Electronic data collection using mobile computing technologies

Rex van Olst

School of Electrical and Information Engineering, University of the Witwatersrand, Johannesburg, South Africa

Abstract:
Research has been conducted on a large telecommunications utility to automate an important business process of the utility, that of collecting information on its geographically dispersed network assets, using mobile computing and wireless technologies. The results of the pilot for this automated business process have been encouraging and indicate a means to improve the productivity of the data collection process, and its integrity. The research compares this automated process with the current, manual, process of sourcing the field network asset data using paper-based templates. This sourcing process is followed by a data capture process to input the data from the paper template into the utility's central GIS. The new electronic process is also a two-step process, but the second step, is a quality assurance process prior to submitting the sourced data directly into the GIS database, as the field data is already captured electronically by the PDA.

The automated business process has been geared for use by low-skilled field workers, so important to improve productivity in third world economies such as those in Africa. An aspect of the research was the technology acceptability by users of the electronic data collection process.

Keywords: **Mobile computing; IT investments, productivity, usability, data collection process, Geographical Information Systems.**

1. INTRODUCTION

It is a matter for debate as to whether organisations have restructured their company, its internal cultures, and its processes to implement best management practices using the better decision-making tools that IT has provided. Aligning the IT investments with business strategy is critical to achieving productivity improvement, including that of a workforce.

According to Johnson, there are three primary ways of improving productivity of a workforce [1]. These are through:

i) The development of new technologies;
ii) Increased capital expenditure; and
iii) Education and training.

The research question presented in this paper is to prove the productivity gains for a mobile workforce exposed to new technologies to improve the process and accuracy of collected field asset data. This 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 [2]. As an example of the use of these new technologies for productivity enhancement, the research focussed upon the needs of a large utility corporation, Telkom SA, 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 and wireless communications technology. This way the productivity of the field workforce can be greatly enhanced.

To deal with the key challenge of network data collection the School of Electrical and Information Engineering at the University of the Witwatersrand is carrying out research to develop appropriate software solutions and business processes to achieve more productive data sourcing and capture. This research involved the measurement 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.

2. NEW TECHNOLOGIES AND PRODUCTIVITY

Multiple studies confirm productivity gains of between 15 and 25% when the mobile workforce is equipped with mobile computers and wireless access [5]. These productivity savings came about in three ways: time savings, flexibility, and quality of work.

In his paper on the impact of mobile application technology on today's workforce, Rochford outlines how this technology enables significant structural change to how organisations perform their tasks and accomplish business goals [3]. This can now be achieved by moving existing business processes, automated or manual, beyond the organisation's office to wherever and whenever those tasks can be carried out efficiently. One of the key enablers to this move is through the use of GIS.

Geospatial/Geographic Information Systems (GIS)

In the developed world, as GIS 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 teams to rectify those faults.

One of the real challenges of using GIS technology to improve the Operations Service Support (OSS) systems within large utilities is the fact that current geospatial resource management systems used for network planning and operations support require that the utility collect 100% of its network assets information and geo-code this attribute information on each asset, before any significant returns on the investment in a geospatial resource management system can be obtained. The cost of this data collection exercise is often many times that of the cost for the hardware and software of the information technology solution itself. This was the challenge responded to by the research team using mobile computing and wireless technology to reduce the time and thereby the cost of geospatially dispersed data collection.

The availability of technologies such as GPS, wireless communication, mobile computer systems coupled with compact 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 IDC has identified the mobile worker and the usage of intelligent wireless mobile computing devices as "the third paradigm of computer usage" [4].

<u>The Paper Chase</u>

Today there are several organisations with field workforces which continue to perform daily operations using the traditional paper-based, clipboard system. Paper-based processes have long been the *de facto* method for data collection and information management. Research shows that some 70% of all errors in corporate databases can be attributed to the manual entry of paper-based data. [8].

<u>Human – Computer Interaction (HCI)</u>

The development of mobile computers has brought a completely different perspective and approach on how humans communicate with computers. Interaction with mobile computers is vastly different 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. Cobb states that "usability" is important for any mobile computing application or device, but it is even more important for capability-constrained devices with limited display or input, [9]. Thus usability analysis should encompass any wireless / PDA application project from start to completion.

<u>Technology Acceptance Model</u>

In their paper, Davis et al presented a scientific methodology for testing the usability of software prototypes [2]. This primarily focuses upon the use of a "Technology Acceptance Model (TAM)" which states that the behavioural intention (BI) to use a new system is determined by perceived usefulness (U), 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 (EOU), i.e. the user's perception of the amount of effort is required by the user to use the new system. These were tested in research questionnaires to survey the reaction to the technology by Telkom field workforce participants. Enhancements were then implemented in the software prototype in accordance with the data surveyed.

3. THE TELKOM NETDATA PROJECT

Telkom has rolled-out an extensive 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 the new project, NetData, which is 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. In this 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.

NetData is also critical for the success of other initiatives in Telkom's Operating Support Services (OSS). Some examples of these initiatives are Correlated Fault Management and Service Assignment

<u>Current (manual) workflows for data sourcing and electronic capturing.</u>

The current manual data collection consists of two tasks. 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:

1. Street Distribution Cabinets (SDCs)
2. Underground Utility Closures (UUCs), or "manholes"
3. Distribution Points (DPs); and
4. 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.

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. A typical regional depot was used for this investigation.

The investigation was commenced by 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). The researchers travelled with the Sourcing team to its assigned geographical area and observed the sourcing process throughout the shift. The sourcing of cables and their connectivity within a UUC was carefully observed. (See photographs, Fig 1).

Figure 1: Field data sourcing team at work

The researchers investigated the data capture process by observing a senior data capture clerk who was capturing the data from the carefully ordered sourcing sheets 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 cables themselves were located within the pipes). Although the GIS graphical user interface did supply electronic templates for these items, the capture clerk preferred editing the duct pipe configurations on entry. Another challenge in the 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 cable information connectivity, but only end-to-end (switch to DP). Often the cable connectivity traverse through UUCs and JBs, and between these elements, has to be accomplished with "educated guesswork" from the SMEs.

A comprehensive analysis, by the researchers, was made on the Telkom NetData business case calculations used by Telkom management to estimate the total cost of the manual data collection project. 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. 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 into the integrity of the proper functioning of the operations systems support and network planning services mentioned. 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.

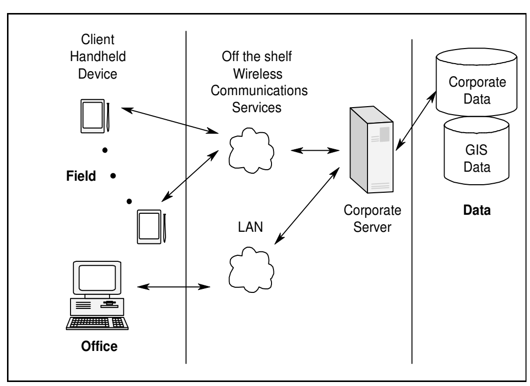

Figure 2: The electronic data sourcing procedure

4. THE ELECTRONIC DATA CAPTURE METHOD

The research continued to be applied to the real challenge of accurately collecting the data on Telkom's telecommunication network. Figure 2 shows the electronic data collection process. It consists of a field data sourcing device (PDA) which could have been connected via wireless communication to the regional depot (or even to the central Telkom office where the corporate GIS database resides). In the current research project, the researchers used the "sync-and-go" methodology of downloading the latest sourced Telkom Network Element specifications to the PDA and uploading the information sourced by the PDA by the field workforce into the corporate GIS database. This was done using the mobile computer's standard "cradle" connected via the USB port to the office computer.

As an engineering experiment, empirical usability tests were carried out in the field at actual Telkom data sourcing sites to evaluate the usefulness and ease-of-use of the prototype, [11]. Samples of Data sourcing team members from Telkom participated in the usability testing. The participants were trained for a few hours to orientate and familiarize with the prototype before the testing could begin. The test participants were asked to complete a list of data sourcing tasks using both the prototype and a paper sourcing form. The duration and accuracy of these tasks were recorded using paper logging forms.

Fig 3 shows how the cable routing information is sketched onto the paper template in the manual data sourcing process and how it is captured onto the PDA in the electronic data collection process.

During the usability tests, the sourcing team members were actively probed for their understanding of the tasks. The sample test participants were again interviewed after the test and asked to complete the questionnaires addressing overall usability of the prototype as well as about specific user interface design issues.

Both the performance and subjective measures of the field data collection prototype were collected during the usability test. The former is a measure of how well the participant can carry out the data sourcing tasks using the prototype relative to that of paper sourcing forms. The performance measures include:

Completeness – is the percentage of total assigned work completed within the allocated time.
Correctness – is the percentage of completed work that is correct.
Effectiveness – is the correctly completed work as a percentage of total work.
Efficiency – is the **Effectiveness** per unit time
Productiveness – is the percent of total subject time spent productively.

Unproductive time included time spent seeking help from the conductor of the test.

In the researcher's analysis of the usability of the data collection prototype, it was found that the test sample of sourcing team members, with very little training on the new technology, only took a short while longer to source the required field information than the manual paper-based sourcing templates. In fact the sourcing performance showed a productivity of slightly less that 100%; i.e. they took approximately the same time as that taken for the manual sourcing process.

The overall performance of the prototype was thus deemed satisfactory. Bear in mind that this is the first time that the participants used the prototype (training aside) whereas they had been using the paper sourcing forms for the past few months. On average, the participants found the data sourcing tasks "easy" to do using the prototype. They were very eager to use the prototype in their work. However, the participants were unable to provide clear suggestions on possible improvements for the prototype.

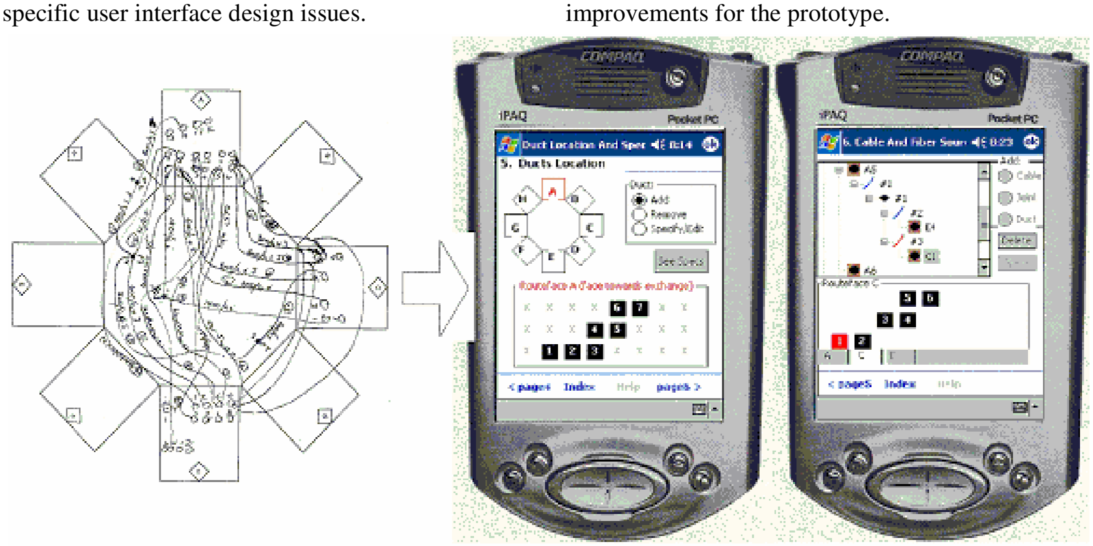

Fig 3: Manual (Left) and Electronic (Right) interface for the topographic view of a UUC cable network

	NetData Project * normalised against the total manhours estimated for the project	Manual data collection Proxy cost*	Electronic data collection Proxy cost*
ACCESS Man-hours	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-hours	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-hours	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-hours	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 1: NetData Project man-hour analysis

In the business process calculations summarized in Table 1, the researchers made the following assumptions:

- Electronic field sourcing is 25% longer than current manual. Also the "non-field visit" sourcing takes 25% longer than the manual case. 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. Thus, increasing the sourcing time by 25% in the Table 1 analysis is generous!

- 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" is actually used for verification and quality assurance of the data uploaded from the PDA prior to committing it to the corporate GIS.

- The travel time for field sourcing remains the same in both cases.

The quantitative and qualitative results of the engineering usability experiment proved successful 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 1.

5. INCREASED PRODUCTIVITY OF DATA COLLECTION

Table 1 represents the quantitative analysis upon the summary from the Telkom NetData Business case document. 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. 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% !

Although in the electronic data collection experiment, the "data capture time" as represented in Table 1, was reduced by 75% (it could actually prove to be more), 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.

The Telkom Business Case proposal for NetData states that the current approach for collecting the required data could be a highly costly exercise. The pilot project shows 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 (over four years) to complete the task, but should also render the collection process more reliable and *much* less costly.

Qualitatively, the analysis of the technology acceptability questionnaires also proved encouraging. Naturally, as Davis [2] 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 researchers acknowledge 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.

6. CONCLUSIONS AND RECOMMENDATIONS.

The research described in this paper show 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 has shown the way to other areas which would make interesting and valuable research contributions to the use of information and communications technologies to improve the productivity of a mobile workforce. The researchers are currently considering three of these areas:

1. How the data collection process can be enhanced by using "context-awareness" in the software solution on the mobile computer.
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, and
3. Refining the questionnaires which test the perceived usefulness and perceived ease-of-use of an information technology (IT) solution in data collection applications.

7. 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 with an earlier version of this paper.

8. REFERENCES

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

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

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

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

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

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

[7] Extended Systems; "Tapping the Power of the Mobile Enterprise" [2002]

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

[9] Cobb J, "Enterprise Mobile Solutions", Wireless Development Services, SPRINT White papers, No 5; [2001]

[10] 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.

[11] Kyaw Moe; "A Highly Usable Mobile Application for Field Data Collection", [MSc Thesis (unpublished), 2004]

The Author

R. van Olst is Associate Professor at the Department of Electrical and Information Engineering, University of the Witwatersrand, Johannesburg, South Africa.

(e-mail: r.vanolst@ee.wits.ac.za)