure that user obstruction to the use of these mobile technologies was minimised. The electronic data collection prototype was presented to samples of Telkom's field workers to survey its usefulness and ease-of-use and the results of the survey proved positive. It is postulated that the reason for this outcome was the use of usability engineering techniques and guidelines to design of the prototype data collection tool.

The author acknowledges that the conclusions on productivity gained by the electronic data collection process and its usability to those sampled was based upon small samples of field workers who worked in Telkom's Gauteng region. It is possible that the results from other regions could be different owing to language and cultural issues. However the productivity gains were significant and the usability scores were appreciably high, so it was fair to assume that the business case for using the electronic data collection tool together with its modified business process would be justified for a telecommunications utility.

The following chapter of this thesis covers a survey of the existing literature on mobile computing applications and user technology acceptance guidelines. This leads into a chapter on the key research questions for this thesis and the research methodology employed. A chapter which covers the results obtained and a detailed discussion on these results follows. In particular, the research showed that the electronic data collection prototype significantly reduced the time required for the manual data capture process, thereby condensed the man-hours required in the data collection process, and thus the overall cost of the NetData project.

Finally the thesis is concluded with the finding that large cost savings can be achieved by carefully considered and designed IT applications, provided that some attention is also given to the usability of any new technology-based application by its anticipated user communities. Areas of further research are also identified in this chapter. For example, how the data collection process could be enhanced by using "context-awareness" within the mobile computer; i.e. if the handheld device was aware of its geographical position, it could ensure that all relevant data (e.g. equipment catalogue data, etc) could be downloaded prior to the field worker performing his task. Further, a direct "spin-off" from this research project is a methodology a software application vendor can use to determine the benefit of quantitatively measuring the productivity improvement (or other measure) of the application before going to market with unsubstantiated claims about its expected improvement!

The Appendix to this thesis contains examples of the paper-based data collection templates, the technology acceptability survey questionnaires, and a number of papers which were presented on the research topic at information and communications technology conferences (local and international) by the author from 2003, when the research project commenced, to 2005 when it was completed.

2. SURVEY OF LITERATURE

2.1. Introduction

A survey of existing literature on research both academic and industrial has been conducted focussed upon the key aspects of the research into a mobile computer-based electronic data collection prototype that will be acceptable to the existing utility field workers that are currently responsible for network data collection. These are:

i. Technology and Productivity
ii. Geospatial Information System (GIS) technology
iii. Mobile computing
iv. Wireless technology and handheld computers
v. User technology acceptance

2.2. Technology and Productivity

Over a decade ago, Robert Solow, the Nobel Prize winning economist, famously remarked, “You can see the computer age everywhere but in the productivity statistics”. This offhand remark has stimulated many other economists to conduct more rigorous analyses on the impact of information technology on productivity. [1]. The results of this research into the “Productivity Paradox” had a positive outcome. It was established that on average IT investments did pay-off, in fact it was found that IT investments often had much better Return on Investments (ROIs) than other capital investments in companies. But the concern remains whether organisations have restructured their company and its processes to implement best management practices using the better decision-making tools that IT has provided. Aligning IT investments with business strategy is critical to success, but so is the toning down of marketing rhetoric that creates unrealistic expectations about IT returns [1]. The IT industry is notorious for hyping every minor innovation and for making extravagant claims about the capabilities of its

products. The research presented in this paper quantitatively proves the productivity gains for a telecommunication utility's mobile workforce exposed to new technologies for improving the methodology and accuracy of field asset data collection.

According to Scott Johnson [2], there are at least three primary ways of improving productivity of a workforce. These are through:

i) the development of new technologies;
ii) increased capital expenditure; and
iii) education and training.

Most of these are pertinent in Southern Africa. However if the development of technology is a key to productivity improvement, the technology is worthless unless it is actually used. Great improvements in productivity will be unlikely unless workers have the level of education and skill needed to handle the new (advanced) technologies. Johnson's research highlighted the impact of the advent of computer technology. For example, as the computer became more and more advanced, these refinements in computer technology have led to the development of devices e.g. laptop and/or PDA, that are relatively easy to use. This trend to simplify the use of the computing device results in a lower dependence upon the skill levels of the workforce because the technology reduces the need for much of the mental and physical work needed to conduct daily work tasks.

Multiple studies confirm productivity gains of between 15 and 25% per week when the mobile workforce is equipped with mobile PDAs and wireless access [8]. A 2001 Sage report [9], "Wireless LANs: improving Productivity and Quality of Life", which was based upon interviews with management in a number of large companies, found employees realized an additional eight hours per week productivity when using mobile PCs and a corporate wireless network. These productivity savings came about in three ways:

- time savings,
- flexibility, and
- quality of work.

Although some of these claims may also be a little optimistic, the author has personally experienced an increase in his productivity by using mobile computers in various office automation applications. Clearly such productivity savings could be deployed in the Telkom data collection process and the cost of sourcing and capturing the required network element information should be greatly reduced.

In his paper on the impact of mobile application technology on today's workforce, Rochford outlines how this technology enables significant structural change in how organisations perform their tasks and accomplish business goals [6]. This can now be achieved by moving existing business processes, whether automated or manual, beyond the organisation's office to wherever and whenever those tasks can be carried out efficiently. In the recent past, one of the key obstacles to the successful deployment of mobile applications was the high cost to co-ordinate these tasks out in the field. Practice is already demonstrating that this obstacle has been overcome and that IT can be a catalyst for reducing those costs of task co-ordination.

No literature review on mobile applications would be complete without a comment on security. Once mobile devices leave the well-protected, four walls of an organisation's building, what keeps outsiders from stealing the information stored on the devices? This is especially critical given the recent increase in the use of PDAs for applications like medical patient data collection or sales force automation. Such devices now have customer, inventory, and pricing information that the business has to secure in addition to patient or client information that the business may have a legal or fiduciary responsibility to keep secure [39].

If the mobile devices only stored the data locally and only synchronized locally, the problem would be manageable and containable. But now that the devices have cellular modems, analogue modems, 802.11 LAN cards, and Bluetooth LAN controllers built-in, the users expect to be able to synchronize remotely.
In his paper [39], Tim Landgrave identifies four major areas that they consider essential in device security. These include:

- Synchronization security: There must be a method of securing the data channel that carries any data between the mobile device and whatever device manages the data connection.
- Device security: Once the data is entered into the device, it must be secured in such a way that the casual non-authorized user cannot easily retrieve data and passwords.
- Operating System security: The device must have an operating system or an add-on product that can prevent malicious code from corrupting the operating system, its applications, or data on the device.
- Authentication and authorization security: Whenever the client device connects to the corporate network, the user and the device should be authorized to make any changes to the corporate network. [39].

2.3. GIS technology

In developing countries like South Africa, mobile workforce personnel typically have a lower level of experience and skill than their counterparts in Western Europe and the USA. In bridging this skills gap, modern information and communication technologies have the potential to make a significant contribution. One such technology is Geospatial Information Systems (GIS). Because it adds location information to data, GIS technology has the potential to empower the mobile workforce by providing its task-related information anywhere, anytime, and in any format. The mobile worker is dependent on accurate spatial information such as his/her current location, the destination of his call-out task, and the location of the assets which they will be working. [7]. The appropriate use

of computer applications based on geospatial information will improve the ability of inexperienced and relatively unskilled field personnel, allowing them to reduce costs, improve productivity and accuracy, and be more responsive to customers and clients.

In the developed world, as GIS technology matures, it is increasingly being applied to a variety of new tasks within utilities, including planned maintenance, the real-time location of faults on the network, and the dispatch of maintenance vehicles to rectify those faults. In relying on GIS technology to perform these tasks, managers are discovering an ever-widening range of other applications for which the technology is suitable.

The application of GIS technology, whether in the developed or developing world, is pointing the way to a need for enterprise-wide access to spatial data embedded in the corporate database. The implication of the demand for user access to spatially related data (asset maps, geocoded networks, field workprints and orders, dispatch, and topographical maps) requires that the corporate relational data model includes two simple additional attributes, namely "x" and "y" map co-ordinates, for any outside plant, personnel and customers [21].

Almost all utilities have to face the challenge of capturing and maintaining field asset records, which are required in an "as-built" format to supply accurate information to work teams in the field. With geospatial information content now more easily available, it is possible to source, verify, capture, maintain and access field asset data with the assistance of Geographical Positioning Systems (GPS), personal digital assistants (PDAs) and wireless communications technology, thus enhancing the productivity of field operational work-crews. The dramatic growth in business demand for mobile computing, for example used for the outside plant asset data collection process (described above), is a direct result of the natural synergy between PDAs, wireless technology, and data-driven workstyles.

2.4. The business case for mobile computers

The availability of such technologies as GPS, wireless communication, PDAs and pen-based systems coupled with compact Geospatial Information Systems (GIS) and database components has created an exciting environment for researching new GIS applications. GIS can be the enabling paradigm that unifies this wide array of technology in a form that can be readily used for empowering a mobile workforce. The research organisation International Data Corporation (IDC) has identified the mobile worker and the usage of intelligent wireless mobile computing devices as "the third paradigm of computer usage" [7]. The explosive growth of mobile computing has been phenomenal. For example, in the second quarter 2005, worldwide PDA shipments totalled 3,615,608. This represented a growth compared to the same time in 2004 of 31.5%! [38].

The pay-off for mobile computing comes about through lowering the Total Cost of Ownership (TCO) of the technologies deployed and lifting the Total Benefit of Ownership of the mobile application.

Lower Total cost of Ownership: During 1997 it was estimated by Intel Corporation [8] that the total cost of ownership difference between a notebook computer and a desktop in the USA was approximately $4000. By the year 2000 it had declined to less than $1000 and so the question was posed as to how much extra value does one need from a mobile computer user to make up this $1000 TCO differential. Depending upon the total cost of employment of the user itself, Intel estimated that only one extra hour of production per week is required to justify that TCO difference. With PDAs it could be the same, or less, so lowering the total cost of ownership is definitely feasible in this application. The reader can easily calculate the TCO applicable to its mobile application under consideration. In "Tapping the Power of the Mobile Enterprise" [11], some tips for determining the TCO are provided, covering direct costs of the necessary software licences

and their maintenance, hardware costs, data security and access measures, and staff training and device deployment costs.

Higher Total Benefit of Ownership: A key assumption is that mobile users are more productive. When Intel management investigated its mobile computing initiative, it learned that mobile users realise productivity improvements of between three and eight hours per week. This analysis is borne out in most utility industries as well. According to a study conducted by the Gartner Group [10], business users with a mobile computer, and who spend only up to 20 % of their time out of the office, realise a minimum annual benefit of 20 to 25% of their annual cost of employment through increased productivity and efficiency. Clearly field workers, who spend more time out of an office, can expect higher gains in productivity.

The Paper Chase

Today there are several organisations with field workforces that continue to perform daily operations using the traditional paper-based, clipboard system. In its NetData project, Telkom is currently collecting the network inventory data using this means, but enhanced through the use of digital camera/video technology to supplement the lack of knowledge that some workers have about the nature or type of particular field network equipment. Paper-based processes have long been the *de facto* method for data collection and information management; however, in today's competitive markets this is quickly becoming outdated. Field workers are responsible for exchanging millions of pieces of paper containing information often vital for an organisation's performance. This seemingly limitless supply of paper and information poses a large potential for error and delay as the paper forms make their way through the system and back to the office for filing, or manual entry into the central computer system. Research shows that some 70% of all errors in corporate databases can be attributed to the manual entry of paper-based data. [12]. The Gartner Group found that the time

wasted by the average worker on paper-related tasks was 30% of each day, (regardless of their industry)! [10].

However in his paper "The Fundamental Challenges to Mobile Computing" M Satyanarayanan identified four constraints to mobility. These are that mobile elements are resource poor relative to static elements; these elements are inherently hazardous, e.g. you could be mugged and the device stolen; mobile connectivity is highly variable in performance and reliability; and mobile elements rely on a finite energy source. Provided that the constraints to mobility are carefully considered [22], the pay-offs for mobile computing applications are clear and the University has embarked on many different related research projects, particularly involving the mobile workforce for utilities.

To summarise the business case for mobile computing, the benefits of the proposed technology deployment, incorporating PDAs and wireless access, are quantitative (e.g. cost savings) and provide better responsiveness, better accuracy and better timeliness of network asset information. Also by having access to the corporate databases from field remote locations, the mobile user is assured of accurate and reliable information as stored in the corporate repository. This ensures that mobile workers can be certain that they have the correct tools and information (geospatial and other) for the task at hand. However the fundamental assumption in this business case analysis is that the mobile worker will indeed take on this technology. This appears to have been the case in the first world countries analysed, but will this be applicable to South Africa?

2.5 Wireless Technology and Hand-held Computers

Wireless holds much promise for mobile computing [23]. From real-time access for mission critical applications to automated dissemination of work management information, wireless will dramatically affect mobile computing. This statement is also echoed in the paper "The Challenges of Mobile Computing" [24], where the

authors recognised the fact that the combination of wireless networking and mobility will create new applications and services like those mentioned in this dissertation.

Competing standards and protocols characterize today's wireless networks. Most of the current wireless data networks e.g. GSM, are built to support voice communications. Performance issues (9.6 kbps – 14.4 kbps), reliability issues, coverage, and the general lack of standards make today's wireless networks less palatable than our current wireline networks for reliable real-time remote computing connection. Predictions on the future of wireless are that "3G networks, when fully implemented, will move mobile computing to a new level". [11] This prediction is already being experienced, even in South Africa. "Meanwhile, wireless applications should be implemented carefully." [11] Perhaps one bright aspect to this suggestion is the introduction of GPRS (General Packet Radio Service) networks – these are essentially modified GSM networks. GPRS can today offer speeds up to 144 kbps, which is acceptable for most mobile computing network applications.

As raw data continues to become a more quantifiable business asset, the time it takes to accurately gather and process this data is critical. One factor that is driving the adoption of mobile strategies for utilities like Telkom, is the availability of powerful new handheld devices and personal digital assistants (PDAs) [11]. Their small, light weight form factors, fast processors and improved data storage capacities have made these devices the ideal tools for fast data collection. Coupled with the fact that these devices support pen-based touch screens, colour displays, smaller keyboards and wireless communications capabilities, they are particularly appealing to field service professionals. These devices can be customised to support specific field applications like data collection, so that the data collectors can easily perform their tasks, perhaps in the Telkom case, doing away with the requirement for a video camera facility. Companies today need mobile solutions that provide field workers with a simple-

to-use, highly configurable mobile application to replace paper forms and slow, error-prone, costly methods of collecting data and communicating it back to a central location. Some research has shown that deploying the technologies as proposed, provided it has a simplified user interface; acceptance by field personnel will be obtained [11].

The Human – Computer Interaction (HCI)

The development of mobile computers able to communicate via wireless technology has brought a completely different perspective and approach on how humans communicate with computers. Interaction with mobile computers is vastly different as compared to desktop computers. Desktop computing takes place in a static environment where the user is presented with a large high-resolution user interface and information is stored either locally on the computer, or may be accessed via a data network. [13] states that "usability" is important for any mobile computing application or device, but it is even more important with capability-constrained devices with limited display or input. Thus usability analysis should encompass any wireless / PDA application project from start to completion. This concept is expanded in Section 2.6: User Technology Acceptance.

In contrast, mobile computing has associated with it specific constraints and restrictions which result in the design of very different user interfaces. Two of the most important limitations of mobile computing are:

- **heterogeneous environments** – e.g. mobile devices operate in environments containing different mobile communication network infrastructures affecting the connectivity of the device;

- **limited mobile device resources** – e.g. the mobile device screen size, processing power, network bandwidth, battery power, etc., impose constraints on the design of mobile software applications.

Research work focusing on these paradigms has been carried out over the past decade and is still continuing. Design and architecture frameworks for tackling these issues when designing applications for mobile devices have been proposed and prototypes have been built and tested [16].

Mobile GIS

Because of ongoing operations at utilities, many changes occur on a daily basis in the network. Such changes, for example replacement of faulty equipment in the network during a maintenance operation, are currently reported on paper forms and maps and then, in the rare case of a disciplined utility, transferred from these paper reports electronically to the corporate network database/s. However today utilities are providing their mobile field workers with handheld computers and mobile GIS software to facilitate this process of keeping the utilities' geographically dispersed network information up-to-date [19]. Using these tools the utility can better manage its field workforce and its network assets. For example, daily work instructions and maps relevant to the work location can be downloaded through a wireless network directly to a field worker's mobile computer. This permits the field to view the assets at the work location according to what the corporate database presently reflects [29]. This can be validated and verified on-site by the field worker and any discrepancies immediately rectified. Mobile computing and GIS thus greatly improves the efficiency and effectiveness of the field workforce.

The fundamental challenge in mobilizing an application, such as that of data collection, is to determine how the data collector should interact with the information located on the company's office-located servers. One can decide between two scenarios:

- real-time access – where users are dependent on a network connection to interact with the necessary information; or
- synchronisation – which allows users to work off-line, connecting to the network only occasionally to sync up.

The current state of wireless technology, coupled with the inconvenience of staying perpetually connected via wireline, has created the reality of the occasionally connected user. The best way to accommodate this reality is to build a flexible infrastructure where the users can become indifferent to, if not aware of, whether or not they are connected.

On the PDA application side, it is important to structure and automate the content distribution to the PDA [23]. This makes things much easier for the end user, thereby engineering much of the anxiety out of its usage. With automated content distribution, the most current files/data are automatically maintained and delivered to the appropriate personnel with no user intervention required; an advanced data synchronisation software application is advantageous for this function. Some limited access to unstructured content like email, spreadsheets, word processing documents, and maps should be made easy for the end-user to download if it is required over and above the actual application.

2.6. User Technology Acceptance

The Technology Acceptance Model (TAM)

The technology acceptance model was developed by Fred Davis [20]. TAM recognizes attitude measures with the two technology acceptance measures—*ease of use*, and *usefulness*. TAM has strong behavioural elements; it assumes that when someone forms an intention to act, that they will be free to act without limitation. In the real world there will be many constraints, such as limited ability,

time constraints, environmental or organisational limits, or unconscious habits which will limit the freedom to act.

In their paper [5], Davis and Venkatesh present a scientific methodology for testing the usability of software prototypes. This primarily focuses upon the use of the "Technology Acceptance Model (TAM)" which states that the behavioural intention to use a new IT system is determined by:

- perceived usefulness, i.e. the user's perception of the degree to which using the new system will improve that person's performance in the workplace; and
- perceived ease-of-use, i.e. the user's perception of the amount of effort that is required by the user to use the new system.

In the work performed by Venkatesh et al [4], the prior work by Davis was taken a step further and it was proposed that the attitude measures above, i.e. Perceived Usefulness and Perceived Ease-of-Use, could be influenced themselves by further attitude measures of:

- 'Performance Expectancy' (i.e. the degree to which the worker believes that using the IT solution will help him or her to attain gains in job performance);
- 'Effort Expectancy' (i.e. the degree of ease associated with the use of the solution);
- 'Social Influence' (the degree to which the worker perceives that important co-workers believe that he or she should use the new solution) and
- 'Facilitating Conditions' (i.e. the degree to which the worker believes that the organisational and technical infrastructure exists to support the new solution).

Whilst it was recognised that gender, age, prior experience, and 'voluntariness of use' (i.e. the degree to which the use of innovation is perceived as being voluntary, or of 'free will') were also factors which influenced Behavioural Intention and Use Behaviour indirectly; see Figure 3.

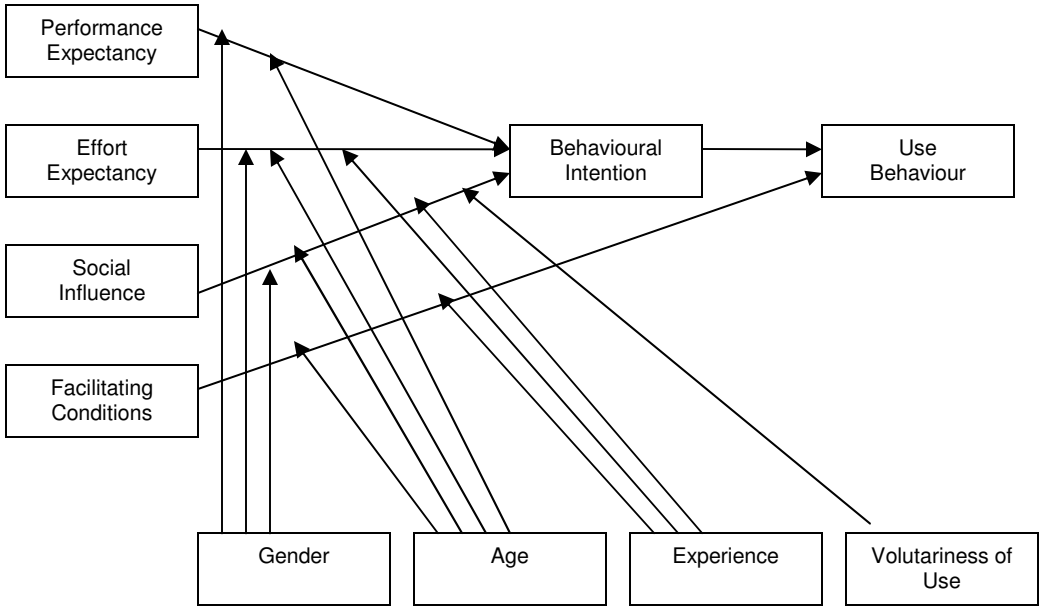


Figure 3: Enhanced technology acceptance model [5]

Usability Engineering

Information Technology (IT) projects are often proposed, developed and implemented without much regard for their end-users. Randall B [32] and Spencer A [33] in their papers presented at the 2003 and 2004 Geospatial and Information Technology Association (GITA) conferences respectively, suggested that issues over user acceptance remain a key concern for successful deployment of mobile applications.

Application software design and development did not always have a concern for users or a focus upon the usability of systems. Nowadays the user population for information systems is so different from that of the past that more and more attention is required to user and usability needs than ever before, especially giving consideration of the pervasiveness of mobile computing applications. User-Centred system design methodology is one that focuses on users and their needs in as effort to design usable systems. There are two key components of user-centred design; user analysis and task analysis [25]. The deliverable from the former component is an audience definition that describes skills and abilities of

target users and job characteristics of the user group. These user profiles also include the willingness and preparation for learning, and the expectations and interest of the users. Task analysis on the other hand, is a method of determining how the target users actually perform their work. A deliverable from this component is a list of current tasks, and future tasks (given the expected impact of the new system), including scenario modelling.

The emerging view of IT systems as tools is referred to as Usage-Centred system design [25]. Since good tools support work, making someone's job easier, faster, simpler and often more flexible, what is really important is building software systems around *uses*, rather than users. So usage-centred system design focuses on the work that users are trying to accomplish and on what the system will need to supply as a user interface to help them accomplish the work. The following questions are addressed carefully in the development of usable systems using usage-centred design [25]:

- Who are the users and how will they relate to the systems?
- What tasks are users attempting to accomplish through the system that is being designed?
- What do these users need from the system in order to accomplish their tasks and how should the system be organised?
- What are the operating conditions under which the system will be used? and
- What should the user interface look and feel like, and how should it interact with the user?

These guidelines include both usability rules and principles of design, but in reality, these rules and principles are simple common sense. Nielsen and Molich [30] reduced them to nine broad guidelines:

- Simple and natural dialogue
- Speak the user's language

- Minimize user memory load
- Strive for consistency
- Offer error prevention, and simple error handling
- Provide clearly marked exists
- Provide informative feedback
- Permit easy reversal of actions
- Support internal locus of control
- Enable frequent users to use shortcuts

Schneiderman [31] proposed eight 'golden rules of user interface design' which are comparable to the above guidelines. They are:

- strive for consistency
- enable frequent users to use 'short-cuts'
- offer informative feedback
- design dialogues to yield closure
- offer error prevention and simple error handling
- permit easy reversal of actions
- support internal locus of control, and
- reduce short-term memory load

In the work carried out by K Moe and D Hurwitz [17, 26] to develop an electronic data collection prototype for a mobile computer, the use of a usage-centred design process proved effective when the usability of the application was evaluated in the field. For example, the electronic Sourcing Template for the underground utility closure (UUC) consisted of a number of screens which are automatically phased consecutively to ensure the electronic data sourcing process flows from the correct point, i.e. entering the sourcing team member, the date and time, site information, the UUC asset number, and its geographic location [17]. Note that in the context-aware development of the EDC tool [26], it was envisaged that much of this information could be automatically downloaded to the PDA via wireless once the geographic location of the sourcing team member and the utility asset

has been recognised. In addition, these researchers recommended that the user interface of the prototype developed could be expanded using extensible mark-up language (XML) and scaleable vector graphics (SVG) to improve the usability of field business process applications of mobile computers which are required to support interoperability with office-based applications like Geospatial Information Systems [17]. XML was used to transfer data between the PDA and the office computer system, whilst SVG improved the “look & feel” of the PDA user interface.

By deploying these design methodologies in the new mobile computer-based electronic data collection application based upon some of the technologies covered in this dissertation, one can be more assured of the user population of the application deriving the benefit originally planned.

3. RESEARCH QUESTIONS AND METHODOLOGY

The project described in this dissertation involved the investigation into the use of current information and communication technologies to improve the efficiency and accuracy of a telecommunication utility's network data collection business process. This was measured by comparing the existing manual data collection process with that using a mobile computer-based electronic data collection prototype.

Three sub-questions were investigated as part of this research process:

1. Are mobile computing applications usable for field data collection?

2. What are the estimated cost savings (in percentage terms) by deploying the mobile computer-based electronic data collection prototype? i.e. this was the estimated productivity improvement.

3. What are the application design constraints for the electronic data collection prototype to ensure that user obstruction to the technologies used in the application are minimised?

To deal with the key challenge of network data collection the School of Electrical and Information Engineering at Witwatersrand University has carried out research focused on developing appropriate business processes to achieve more productive data sourcing and capture. This research involves the measurement of the existing data collection productivity within South Africa's telecommunications company, Telkom. The "quantifiable increase in productivity" was measured by applying the proposed electronic data collection business process and technology to a pilot regional Telkom site and then the productivity gains over the baseline assessed. In a similar way data accuracy improvements were qualified. These measurements were conducted by working with Telkom's own personnel responsible for collecting the network asset information in the field. The Telkom field personnel were trained on using the electronic data collection

prototype and then used this device instead of the paper sourcing templates during a typical field sourcing shift. In this manner the researchers ensured that the measurements were not "skewed" by introducing alien processes through the usage of other specially trained field personnel for the data sourcing and capture implementation. Clearly an important aspect of the research project was to minimise user obstruction to the new technology-based business process by Telkom's own field personnel.

3.1 Assessment of current network data collection processes

The researchers visited one of the regional depots of Telkom to become fully appraised of the data collection workflow for Telkom's NetData project. Time was spent with the Operations Manager at the depot who described the major challenges that currently exist within the processes and their likely impact on the integrity of the data captured. Both the data sourcing process (field) and the capture process (depot office) were investigated over a number visits spanning about three months. A typical Telkom regional depot was used for this investigation, which was selected by the Telkom's Senior Engineer: Gauteng Operations on the basis of it having co-operative management. As part of this requirements elicitation process, the researchers also attempted to assess the level of IT literacy of the field workers and the data capture clerks. A "Pre-Test Questionnaire" was developed for this purpose; see Appendix 2. An examination of the questionnaires completed by the targeted field workers helped to design the prototype electronic data collection prototype against its 'technology acceptability' constraint.

The investigation started with the researchers attending a field team's daily sourcing shift. This commenced at the regional depot, where the Data Sourcing Officer was handed his work-pack specifying the locations and items to be sourced in the period (which was not necessarily one shift). Currently this work assignment is partially automated through the Records Verification operation which has an internal Telkom website containing records, electronically stored, of some of the equipment to be sourced. The website can be accessed by all

accredited Telkom network operations employees and provides the street address and item identifier of the network elements to be sourced. The researchers travelled with the Sourcing team to its assigned geographical area and observed the sourcing process throughout the shift. As an example for this research project, the sourcing of cables and their connectivity within an Underground Utility Closure, or UUC (i.e. manhole), was carefully observed. (See photograph, Figure 4).

The researchers analysed the paper template used for sourcing manhole information (see Appendix 1). This is called a "Butterfly diagram" by the field personnel. This template's current form has evolved within Telkom over many years of stepwise refinement. The researchers carefully analysed the business process of sourcing, and how this template was completed (in the field). A typical butterfly diagram template, once completed, is shown in Figure 5. In summary, the process for sourcing the data entailed tracing a cable from the template's routeface "A" (which pointed to the upstream telephone exchange), through the manhole, including a junction box (splitter), or not. Thereafter the routeface through which the cable exited was sourced, i.e. downstream to the next manhole or Street Distribution Cabinet (SDC). The field sourcing engineer drew these cables on the butterfly diagram and labelled each cable appropriately. This analysis was used in the usability design of the mobile computing application.



Figure 4: Field data sourcing team at work

The researchers also investigated the data capture process by observing a senior data capture clerk who was capturing the data from the carefully ordered sourcing sheets (paper) and also cable (inter-)connectivity information through a number of associated (UUCs) and junction boxes (JBs). It was observed that the data capture process first captured the associated connectivity of cables (copper and fibre) and then populated the regional database server with the details of the network elements from the paper sourcing sheets. During the inter-connectivity capturing process, a large amount of editing of the sourced data was required, especially that consisting of trenches, ducts, and pipes within ducts. (The actual telecommunication cables themselves were located within the pipes). Another challenge in the data capture workflow was the capturing of cable jointing connectivity. This was easier for fibre cables and was performed by the senior data capture clerks, but copper joint connectivity required the input of Telkom "Subject Matter Experts" (SMEs).

The data capture workflow does require information from other Telkom IT applications. For example, the data capture clerk uses the utility's Customer Billing Systems for end-to-end cable information connectivity, i.e. from a suburban switch to a roadside Distribution Point (DP). Often the cable connectivity traverse through UUCs and JBs, and between these elements, has to be accomplished with "educated guesswork" from the SMEs.

The author performed an analysis on the Telkom NetData business case calculations used by Telkom management to estimate the total cost of the manual data collection project. [14]. The estimate of man-hours for sourcing the required information on the field network equipment, including travel, and the subsequent capturing of this information from the sourcing sheets was prepared on an Excel workbook. This analysis is summarised in Table 2 of Section 4.4 later in the dissertation. Included in the data capturing man-hour estimate was also an estimate of the capture of the Logical Network Inventory connectivity in accordance with empirical formulae which used the total number of SDCs and

DPs in the network. It was noted in this analysis that almost 80% of the man-hours estimated for the total NetData collection process were allocated to the data capture sub-process, which included the cable connectivity information.

Observations and Recommendations

Apart from the observations of the data capture workflow and its challenges mentioned above, it was also noted that the paper data sourcing sheets were often not meticulously completed by the field engineering personnel. Perhaps the sourcing team members at fault considered the information omitted to be obvious or trivial, or that the data capturing clerks would know this information themselves. However these omissions also resulted in educated guesswork from the capture clerks and thus the accuracy of the data collected may be suspect.

This manual data capture process thus affects the integrity of the network data in the NetPlan repository. This has a ripple effect on the integrity of the proper functioning of the operations systems support and network planning services mentioned. It is important for users of these services to have confidence in the information they are analysing as part of their work function. However it could be argued that merely by improving the quality of field manual data sourcing, an improvement in productivity of this business process could be achieved. This question was put to Telkom Field and Office management and the argument discarded. Telkom and other utilities, have been trying for many years to improve the quality of data collected by field workers with only minimum success!

It was postulated in this research that "capturing" as much of the network data *once* electronically in the field, thereby eliminating the two-step process currently employed, would save much time and improve the integrity of the data thus captured. It was also postulated that this process would also improve the productivity of field asset data collection for other utilities as well.

3.2 Usability engineering of the Electronic Data Collection prototype

A key hypothesis of this research was that when designing the mobile computer-based electronic data collection prototype, considering a 'usage-centred' system design with a focus on increased productivity (expectancy) for the user of the prototype, and a 'user-centred' system design with a strong focus on human-computer-interaction (HCI) i.e. decreasing user effort expectancy, in the design would result in a minimising of user obstruction to using the device as proposed.

The 'rules of usability' and design principles covering a usable software development approach (see Section 2.6) which lead to the methodologies of 'User-Centred Design' and 'Usage-Centred Design' were thus used to engineer usability into the electronic data collection application on the mobile computer device for Telkom's field workers.

The design and implementation process for the development of the electronic data collection prototype consisted of a requirements elicitation phase, the selection of the mobile computing device for the prototype application, a user-centred and usage-centred design approach for the prototype software, and usability testing. Although the author of this dissertation was the overall project manager and also contributed in the design specification phase, the actual usability engineering of the prototype for was carried out by the post-graduate students, Kyaw Moe and Dan Hurwitz [17, 26]. The usability testing was performed by the research team together.

3.2.1 Requirements Elicitation Technique

The technique used to gather requirements information involved interviews with Telkom's field personnel over many shifts, and the analysis of the paper-based forms presently used for sourcing information on the utility's network assets. The

interviews were carried out on a team of seven data collection field workers from Telkom during a normal work shift to source network related data. The interviews were informal and open-ended. The intention was to let the potential users for the electronic data collection prototype talk freely about their work without the researchers imposing their own view upon the process. This was designed to assess the computer literacy of the field workers and to design in accordance with technology acceptability of the mobile application prototype.

The field personnel use paper forms (an example of one of the pages of such a form i.e. the butterfly diagram is shown in Appendix 1), termed "Sourcing Templates", to record the network asset information that has been collected in the field. There are sourcing templates for each of the main network items sourced. These are:

i. Street Distribution Cabinets (SDCs)
ii. Underground Utility Closures / Boxes (UUC/Bs), or "manholes"
iii. Distribution Points (DPs); and
iv. Overhead routes and specialised resources.

Sourcing sheets are completed in the field, typically on a daily shift (approx. 7.5 hours). Data sourcing is a form completion activity and to understand what the work is all about, the forms were analysed. In this dissertation attention was focussed only upon the most complicated sourcing template. This was the sourcing sheet for an Underground Utility Closure (UUC), or "manhole". The information contained in this sourcing sheet (eight pages), when completed, covered the shape of the UUC, its dimensions, the wall ducts from which cables entered the manhole from the upstream telecommunications switch, and the wall ducts that the cables left the manhole to connect "downstream" cables and network equipment, and the cables themselves (see Figure 5). One of the forms in this sourcing template, termed the "butterfly diagram", also permitted the collection of the type of each cable (i.e. Copper or Fibre) and how many pairs were within each cable, and whether there were joints or splitters in any of the cables.

Note that individual cables were identified by a unique alphanumeric code.

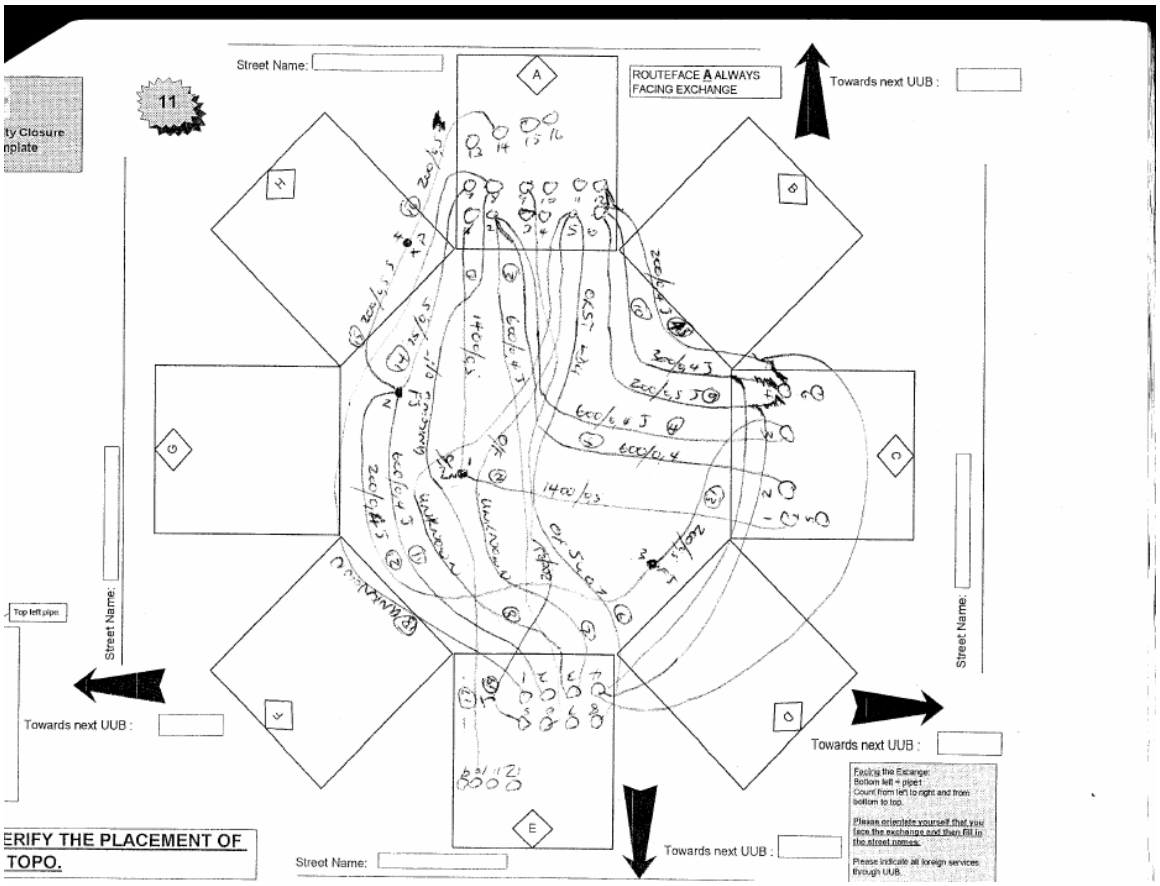


Fig 5: The 'Butterfly' diagram representing the cables within a manhole (UUC)

When the sourcing template was completed, especially the cable interconnectivity as represented on the 'Butterfly diagram', the paper-based data collection deliverable was not easy to decipher. This, in terms of the manual process, was not the responsibility of the sourcing engineer, but rather that of the data capture clerks back at the depot.

In addition to the interviews and forms analysis, the researchers observed the data sourcing teams actually at work. This has been recognised as the most effective requirements elicitation technique [27]. The researchers also used electronic recording technology, i.e. a digital video recorder and a digital camera to capture the work process for subsequent analysis. This was useful for analysing activities from the sourcing process which happened quickly. In this way the researchers

were able to slow-down, or freeze frames, so that the patterns of interaction and user behaviour during the sourcing activity could be carefully analysed. The researchers worked with the Telkom sourcing teams for approx. 10 days, whilst they captured the information on the network elements throughout the Rosebank area of Central Johannesburg.

In addition to working with the Telkom sourcing teams in the field, the researchers also spent a few days observing the data capture clerks at work. Their task was to electronically capture the utility asset information sourced by the field engineers on the paper templates into the electronic database using the electronic templates provided by the GIS software application for network planning and operation (Smallworld). This was an extremely tedious task and took approx. four times as much time to accomplish as that for the field sourcing process for the same network element. The data capture task was often rendered more complex by the untidiness of the information sourced on the paper templates, and the data capture clerk often had to make a 'judgement call' on what was presented. This call clearly affected the integrity of the electronic data captured. In some cases the field engineers had to re-source the asset information as it was just not able to be interpreted reliably by the data capture clerks. Because paper templates do not have an explicit 'closure' to the sourcing information, some templates were received by the data capture clerks uncompleted. This dynamic was noted by the researchers and the PDA-based user interface was implemented in a manner which 'forced' completion of the sourcing job before that task could be closed.

What was also observed in the data capture process was that in frequent cases, especially with fibre cables, the data capture clerks had to refer the electronic capture process to Telkom 'Subject-matter-experts' (SMEs) to complete the process due to the complexity of the task, and the lack of quality of the sourced information on the template. An advantage, therefore, of the electronic application was that in many cases, the sourcing engineer had enough knowledge to complete the task in the field without reference to a SME.

3.2.2 Selection of Mobile Computing device

A number of mobile computing devices were considered for the field data collection process at Telkom. The utility itself encouraged the researchers to develop the solution for the Husky Model *fex21* handheld computer as it had purchased many of these devices for a Mobile Work Management application which was subsequently halted. However the software development environment for the Husky was seriously restricted and out-moded. The researchers felt that it was important for the portability of the electronic data collection application to other utilities that the mobile computer selected supported current software development tools and environment (e.g. Microsoft's .NET software development and operational environments). It was also planned that the PDA and its operating system would be using Intergraph's IntelliWhere OnDemand GIS gateway for downloading maps for the field workers and uploading collected network asset data to Telkom's corporate GIS database. The reason this gateway was used was that it was made available to the researchers as a result of the School having a research alliance agreement on GIS solutions with Intergraph Corporation. Also at the time the platform selection was made, Smallworld (now GENS) did not have a PDA-based GIS solution. The device selected had to support the Intergraph IntelliWhere Pocket PC application. The researchers thus selected the HP/COMPAQ Model 3970 iPAQ Personal Digital Assistant (PDA); see picture over leaf. This offered good resources for a mobile computer as well as the support for the development environment and COTS (Commercial Off-the Shelf software) applications required. See Figure 6.

As mentioned in Section 2.5, real time access and synchronisation were taken into consideration when developing the customised PDA data collection application required by Telkom for the sourcing and capture of its network element data. Also covered in the electronic data collection design prototype were geospatial references, if applicable, and the knowledge and skill of the field worker used in this business process. However starting with a field-tested commercially off the

shelf (COTS) package like Intergraph Corporation's IntelliWhere OnDemand, some of the usability features of the PDA user- and gateway- interface, and the content distribution application, were already available [15].

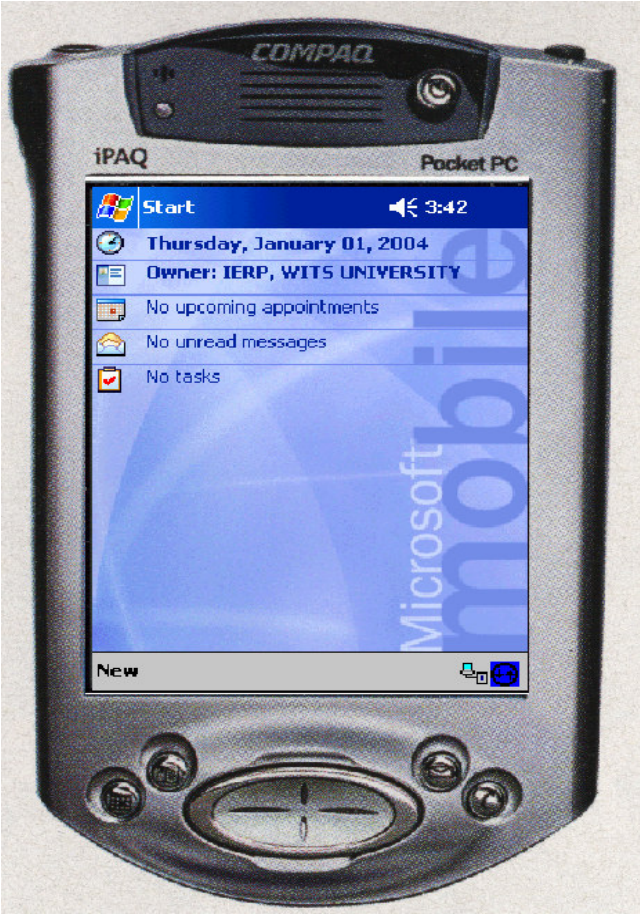


Fig 6: HP/Compaq Model H3970 iPAQ Personal Digital Assistant (PDA)

3.2.3 User-Centred and Usage-Centred Solution Design

Basic usability design guidelines help designers make decisions that lead to highly usable systems. These guidelines contribute to the design of systems that are easy to learn, easy to remember, are efficient, reliable, and satisfying to use; i.e. all the aspects of Usability as defined (See Section 2.6).

The principles and guidelines of Usability Engineering were used to design the User Interface for the mobile computer-based device for electronic data collection of information in the Underground Utility Closures and field-tested in an urban area of Johannesburg where there were many UUCs and most had many cables, both copper and fibre, transversing these network elements.

3.3 Conclusion

The methodology outlined in this section culminated in the design and development of a PDA-based electronic data collection prototype which went through a number of iterations over a period of twelve months. Each iteration was tested in the field with the Telkom depot's sourcing personnel and the results were used to provide more functionality and make it easier to use. During this period the prototype was also demonstrated to Telkom NetPlan management and an XML-based application proven in the device to download to the PDA and upload from the PDA to Telkom's Smallworld NetPlan database.

4. THE RESEARCH RESULTS

A key result of this research was the major improvement to both productivity of the data collection process (i.e. the field sourcing and depot data capture sub-processes) and the integrity of the data collected. In theory, using the Electronic Data Collection tool enabled data collection to be combined into one business process i.e. that of sourcing the information in the field directly into an electronic format compatible with that required by the Utility's geo-spatial resource management system for network assets. See Fig 7 below. In practice the researchers recommended that the information sourced into the mobile computer be first posted (up-loaded) into a 'dummy' geo-spatial database, for validation by data capture clerks and subject-matter-experts (SMEs), prior to being committed into the Corporate GIS database used for network operations and planning. Even with this added 'verification' workflow, the increased productivity in the collection process and increased integrity of the data collected pointed strongly to it adoption by utilities with geo-dispersed network assets. The results of the productivity improvement forecast are included later in this Chapter. However given the research conducted into usability and user technology acceptance outlined in Section 2.6, it is important that these aspects be reported upon first.

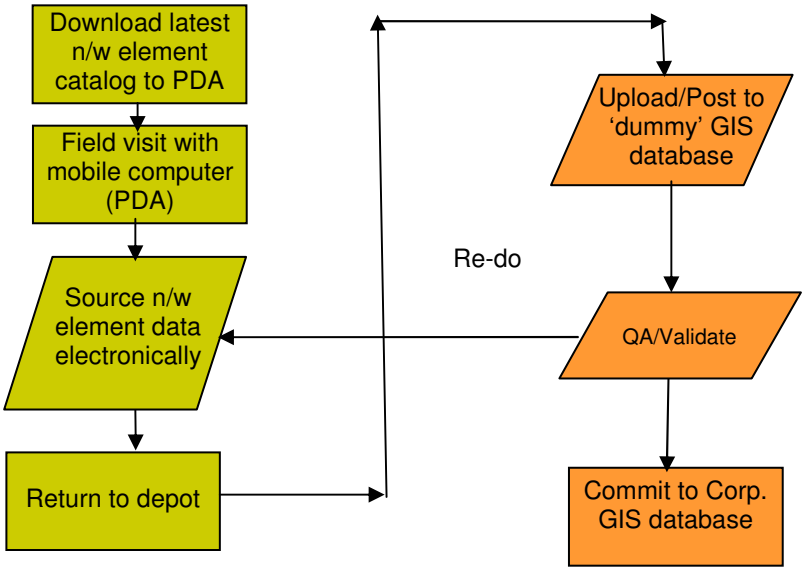


Fig 7: The Prototype Electronic Data Collection Workflow

4.1 User Acceptability testing

An IT project's success depends upon its acceptance and usage, see section 2.6. This was particularly true in the case of field workers who are responsible for data collection and maintenance processes in utilities like Telkom SA. It is important to recognise and respond to user resistance to new technologies and not adhere to the misconceived notion about software systems that users can be trained to accept usability inadequacies by determining 'work-arounds'.

In the research project, usability tests were carried out in two phases. The initial phase involved testing of the PDA-based solution in the field on a team of Telkom's sourcing engineers who had been exposed to the project during the requirements elicitation phase discussed in 3.2.2. These engineers were first subject to a day of user training on the solution and then they used the mobile computing application to collect the field asset information in parallel with the use of the manual paper template method described in a previous section. The data collection operations (electronic and manual) were timed and these times recorded over a period of a few days at various UUC (manhole) visits by the Telkom Sourcing team. The data sourcing times were compared.

4.1.1 The Manhole User Interface

The user interface for electronic data collection of the cables and cable-joints within a manhole needs some explanation. This was covered comprehensively in M Sc (Eng) student Kyaw Moe's thesis [17]. The sourcing process includes the capture of information on the manhole itself. For example, one can specify the nature of the manhole cover, whether there is water in the manhole, the shape of the manhole internal (which can be selected from a pull-down menu of standard shapes), and the manhole's physical dimensions. The user interface also enables the sourcing engineer to capture information of the ducts and their physical position (placement) on the internal route faces of the manhole. This information is captured without drawing as is the case in the paper template 'Butterfly

Diagram', see Fig. 5, and Section 3.2.1. The PDA user interface also includes a tool to orientate the sourcing engineer within the manhole. The route face "A" is always defined as being the closest to the upstream switch. The ducts within the other route faces contain the ducts of downstream cables to the network served by the manhole. The duct specifications can also be entered using a pull-down menu of standard types or using text as entered via the PDA standard picture 'keyboard', Fig 8. Note an important aid to the improved productivity of this collection process, is the fact that the sourcing engineer can download the latest set of equipment and cable specifications that exist in Telkom's equipment database accessible to all depots via the internal intranet. This download also ensures the overall integrity of the electronic data collection processes.

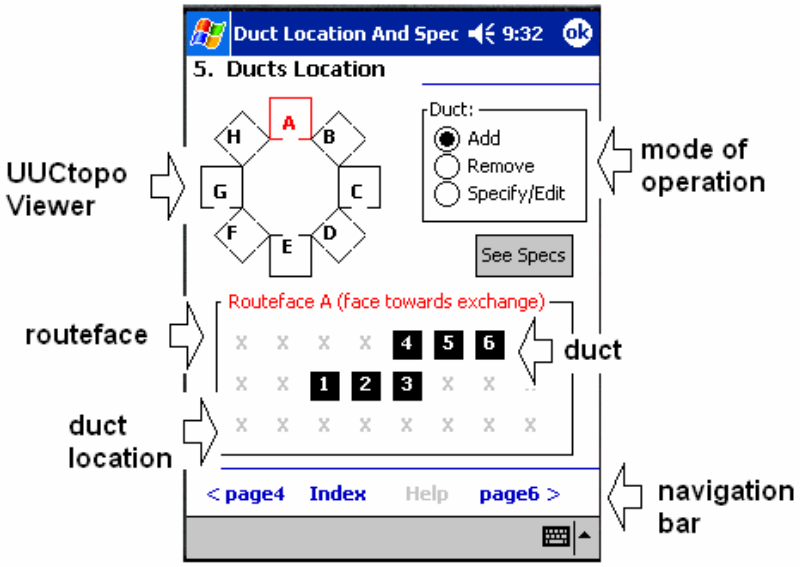


Fig 8: User interface for capturing the duct location and cable specification

In order to trace the cables and their paths within the manhole, the user interface uses a template to create and view the cable network, see Fig 9. It displays the full path of cables and joints connected to a particular route face and duct in a tree-view format. The tree-icons help the user to recognise what each node in the electronic 'butterfly' diagram represents. The user can place and connect cables,

joints and ducts onto the network by selecting appropriate option buttons on the user interface. The rules of these connections are also included and automatically implemented into the user interface (e.g. by disabling buttons that are not applicable in a particular sourcing process) so that the sourcing engineer cannot enter invalid connections. The nature (copper or fibre) and specification (number of pairs) of the cable can be entered through the use of pull-down menus or through the picture keyboard. A 'NotePad' is also included in the user interface for the sourcing engineer to add accompanying notes during the process, if applicable.

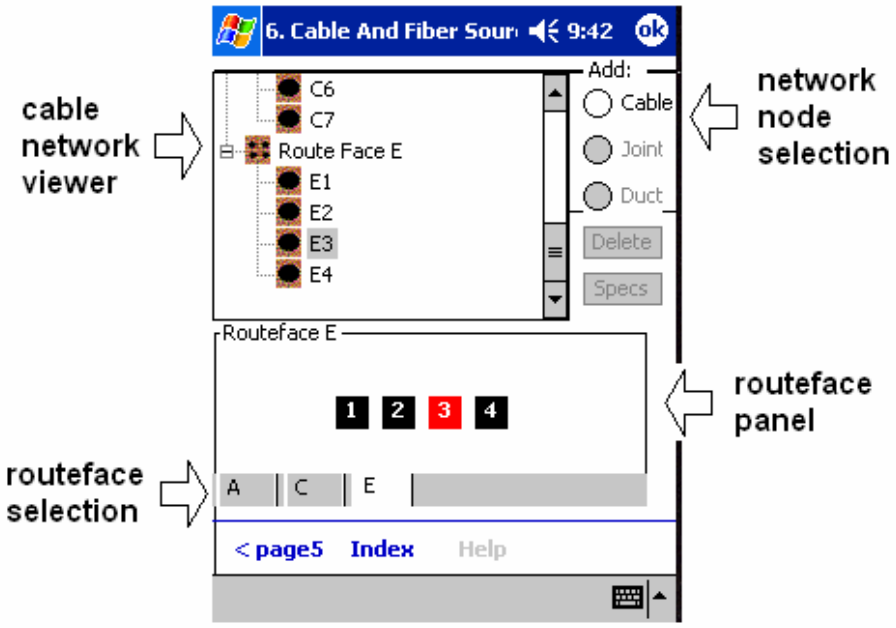


Fig 9: User interface for displaying the cable network into and out of the UUC

Further enhancements to the PDA-based prototype were introduced after close examination of the manual data capture process (i.e. as performed in the Telkom depot) using the paper-based sourcing templates. It was found, for example, that the data capturer had to input the cable route information external to the manhole information being captured, prior to capturing the UUC's internal cable routing information. This was often a tedious process and invariably involved much educated 'guesswork' by the data capture clerk. The researchers decided that most of this cable connectivity information could actually be captured on the mobile

computer in the field during the field sourcing process. The software programme covering this sourcing process was modified and the field usability test again conducted. Although the time taken to source the UUC information increased nominally as a result of this additional information, the data capture process reverted to a check and verify process only; again vastly reducing the data collection time overall.

4.2 Technology Acceptance testing

The second phase of usability testing was conducted at two Telkom field offices. The objective of these tests was to assess the technology acceptance of the mobile computer-based electronic data collection prototype. The test was designed in accordance with the guidelines from the F Davis [5] research described in Section 2.6, and consisted of a survey questionnaire to test perceived usefulness and perceived ease-of use of the mobile application by the sourcing engineers. An example of the questionnaires used is included in Appendix 3; i.e. "Perceived Usefulness & Perceived Ease-of-Use Questionnaire (summary)" and "Perceived Usefulness & Perceived Ease-of Use Questionnaire (enhanced)". The first six questions in the "summary" questionnaire surveyed "Perceived Usefulness"; whilst questions 7 to 12 surveyed "Perceived Ease-of-Use". The "enhanced" version sorted the questions into the categories of "Performance Expectancy" (i.e. the degree to which the data sourcing engineer believes that using the IT solution will help him or her to attain gains in job performance), "Effort Expectancy" (i.e. the degree of ease associated with the use of the solution), "Social Influence" (the degree to which the data sourcing engineer perceives that important co-workers believe that he or she should use the new solution), and "Facilitating Conditions" (i.e. the degree to which the engineer believes that the organisational and technical infrastructure exists to support the new solution) as described in Section 2.6 of this thesis. The Telkom depot personnel surveyed for technology acceptance testing completed the summary version of the questionnaire only. The author re-analysed the results in accordance with the "enhanced" questionnaire. It

is important to note, when analysing the results of the survey below, that the users' score range was from 1 (extremely unlikely to use technology) to 7 (extremely likely to use technology).

The two survey samples, although not random, were selected with Telkom management's assistance. The first sample consisted of the entire sourcing and data capture teams at the depot that had been used for the requirements elicitation and initial usability tests. This sample had already completed its "Pre-Test Questionnaire" (Appendix 2) to ascertain some idea of each member of the sample's IT literacy. The second sample that Telkom management selected for the technology acceptance test was from another depot in Gauteng Region but remote from the first. At this depot the sourcing engineers and the data capture clerks had not even heard of the research project, and were using the paper template-based manual asset data collection methodology. In this case the "Pre Test Questionnaire" was also completed by each member of the sample, prior to the usability test survey. For both samples, the researchers spent a morning demonstrating the PDA-based application prototype, and then requested that the relevant depot staff complete the questionnaires anonymously. These completed questionnaires were analysed under the constructs of Behavioural Intent and User Intent covering Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. The responses were averaged for each sample (Depot # 1, Depot # 2) and the standard deviation of each sample's responses calculated. Note that there were four survey questions each to assess the Performance Expectancy and Social Influence constructs, three questions for the Effort Expectancy construct, and one for the Facilitating Conditions construct. The results of this usability survey are shown in Table 1 and Fig 10.

Survey Questions			Q1	Q2	Q3	Q4
Performance Expectancy	Depot#1	Average	6.44	6.11	6.33	6.22
		Std Dev	0.73	1.27	1.12	1.09
	Depot#2	Average	6.11	6.33	6.22	6.33
		Std Dev	0.78	0.71	0.44	0.50
Effort Expectancy	Depot#1	Average	6.22	5.89	6.44	N/A
		Std Dev	0.83	0.93	0.73	N/A
	Depot#2	Average	6.22	6.00	6.56	N/A
		Std Dev	0.67	1.00	0.73	N/A
Social Influence	Depot#1	Average	6.33	6.44	6.22	6.33
		Std Dev	0.71	0.73	0.83	1.12
	Depot#2	Average	6.11	6.22	6.11	6.44
		Std Dev	0.60	0.67	0.78	0.73
Facilitating Conditions	Depot#1	Average	6.44	N/A	N/A	N/A
		Std Dev	0.73	N/A	N/A	N/A
	Depot#2	Average	6.33	N/A	N/A	N/A
		Std Dev	0.71	N/A	N/A	N/A

Table 1: Results of User Survey of Technology Acceptability

The average values were then combined for both samples (Depots 1 and 2) and the average survey score is represented in the chart (overleaf).

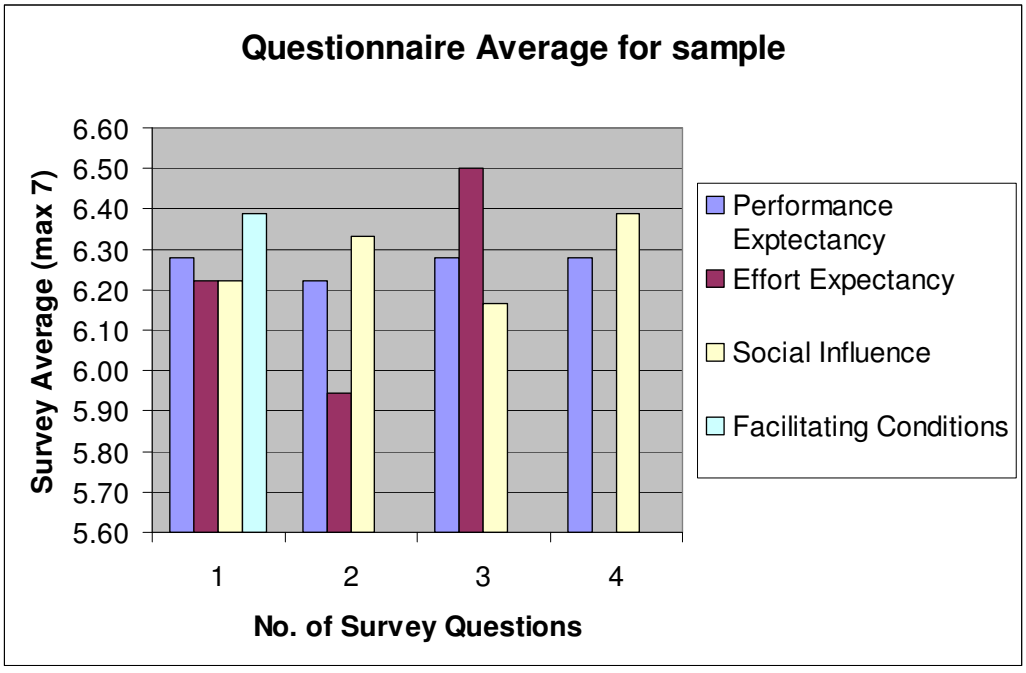


Fig 10: A Chart representing the results of the Technology Acceptability user survey

Clearly the results of this survey and the usability tests show a high degree of acceptance by the field sourcing engineers and data capture clerks that were interviewed in these tests. The field engineers would use the Electronic Data Collection tool and did find it an aid to increasing productivity of the asset information collection project (NetData) at Telkom. Although it is acknowledged by the researchers that the samples surveyed were small in number, they felt confident that Telkom could roll-out the new technology-based process nationwide with a god expectation that significant productivity gains could be achieved and a higher accuracy of the data collected.

4.3 Productivity gains

Against the background of the productivity improvement results for the UUC data collection from this research project, the author investigated the entire manual data collection business processes (i.e. covering all equipment in the Access network e.g. UUCs, SDCs, DPs etc; the Switching network; and the Transmission network). The Telkom NetData Business Case document [14] provided much of the information on manhours expected for the total project, broken down into the various network systems components in operation. Using the manual data collection process as compared to the electronic process for the UUCs as the basis for the manhour assumptions, manual data collection figures were compared with those usng the electronic data collection prototype and recorded in Table 2.

In the business process calculations summarized in Table 2, the researchers made the following assumptions:

- Electronic field sourcing was 25% longer than current manual. Also the "non-field visit" sourcing took 25% longer than the manual case. These were conservative assumptions and were motivated by the researchers' belief that the field engineers would take longer using the PDA application compared with the paper sourcing templates which had been in use for many years. In an actual field test of the electronic data sourcing prototype, using Telkom's

own field workforce, the sourcing duration for a UUC was only marginally longer than the manual process; i.e., less than 5%. This was after limited exposure to the new methodology [17].

- Data capturing time reduced by 75% in going electronic. In fact, it assumed that by using the electronic process, the time allocated to "data capture" was actually used for verification and quality assurance of the data uploaded from the PDA prior to committing it to the corporate GIS. This was also a conservative assumption motivated by researchers' belief that Telkom management would be wary of permitting electronically captured data in the field to be directly uploaded to its corporate GIS database.
- The travel time for field sourcing remained the same in both cases.

The quantitative and qualitative results of the engineering usability experiment proved successful for the field engineering sourcing team tested and were presented to Telkom management for its consideration. The man-hours that could be potentially saved by using the electronic data collection process were estimated and displayed in Table 2 which represented the quantitative analysis performed upon the summary from the Telkom NetData Business case document [14]. In order to preserve the confidentiality of Telkom's business operations, the total costs of both the manual and electronic processes have been "normalised" against the total estimated man-hour costs to collect all the data required in NetPlan by the current (manual) method.

	NetData Project * normalised against the total manhours estimated for the project	Manual data collection Proxy cost*	Electronic data collection Proxy cost*
ACCESS Man-hour costs	Sourcing M-hrs (Field Visit)	4.46%	12.81%
	Capturing M-hrs	28.43%	16.34%
	Sourcing M-hrs (No Field Visit)	5.22%	14.99%
	Travel M-hrs	1.24%	2.86%
	Total M-hrs	39.34%	46.99%
SWITCHING Man-hour costs	Sourcing M-hrs (Field Visit)	0.81%	2.33%
	Capturing M-hrs	7.46%	4.29%
	Sourcing M-hrs (No Field Visit)	1.32%	3.79%
	Travel M-hrs	0.43%	0.98%
	Total M-hrs	10.02%	11.39%
XMISSION Man-hour costs	Sourcing M-hrs (Field Visit)	2.06%	5.91%
	Capturing M-hrs	44.98%	25.85%
	Sourcing M-hrs (No Field Visit)	2.75%	7.89%
	Travel M-hrs	0.86%	1.97%
	Total M-hrs	50.64%	41.62%
TOTAL Man-hour costs	Sourcing M-hrs (Field Visit)	7.32%	21.04%
	Capturing M-hrs	80.87%	46.48%
	Sourcing M-hrs (No Field Visit)	9.28%	26.67%
	Travel M-hrs	2.53%	5.81%
	Total M-hrs	**100.00%**	**43.50%**

Table 2: Comparison of Manual vs. Electronic Data Collection man-hours (Electronic sourcing @ 25% more time than manual)

The analysis separates the data collected into each of the networks within Telkom, namely the Access, Switching and Transmission Networks. Using the assumptions outlined, the total man-hour and costs for the electronic data collection process are 44% of those for the manual process. This represents a saving of 56%!

However, after the prototype was tested in the field, it was agreed that allowing 25% more time for the electronic sourcing process in the productivity estimates was a conservative comparison with the current manual data collection one. This was changed to a less conservative 5% increased time for electronic sourcing in the summary in Table 3, giving a total savings percentage of almost 60% for the field engineering sourcing team tested.

	NetData Project * normalised against the total manhours estimated for the project	Manual data collection Proxy cost	Electronic data collection Proxy cost
ACCESS Man-hour costs	Sourcing M-hrs (Field Visit)	4.46%	11.48%
	Capturing M-hrs	28.43%	17.43%
	Sourcing M-hrs (No Field Visit)	5.22%	13.43%
	Travel M-hrs	1.24%	3.05%
	Total M-hrs	39.34%	45.39%
SWITCHING Man-hour costs	Sourcing M-hrs (Field Visit)	0.81%	2.09%
	Capturing M-hrs	7.46%	4.57%
	Sourcing M-hrs (No Field Visit)	1.32%	3.40%
	Travel M-hrs	0.43%	1.05%
	Total M-hrs	10.02%	11.11%
XMISSION Man-hour costs	Sourcing M-hrs (Field Visit)	2.06%	5.30%
	Capturing M-hrs	44.98%	27.58%
	Sourcing M-hrs (No Field Visit)	2.75%	8.42%
	Travel M-hrs	0.86%	2.21%
	Total M-hrs	50.64%	43.50%
TOTAL Man-hour costs	Sourcing M-hrs (Field Visit)	7.32%	18.86%
	Capturing M-hrs	80.87%	49.59%
	Sourcing M-hrs (No Field Visit)	9.28%	25.25%
	Travel M-hrs	2.53%	6.30%
	Total M-hrs	**100.00%**	**40.77%**

Table 3: Comparison of Manual vs. Electronic Data Collection man-hours (Electronic sourcing @ 5% more time than manual)

In both these cases, the researchers have assumed that the data capture time is reduced by 75% from that applicable in the manual case. This is still felt generous time enough to handle the quality assurance of the electronically sourced data uploaded to a "post-box" copy of the NetPlan inventory repositories, where it can be checked and connectivity information added prior to the records' commitment to the actual on-line NetPlan repository.

4.4 Summary of Results

The Telkom Business Case proposal for NetData stated that the current approach for collecting the required data could take over four years to complete, and take

almost 4 million man-hours. The pilot project in Gauteng showed that, if implemented on a national scale, this data collection process could be done more quickly and more accurately. This would not only shorten the estimated time to complete the task, but should also render the collection process more reliable and much less costly. Note that the manual NetData project commenced in 2003. At the time of writing up this thesis (mid-2005), i.e. halfway into the forecast completion period, Telkom had not yet collected 50% of its network asset data manually. However it is appropriate to add that even given the encouraging results from the Gauteng data collection pilot, the supplementary applicability of mobile techology to other Telkom regions should also be researched; i.e. costs and risks of the mobile devices being stolen, battery life when collecting data in remote areas, etc.

In interpreting the analysis in Tables 2 and 3, it is clear that the data capture man-hours are an extremely large proportion of the total man-hours for the manual data collection process (over 80% overall). Thus, by using an electronic data collection process (notwithstanding the man-hours allocated for quality assurance of the sourced data) both the total time to collect the NetPlan data and its man-hour costs are halved. Given the estimated NetData project costs and its duration, using the data collection technologies outlined would result in significant savings by the telecommunications utility.

The analysis of the technology acceptability questionnaires also proved encouraging. Naturally, as Davis [4] points out in his paper, the ability to predict Information Technology (IT) adoption behaviour of users is dependent upon the specific measuring instruments being used. The author acknowledges that this aspect should be investigated further by refining the questionnaires and thereby attempt to illicit more feedback on the perceived usefulness and perceived ease-of-use of the electronic data collection prototype. Telkom is embarking on just such a qualitative analysis given the importance of this project to this utility, and considering the low-level of skills prevalent in its field workforce. It has been

acknowledged by Telkom management that in order to realise the time-saving and financial benefits of an electronic data collection process, the workforce will require more training on the use of the prototype. In addition, because the targeted users (i.e. Field workers) may react negatively to the change initiative proposed for their workplace, they should undergo a “cultural intervention”, or change management [18] process to ensure that these workers accept the proposed organisational innovations.

5. CONCLUSION

Telkom South Africa is currently installing an enterprise-wide GIS for new services planning and operational management of its network (physical and logical). It is critical for this utility to be able to operate on reliable and accurate digital data for the process to work as designed and to reap a tangible financial return on the investment in the GIS implementation. It has been established that, mainly as a result of manual operation for planning services and legacy IT systems, the currently existing information on Telkom's network assets is neither up-to-date nor accurate, and nor is it completely available in digital (electronic) form. It is estimated that to capture and/or migrate this existing data into a format usable by its investment in new information technology systems for Network planning and operation would take a minimum of four years and conservatively cost over 300 million SA Rand.

This research project proposes a methodology which author believes will significantly enhance the productivity of the network data collection process, whilst also reducing its capture time and cost, and an improvement in the quality of the data captured. It is anticipated that the application of the methodology will also yield significant improvement on the accuracy of existing network data. Although this research project was geographically constrained into a controlled "pilot" area, it is anticipated that the results can be projected across the entire field network for Telkom, as the utility does train its personnel on its operational "best practices" on a national basis. By adopting this electronic data collection process, Telkom could produce an alternative forecast for the scope of the whole NetData collection process and an estimate of the time that could be saved. This will enable the utility to better estimate the ROI that can be obtained from a quicker deployment of the NetPlan GIS tool and the other identified Telkom business processes within the network-planning domain.

Further, some Information Technology vendors have been quick to promise significant productivity benefits from deploying new software solutions, often with no quantitative data to back-up these claims. A direct spin-off from this project is a methodology for

determining quantitative measure of productivity improvements for the field data collection process, as applicable to any utility and municipality, or indeed any organisation with "network" assets distributed over a geographical land-base. Thus in this increasingly service-oriented and partner-based economy, where mobility is becoming critical to workforces of all sorts, it can be postulated that these productivity enhancements could be applicable to many other types of mobile workforces [28]. The Gartner Group predicts that over 54 million employees were involved in some form of remote work by the end of 2002. Whilst ResearchPortal.com foresees that the number of "small form" computing devices will grow from about 75 million units in 2001 to nearly 450 million units in 2007, thus outnumbering desktop and notebook PCs [28]. Further, despite the weakening world-wide economy in 2001, revenues from mobile information management software solutions rose 37% on the prior year [11]. This indicated that well managed mobile device and application deployment can create a competitive edge, despite curtailed spending on other IT efforts.

The research described in this dissertation shows that the pay-offs for mobile computing applications are clear, even given the challenge of ensuring these applications are put to the designed usability by the field workforce. IT investments can produce significant returns on their investment. In addition the results of this research point the way to other areas which would make interesting and valuable research contributions to the use of technologies to improve the productivity of a mobile workforce. The researchers are currently considering two of these areas:

1. How the data collection process can be enhanced by using "context-awareness" in the software solution on the mobile computer, and
2. Investigating the hypothesis that a utility does not need 100% of its network data to be collected to effectively use operation support systems and planning tools.

The concept of a context-aware computing paradigm was explored to enhance the efficiency and accuracy of the data sourcing procedure in the current project. Although the definition of "context-awareness" is often disputed, our research team was focussed upon the use of the paradigm to improve the usability of the mobile computing device within confined areas like a UUC (manhole). Where "context-awareness" could enhance

the data collection process even further is where the actual geographic locations of the network element/s are taken in context. In this example, the mobile computer senses its geographic location. When the field worker commences his data sourcing task, the computer first downloads, from a regional corporate data repository, all the existing information pertaining to that asset, at that location. The sourcing task thus becomes a simply one of checking the downloaded data.

The other area of useful further research would be to investigate whether a utility could perform most of the important functions in its operations system support and network planning without having to collect 100% of the network asset information. This would be especially relevant in Africa where the operating costs and the capital costs of a network utility need to be driven downwards. The current high costs of collecting the existing network data (manually or electronically) and the high costs of maintaining the accuracy of the data through out the network's life-cycle could not be sustained.

A number of papers have been published in conference proceedings on this research work [34, 35, 36, 37 and 40]. These papers cover the research project's development from its inception in 2003 until the analysis of the technology acceptance tests (2005) at Telkom, and their impact on minimising user obstruction to IT applications. These papers are included in the Appendix 3 (i through iv) to the dissertation.

Given the success of the research project, a natural way to proceed forward would be to deploy the mobile computing technology in a utility maintenance application. A Utility operational management ethos is that if there is no commitment to maintain the integrity of field network data, there is no point in collecting it in the first place! So in the maintenance function, the mobile workers would have the actual information, formerly collected, that they require at the site of the maintenance activity, downloaded to the mobile computer from the corporate database, probably using wireless communication. The work required on that network element will be performed on site. When completed, the field worker would enter the relevant (changed) information into the mobile computer and upload this directly into the corporate database. No forms or further reports would

then be necessary, and no reliance on the office workforce entering this changed information from paper reports would be necessary. If so deployed, the asset information database would always remain “as-built” and not degenerate after time. The network planners will have the confidence in the scenario planning process to know that the data they are using is the latest, automatically updated versions.

6. REFERENCES

[1] Kenneth Kraemer "The Productivity Paradox: Is it Resolved? Is there a New One? What does it mean for Managers?" Centre for Research on Information Technology and Organisations, University of California. [Feb 2001]

[2] Johnson SD, "Productivity, the Workforce, and Technology Education", Dept of Vocational and Technical Education, Univ. of Illinois. [1998]

[3] Davison R and Martinsons M G; Guest Editorial to the special edition on "Cultural Issues and IT Management"; IEEE Transactions on Engineering Management pp 3-7, Vol 50 No 1 [February 2003]

[4] Venkatesh V, Morris M, Davis G and Davis F, "User Acceptance of Information Technology: Toward a Unified View"; MIS Quarterly Vol. 27 No. 3, pp 425 – 478 [September 2003]

[5] Davis FD and Venkatesh V, "Toward Preprototype User Acceptance testing of New Information Systems: Implications for Software Project Management", IEEE Transactions on Engineering Management, [February 2004]

[6] Tim Rochford, "The Impact of Mobile Application Technology on Today's Workforce"; iConverse White paper, [March 2001]

[7] Tadeo Schultz, "Mobile Geospatial Applications: A New GIS Paradigm"; GITA Annual Conference Proceedings; [March 2002]

[8] Intel White paper, "Mobile PCs and Wireless: Business Users make the Productivity connection" [June 2002]

[9] Sage Research Report, "Wireless LANs: Improving Productivity and the Quality of Life"; February 2001, available at http://www.intel.com/ebusiness/products/related_mobile/wp012603_sum.htm;

[10] Gartner Group Survey Published Positions, "Benefits and TCO of Notebook Computing" [May 2001]

[11] Extended Systems white paper; "Tapping the Power of the Mobile Enterprise" [2002]

[12] NEC White paper; "Why Rapid Deployment is the Key to Field Automation", [Oct 2002]

[13] Cobb J, “Enterprise Mobile Solutions”, Wireless Development Services, SPRINT White papers, No 5; [2001]
[14] Telkom NetData Business Case – (Draft) – Internal Document and attachments; [Jan 2003] CONFIDENTIAL
[15] Product overview of OnDemand – IntelliWhere Solutions Intergraph Corporation Website http://www.intelliwhere.com/ondemand
[16] Cheverst K, Davies N, Friday A, 1998, "Developing Interfaces For Collaborative Mobile Systems," Proceedings of the First Workshop on Human Computer Interaction with Mobile Devices, University of Glasgow U.K, 21 -23 May 1998, pp.73-88.
[17] Kyaw Moe; “A Highly Usable Mobile Application for Field Data Collection”, MSc Thesis, 2005; Witwatersrand University.
[18] J Dooley; “Cultural Aspects of Systemic Change Management”; Proceedings of AS Quality Conference; Santa Clara, California 1995.
[19] Mark Vioroso; “The Mobile Field Service Benchmark Report: Bridging the Chasm between the Field and the Office”; Aberdeen group white paper, Oct 2004; http://www.aberdeen.com/summary/report/benchmark/mobileFS-093004.asp
[20] Fred Davis; “Perceived Usefulness, Perceived Ease-of-Use, and User Acceptance of Information Technology”; MIS Quarterly, September 1989 (pp 319 – 340)
[21] J Lancaster, D Alston; “The Inside Story on Outside Plant Spatial Data warehousing”; AGM of AM/FM International, Australia, 1996
[22] M Satyanarayanan; “Fundamental Challenges of Mobile Computing”; Proceedings of 15th Annual ACM Symposium on Principles of Distributed Computing; ACM Press, New York, pp 1-7, 1998
[23] Synchrologic white paper; “The Future of Enterprise Mobile Computing”; August 2002
[24] G Forman, J Zahorjan; “The Challenges of Mobile Computing”; University of Washington, Computing Milieux, 1994
[25] L Constantine; “What do Users want? – Engineering Usability into Software”; Windows Technical Journal, June 2002
[26] D Hurwitz; “Capturing utility network data through a context-aware mobile computing paradigm”; M Sc thesis, 2004, Witwatersrand University.

[27] J Pascoe, P Morse; "Using while Moving: HCI Issues in Fieldwork Environments" ACM Transactions on Human-Computer Interaction; vol 7, no. 3, pp 417-437; 2000
[28] J Vivadelli; "Managing the Mobile Workforce", Agilquest white paper, January 2001
[29] K Kwan, W Shi; "A Study of Dynamic Databases in Mobile GIS"; Hong Kong Polytechnic University, symposium on Geospatial Theory, Processing and Applications, Ottawa, 2002
[30] J Nielsen, R Molich; "Heuristic evaluation of User Interfaces"; Proceedings of CHI '90, ACM Press, New York, pp 249 – 256; 1990
[31] B Schneiderman, "Designing the User Interface. Strategies for Effective Human-Computer Interaction"; 3rd Edition, Addison-Wesley Longman, 1998
[32] B Randall, "Implementing a Mobile GIS to Enhance the Efficiency of Field Operations"; GITA Annual Conference proceedings, 2003
[33] A Spencer, "Implementing Geospatial Resource Management—How to Maximize the Benefits"; GITA Annual Conference proceedings, 2004
[34] R. van Olst, B Dwolatzky; "Network field maintenance and data collection in developing countries – a case for location-based services technology" Geospatial World Conference proceedings, Atlanta USA, 2003
[35] R. van Olst, B Dwolatzky; "Using IT to improve the efficiency and accuracy of network data collection"; AFRICON Conference, Gaberones, 2004
[36] R. van Olst; "Electronic data collection using mobile computing technologies"; SATNAC Conference proceedings, Stellenbosch, 2004
[37] R. van Olst, B Dwolatzky; "Electronic data collection using mobile computing technologies", GITA Annual Conference proceedings, Denver USA, 2005
[38] Gartner Group; "PDA markets ebbs upward; Windows CE holds lead", August 2005
[39] Tim Landgrave; "Focus on these four areas when securing mobile devices"; August 2005.
[40] R. van Olst; "Minimising the effect of user obstruction to the deployment of information technologies for mobile applications within Africa"; SATNAC Conference proceedings, Drakensberg, 2005.

DISSERTATION APPENDICES

1. Underground Utility Closure (UUC) Butterfly diagram sourcing template; titled "UUB and Closure Sourcing" sheet. (UUB is Underground Utility Box).
2. User Survey Questionnaires
    i. Pre-Test Questionnaire
    ii. Perceived Usefulness & Perceived Ease-of-Use Questionnaire summary i.e. does not include the space allowed for comments
    iii. Perceived Usefulness & Perceived Ease-of-Use Questionnaire for the "Enhanced Technology Acceptance Model"
3. Papers published in International and Local Conference Proceedings
    i. "Minimising the effect of user obstruction to the deployment of information technologies for mobile computing applications within Africa"; Rex van Olst; SATNAC 2005 Conference Proceedings, Drakensberg, September 2005
    ii. "Electronic data collection using mobile computing technologies"; Rex van Olst and Barry Dwolatzky; 28th Geospatial Information & Technology Association (GITA) Conference; Denver, USA, March 2005
    iii. "Electronic data collection using mobile computing technologies" Rex van Olst; SATNAC 2004 Conference Proceedings; Stellenbosch, September 2004
    iv. "Using I.T. to improve the efficiency and accuracy of network data collection"; Rex van Olst and Barry Dwolatzky; AFRICON 2004 Conference Proceedings; Gaberone, Botswana, August 2004. Also published in SAIEE Transactions, pp 153 – 158, Volume 96 No 3, September 2005
    v. "Network Field Maintenance and Data Collection in Developing Countries – a case for location-based services technology"; Barry Dwolatzky and Rex van Olst; Intergraph Geospatial World Conference Proceedings, New Orleans, USA, April 2003