

BIOGRAPHICAL INFORMATION

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Specific Responsibilities

Re-joined the University of Witwatersrand in 2002 after 25 years in the IT industry in South Africa. Currently responsible for academic teaching and research in geospatial information systems, knowledge management, and location-based services, primarily focussed upon utilities.

Past Experience

The author has contributed to many large-scale engineering IT projects in South Africa, including computer-based telemetry systems for electrical reticulation and railroad signalling; arc-furnace control; object-oriented engineering document management systems for utilities and large metal beneficiation plants; and AM/FM/GIS systems for utilities. The author was Managing Director of Intergraph Systems in South Africa prior to rejoining Wits University.

Educational Information

B Sc - Electrical Engineering, University of Wwatersrand, South Africa
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Geo-Information Society of South Africa (GISSA)
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Electronic data collection using mobile computing technologies

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ABSTRACT

Research has been conducted on a large telecommunications utility to automate one of its important business processes of the utility, that of collecting information on its geographically dispersed network assets, using a Personal Digital Assistant (PDA) and wireless technologies. The results of the pilot implementation 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 manual 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. An aspect of the research was the technology acceptability by users of the electronic data collection prototype.

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 information technology has provided. Aligning the IT investments with business strategy is critical to achieving productivity improvement, including that of a field workforce.

According to Johnson [1], 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 was to prove the productivity gains achievable 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 telecommunications utility corporation, with its assets distributed geographically throughout the country.

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 has carried 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. 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 a network, and the dispatch of maintenance teams to rectify those faults.

One of the real challenges of using GIS technology to improve the Operations Support Systems (OSSs) 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 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 Paper Chase

Today there are several organisations with field workforces which continue to perform daily operations, including the collection of network element information, 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].

Human – Computer Interaction (HCI)

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.

Technology Acceptance Model

In their paper, Davis et al [2] 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 required by the user to use the new system. These were tested in research questionnaires to survey the reaction to the technology by the telecom company's field

workforce participants. Enhancements were then implemented in the software prototype in accordance with the data surveyed.

3. THE MANUAL DATA COLLECTION PROJECT

The South African telecommunications utility (Telkom) has rolled-out an extensive GIS-based network asset management and planning system. The utility's management identified serious deficiencies in its existing network data. For this reason a new project was initiated to provide the network planning systems with the data it required for providing a holistic view of the telecommunication network. For this project, the utility is currently collecting network inventory data using paper sourcing sheets. The main purpose of the project was to source and capture data for the provisioning of the planning system's network inventory repository. The system will operate on this data repository, using it as the master source of data.

The planning system is also critical for the success of other initiatives in the utility's Operating Support Systems (OSS). Some examples of these initiatives are Correlated Fault Management, Customer Billing, and Service Assignment

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

The current manual data collection consists of two tasks. Firstly the network information is *sourced* by 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 corporate GIS database using prepared schemas.

The researchers visited one of the regional depots of the telecom utility to become fully appraised of the data collection workflow for the manual collection 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 began 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 completed and 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).

A comprehensive analysis was made of the utility's business case calculations used by 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 manual 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 often resulted in educated guesswork being required from the capture clerks, and thus the accuracy of the data collected may be suspect. For this reason the manual data capture process affects the integrity of the network data in the GIS repository. This has a ripple effect into the integrity of the proper functioning of the operations support systems 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 collected.

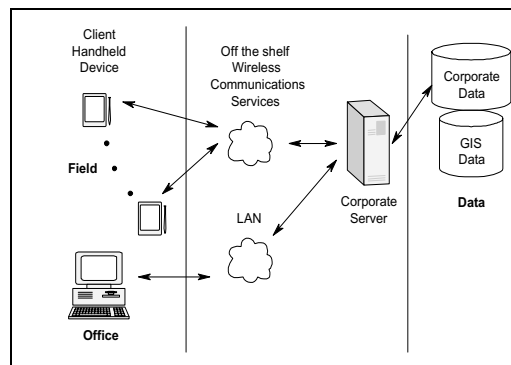


Figure 2: The electronic data sourcing procedure

4. THE ELECTRONIC DATA CAPTURE METHOD

Figure 2 shows the electronic data collection process and its components. The ‘active’ data sourcing device is a PDA which was used by the field workers and could be connected via wireless communication to the regional depot (or even to the central 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 Network Element specifications to the PDA and uploading the information sourced by the PDA into the corporate GIS database. This was done using the mobile computer’s standard “cradle” connected via the USB port to the office computer.

Standard (commercial-off-the-shelf) COTS software was used in this new data collection process. This software is Intergraph's package called Intelliwhere OnDemand. This software operates jointly between a corporate GIS system and, through a gateway interface, with software on a standard Personal Digital Assistant (PDA) to location-enable a mobile workforce. It allows field workers to work in an "occasionally connected" mode to view and update intelligent maps, asset information, and diagrams from the corporate geographic information system [4].

The Experiment

As an engineering experiment, empirical usability tests were carried out in the field at actual data sourcing sites to evaluate the usefulness and ease-of-use of the data collection prototype, [11]. Samples of data sourcing team members from the utility participated in the usability testing. The participants were trained for a few hours to orientate and familiarize themselves with the prototype before the testing began. 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.



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

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.

In the 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. 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 a few months. On average, the participants found the data sourcing tasks "easy" to do using the prototype. Also the participants were very eager to use the prototype in their work as they highly rated its perceived usefulness to the data collection task. However, the participants were unable to provide clear suggestions on possible improvements for the prototype.

	NetData Project * normalised against the total man-hours 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: Comparison between manual and electronic data collection

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

- Electronic field sourcing took 25% longer than the current manual process. Also the “non-field visit” sourcing would take 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% longer. 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 remained the same in both cases.

The Results

The quantitative and qualitative results of the engineering usability experiment proved successful and were presented to the telecom utility’s 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 performed on the summary from the actual manual data collection business case. In order to preserve the confidentiality of the utility’s business operations, the total costs for both the manual and electronic processes were “normalised” against

the total estimated man-hour costs to collect all the data required by the current (manual) method. The analysis separated the data collected into each of the networks within the utility, namely the Access, Switching and Transmission Networks. Using the assumptions outlined, the total man-hour and costs for the electronic data collection process were found to be 44% of those for the manual process. This represented 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 would actually prove to be more), this was still felt generous time enough to handle the quality assurance of the electronically sourced data uploaded to a “post-box” copy of the corporate GIS inventory repositories, where it could be checked and connectivity information added, if applicable, prior to the records’ actual commitment to the on-line GIS repository.

The Business Case proposal for the manual data collection project stated that the current approach for collecting the required data would be a highly costly exercise. The pilot electronic data project showed that, if implemented on a national scale, this process would 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. Telkom is currently 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.

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 intended usability by the field workforce. IT investments can produce significant returns. 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 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. Such a process would be particularly useful for maintaining the quality of the collected data over time.
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.

7. ACKNOWLEDGEMENTS

The authors would like to express their appreciation of Telkom SA management for their support and encouragement during this research; to Intergraph Mapping and Geospatial Solutions for their generous donation of the software licences utilised on the PDA; and to the School of Electrical & Information Engineering at Wits University for sponsoring the project.

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, [February 2004]
- [3] Tim Rochford, "The Impact of Mobile Application Technology on Today's Workforce"; iConverse White paper, [March 2001]
- [4] Intergraph white paper, "IntelliWhere OnDemand solution"; 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]