Using the Living Lab Approach to Develop and Adapt a Context-Aware ICT4D Solution

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Abstract
The rising use of mobile smartphones by people in rural areas of the developing world has resulted in increased deployment of information and communication technology for development (ICT4D) solutions targeted at empowering rural communities to overcome various socio-economic challenges. However, shortfalls in infrastructure, community buy-in, training, and management of ICT interventions are widely cited as impeding user acceptance and sustainability of potentially useful rural ICT4D interventions. This article outlines a deployment of the living lab approach to develop and adapt a mobile, web-based, e-procurement solution for small-scale retailers in Kgautswane, a remote rural area in South Africa's Limpopo Province. The living lab approach is an open-innovation methodology for development of context-based sustainable ICT4D solutions.

Keywords
ICT4D, rural areas, sustainability, living lab, open innovation, context-aware computing, usability, Kgautswane, South Africa

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1. Introduction

Deployment of information and communication technology for development (ICT4D) is increasingly being regarded as a key driver of socio-economic upliftment (Brown & Grant, 2010). Indications of how ICT4D interventions have significantly improved the living conditions of people in remote, developing-world communities have been reported by many authors (Brown & Grant, 2010; Roztocki & Weistroffer, 2011). Sectors in which ICT4D has been extensively explored and seen to produce positive impacts in the developing world include health, small business, agriculture, education, and governance (Thompson & Walsham, 2010). The observed improvements are identified as being mostly due to high penetration, adoption, and use of various forms of enabling ICT tools and online services, particularly via mobile devices.

The proliferation of mobile phones and Internet connectivity in rural areas in the developing world has provided an increasingly conducive environment for the implementation of rural ICT initiatives (Aker & Mbiti, 2010; Asongu, 2013; Gumede et al., 2008). Most rural areas in developing countries are now covered by mobile data communication networks capable of providing connected individuals and communities with a wide range of new opportunities (Aker & Mbiti, 2010; Gumede et al., 2008). Several ICT initiatives that build upon the existing network connectivity and mobile phone use in rural areas have been deployed. Yet many rural ICT4D interventions fail to achieve their intended objectives because of factors such as lack of technology feasibility, lack of adequate infrastructure, lack of community buy-in, and, more generally, the absence of a sustainability strategy (Etta & Parvyn-Wamahiu, 2003; Thompson & Walsham, 2010). Various methodologies have been put in place that seek to overcome the challenges of development and deployment of ICT4D solutions in rural areas. One such method, which was deployed in the study that is the focus of this article, is the living lab methodology (ENoLL, 2015; Gumbo et al., 2012). The living lab methodology seeks to harness a user-centric, open-innovation environment, based on a multi-stakeholder partnership, in order to enable real-life end-users to assume an active role in the research, innovation and deployment process of ICT solutions (Smit et al., 2011).

In parallel to growth in interest in the living lab methodology, there has been increased recognition of the value of context-aware computing. This type of computing incorporates contextual information such as device characteristics and various environmental factors within the user environment (weather data, for example) during applications development and run-time, in order to enhance usability (Bohmer & Bauer, 2010; Lowe et al., 2012).

In this article, we outline and analyse an instance of use of the living lab methodology in the period 2010-14, at the Sekhukhune Living Lab in Kgautswane, South Africa. The living lab approach was used to develop and deploy a context-based ICT4D solution, as part of a larger ICT4D initiative spearheaded by the South African arm of SAP Research, a research entity established by German-based international software and systems developer SAP. Our particular contribution to the study, which we contributed on behalf of the University of South Africa (UNISA) School of Computing, was alignment of the living lab approach to context-awareness, usability and sustainability of the ICT4D intervention.

This article provides the conceptual and practical context for the living lab deployment in Kgautswane, explaining the components of the living lab approach and context-aware computing. We then explain how the living lab approach and context-aware computing were deployed in the Kgautswane's Sekhukhune Living Lab, with particular focus on the evaluation of the initiative, conducted between June 2012 and December 2013. As explained in the concluding section, it was our finding that the living lab approach was effective, with the ICT4D solution proving to be usable, acceptable and sustainable for the users who were engaged by the living lab intervention. Through the use of the living lab methodology, environmental factors and challenges within the deployment environment of the solution were effectively utilised as opportunities, and were contextualised to ensure deployment of as sustainable a solution as possible.

2. The living lab methodology

Rural areas in developing-world countries such as South Africa are often characterised by a lack of adequate infrastructure and adequate public services, for example, poor roads, limited health facilities, and unreliable electricity (Thompson & Walsham, 2010). These issues impact negatively on the socio-economic development of communities and aggravate additional challenges such as the spread of preventable diseases, low levels of educational attainment, and long, cumbersome travel to access facilities.

Several ICT4D interventions that leverage the high penetration of mobile phones in rural areas have been implemented and proven to help remote communities overcome some of these challenges (Aker & Mbiti, 2010; Asongu, 2013; Thompson & Walsham, 2010). ICTs, and specifically mobile ICTs, can provide seamless access to information, even to isolated rural communities, which in turn can empower rural communities and people in their development, drive innovation, and provide solutions for many socio-economic problems (Asongu, 2013).

Mobile-phone-based ICT4D interventions that have had positive impacts on the lives of rural people in the developing world include (Asongu, 2013; Thompson & Walsham, 2010):

- financial services, such as M-Pesa developed in Kenya;
- health services, such as the BBC Ebola WhatsApp service that provided up-to-date information on Ebola in English and French (BBC, 2014); and

- agricultural services, such as those in India using SMS to send useful information, e.g., on weather patterns, to farmers.

Irrespective of the reported benefits of some ICT4D tools, many face challenges in terms of acceptance, critical sustainability, scalability and impact. Among other things, ICT4D interventions in rural areas are susceptible to top-down approaches (Etta & Parvyn-Wamahiu, 2003) that undermine success. Friedmann (1992) argues that a bottom-up participatory approach to solving a problem, in close collaboration with communities, is likely to provide better results than the top-down approach. Participatory approaches provide solutions from a community's viewpoint (Smit et al., 2011). The living lab approach is a method that formalises bottom-up principles.

Definition

The term living lab emerged from the "ambient intelligence" (AmI) research context, and more specifically from discussion of experience and application research (EAR) (De Ruyter et al., 2007). The thinking and practice behind the living lab methodology was developed by William Mitchell of the MIT Media Lab and School of Architecture and Planning (ENoLL, 2015). In recent years, the term has been promoted and implemented by the EU, resulting in creation of the European Network of Living Labs (ENoLL). From 2008 to 2010, ENoLL expanded beyond European borders, its mission to support innovation environments for ICT-based products, services, and social innovations, and to facilitate innovation and collaboration between users, industry and research stakeholders (ENoLL, 2015). There are a number of definitions for the term living lab in the literature (Schaffers et al., 2010). We propose that a living lab be understood as follows (EC, 2009):

> A user-centred, open innovation real environment based on a multi-stakeholder partnership (public-private) which enables real-life end users to take an active role in the research, development and innovation process (EC, 2009, p. 50).

This definition has four key dimensions: (1) user-centred, (2) open innovation, (3) multi-stakeholder, and (4) real environment. These can be described as follows (EC, 2009; Smit et al., 2011):

- *User-centred:* Users are not only involved in the experimental living lab phase, but also in the maturity and full deployment of the innovation.
- *Open innovation:* This dimension refers to involvement of stakeholders and expertise from outside the customary limits of an organisation. This paradigm is increasingly important in the current innovation environment, where external sources possess ever-increasing knowledge and resources key to the development of sustainable innovations.
- *Multi-stakeholder:* An element of the open innovation paradigm, a multi-stakeholder approach opens up to external stakeholders and includes them

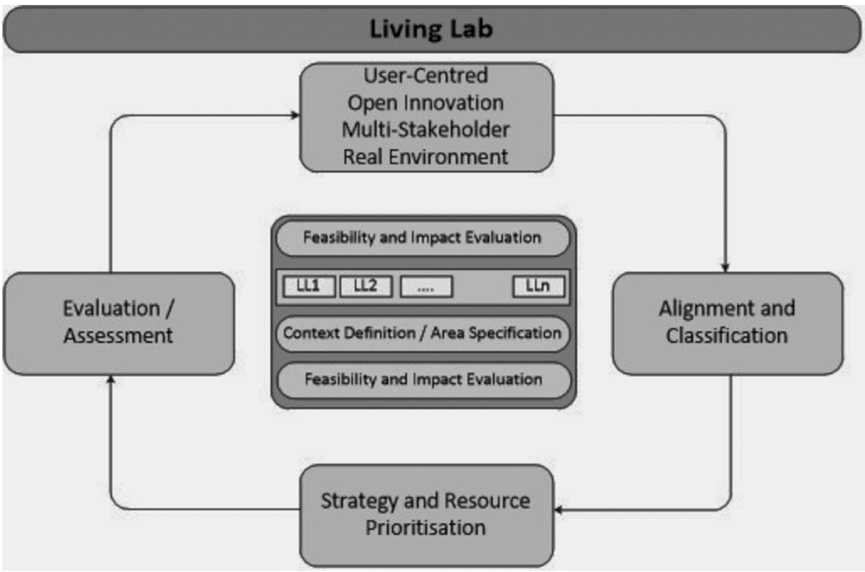
in the innovation process. Stakeholders in the living lab methodology may include users, innovators, policymakers, academic, service providers, donors and sponsors, and researchers.

- *Real environment:* This dimension refers to the conceptualisation, development and deployment of solutions in a real environment, as opposed to a test or laboratory environment.

Implementation

The living lab methodology follows a specific implementation process in order to achieve desired outcomes, as shown in Figure 1 below.

Figure 1: Living lab methodology



Source: Adapted from Smit et al. (2011)

The top box in Figure 1 shows the four dimensions described above (user-centred, open innovation, multi-stakeholder, real environment). And the three other boxes in the outside ring show the other key components of the living lab approach:

- *Alignment and classification:* Details of how the living lab aims to achieve its goals are outlined; stakeholders are identified and approached to be incorporated into the process;
- *Strategy and resource prioritisation:* Resources and stakeholders are assigned roles; activities aimed at achieving the living lab's goals are prioritised; and

- *Evaluation / assessment:* The living lab's ability to deliver on objectives and provide a reliable environment for interventions is evaluated.

The central box in Figure 1 provides more clarity on the core activities that are carried out in a living lab context. All the steps outlined in Figure 1 were carried out for the entire intervention at the Sekhukhune Living Lab, and the development and deployment of the e-procurement application, which is the focus of this article, followed the four dimensions in the top box.

Living labs in South Africa

ENoLL (2015) currently lists two existing and active living labs in South Africa:

- *Sekhukhune Living Lab:* This Living Lab, where the intervention described in this article took place, is located in the Kgautswane community, Sekhukhune District Municipality, Limpopo Province.[1] A number of partners were involved and played critical roles during its establishment as well as in the intervention, including SAP and the Meraka Institute at the Centre for Scientific and Industrial Research (CSIR).
- *Siyakhula Living Lab:* Established in 2006, this Living Lab is located in the Mbashe Municipality, near the Dwesa-Cwebe Nature Reserve, Eastern Cape Province. [2] It is coordinated by Rhodes and Fort Hare Universities through their Departments of Computer Science, with involvement from the universities' Departments of Anthropology, Communication, Education, African Languages, Information Systems, Journalism and Media Studies, and Sociology, thus providing a strong multi-disciplinary flavour. The Lab acts as a field test site for ICT4D interventions from Rhodes, Fort Hare and partners from France, Australia, Brazil, Germany, Italy, Spain, the UK, Greece and Hungary (ENoLL, 2015; Gumbo et al., 2012).

3. Context-aware computing

Incorporating relevant context information during an application's run-time, for the purposes of improving usability of both desktop and mobile applications, is what has been termed "context-aware computing" (Dey, 2001; Lowe et al., 2012; Pettey, 2011; Wagner et al., 2011). Context-aware computing continues to gain attraction, and indications are that context will form a significant part of consumer services in the near future (Pettey, 2011). Context-aware computing that aims to incorporate environmental, technological and other factors during application run-time has a significant influence on the way applications are being developed. For example, context information in the form of user profiles and locations is currently being used to improve usability in applications such as Facebook and Google.

1 See www.c-rural.eu/Southafrica-LivingLab

2 See http://siyakhulall.org

Like the living lab approach, context-aware computing is a relatively new area, with a number of aspects remaining to be clarified. We adopt the definition of "context" provided by Dey (2001), which has been widely cited by other authors (Asif & Krogstie, 2012; Bohmer et al., 2010; Dey, 2001; Lowe et al., 2012; Poulcheria & Costas, 2012):

> Context is any piece of information that can be used to characterise a situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

This definition relies on context being "relevant", which means that any context information that can be derived for use in an application has to be relevant to a specific circumstance or purpose (Asif & Krogstie, 2012; Bohmer et al., 2010; Lowe et al., 2012). "Context information" refers to the set of data elements that constitute or define context (Poulcheria & Costas, 2012). Examples of common context information that developers use to improve usability include location and user preferences (Asif & Krogstie, 2012; Orjuela-Parra et al., 2009).

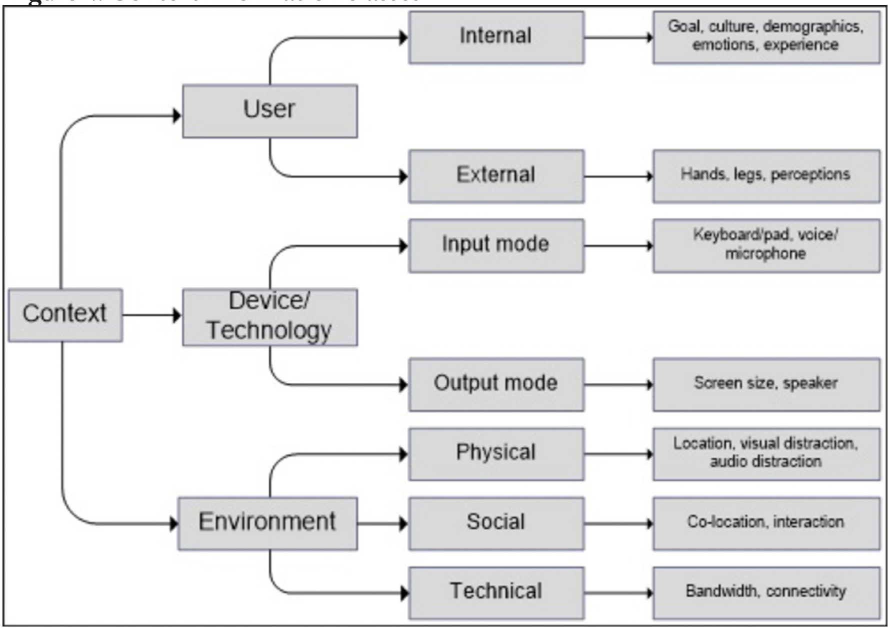
Context information classes

Context information is classified according to the information source, with different authors classifying context information in different ways. We have adopted the three-tier context classification widely utilised by other researchers (Barnard et al., 2007; Coursaris & Kim, 2007; Poulcheria & Costas, 2012):

- *User-specific:* This is context information that is directly related to the actions of the user when in the application, and provides characteristics of the user, for example, whether the user is in motion or stationed in one place. User models (or customer profiles) are usually used as a source of such information in mobile and desktop applications.
- *Device (technology)-specific:* This is context information that is related to the device and technologies being utilised by the user during interaction with an application. For example, is the device touch-screen or otherwise?
- *Environment-specific:* This is context information that is available within the environment in which the user can be found during interaction with an application, for example the bandwidth strength. Environmental context information does not relate to either the user or the device in use.

Figure 2 illustrates the general components of context information in a mobile web application. The figure shows the tree structure for context classes, sub-classes and selected specific examples of context information for each branch.

Figure 2: Context information classes



Acquisition of context information

Literature indicates that context information is acquired through sensors that fall into two broad categories: *physical* and *logical* (Poulcheria & Costas, 2011; Santos et al., 2010). The specific sensors collect pieces of context information and supply the information for interpretation and utilisation in an application (Chin-Chih & Shih-Tsung, 2012; Lowe et al., 2012). *Physical* sensors detect and garner context information through the use of some form of a physical electronic device (Poulcheria & Costas, 2011). A common example of physical context sensors is a GPS sensor. *Logical* sensors use some form of developed software in order to gather context information (Poulcheria & Costas, 2011). An example is the wireless universal resource file (WURFL), which is a widely utilised extensible mark-up language (XML) file that contains specific features and associated real values for nearly all known mobile phones and tablets (Scientiamobile, 2013).

In this study, the living lab approach provided an additional opportunity to acquire information that was contextualised and utilised during the development of the context-aware solution. Section 4 elaborates more on how information collected from the community through the living lab was utilised to adapt the solution.

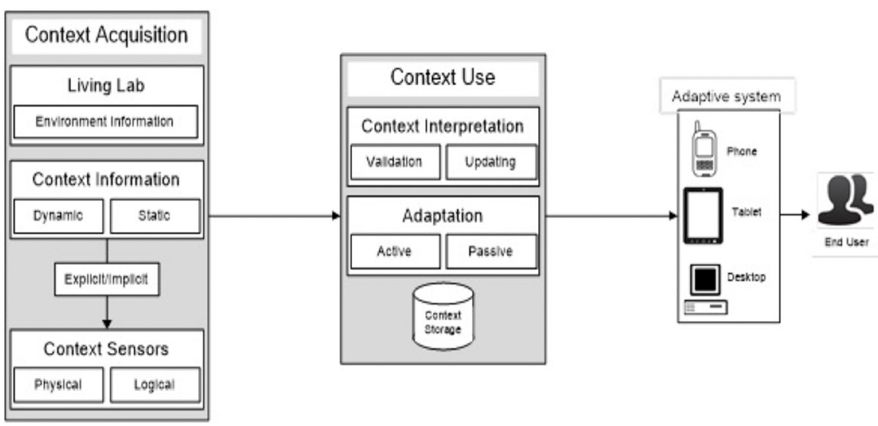
Using context information in applications development

The primary use of context information is to improve usability and user experience in software applications. The following four main types of adaptations can be implemented using determined context in order to improve usability of software applications (Lowe et al., 2012; Orjuela-Parra et al., 2009; Poulcheria & Costas, 2012; Sathish & Pettay, 2006):

- *User interface adaptation*: User interface adaptation refers to the ability of a system to alter the user interface or interaction approach based on the determined user's current context information at any specific point in time.
- *Content adaptation*: Content adaptation refers to the ability of a system to select only relevant content for processing and/or presentation by the application. Based on the determined and available context information, context-aware systems adapt to context in order to meet the user's specific goals for interacting with the system. For example, in most recommender systems, content that the user indicated in his or her preferences is brought first on the interface with an option given to ask for more information or content (see Amazon, n.d.; Takealot, n.d.).
- *Functionality adaptation*: Functionality adaptation refers to the ability of the system to select only relevant functions to be performed by an application based on the available context information.
- *Device adaptation*: Device adaptation is adaptation that performs the above-outlined three adaptations (user interface, content, functionality) to suit the capabilities of the specific device being utilised by the user during interaction.

Figure 3 shows the architecture for a context-aware system with a living lab component, with the living lab providing environmental information that can be interpreted and utilised for adaptation in the solution.

Figure 3: Architecture for a context-aware system



Source: Adapted from Lowe et al. (2012) and Poulcheria and Costas (2012)

4. The living lab ICT4D intervention in Kgautswane

During development of the ICT4D intervention at Sekhukhune Living Lab in Kgautswane, a number of critical initial activities were carried out in order to identify a possible suitable and useful ICT4D solution that could be implemented, and to determine the context for deployment.

Baseline study to determine context and needs

A comprehensive baseline study was conducted as a preliminary step, in order to ascertain the general context of the environment and to determine the critical needs of the community – so that any introduced innovation would have the potential to add value to the users and improve the socio-economic status of the entire community. The baseline study involved in-depth interviews, general observations, and workshops with a sample of 30 community members. The results of the baseline study informed the process of identifying functional requirements for the proposed ICT4D solution.

The baseline results indicated that small-scale retailing was the main economic activity for generating household income in the community, with a small retail shop present about every 500 metres in the community. Considering the challenges that the small-scale shop owners said they faced when conducting business, for example, theft of stock, damage to stock while in transit, and price fluctuations, all of which affect budgeting and planning, it was ascertained that streamlining the retailers' business activities could provide a practical and useful solution for the community. Leveraging the community's high penetration of (lower-end) smartphones, and the availability of mobile network Internet connectivity, a mobile-phone-based, web-based e-procurement solution was proposed, developed and deployed in the community.

The living lab approach provided additional avenues for collecting context information from the community and users. Physical and direct communication that took place during the baseline study enabled the researchers to gather context information, which could have otherwise been cumbersome to determine, for inclusion in the app design process in order to increase the chances that a solution could be suitable and sustainable. Examples of context information that was gathered included the actual levels of socio-economic development in the area, literacy levels, demographics of the intended users, and the actual experiences in the community of using mobile devices and applications. This information was contextualised, interpreted and utilised during the development of the solution in order to improve the applications' suitability to the Kgautswane community environment.

Development of the mobile e-procurement solution

Based on the findings of the baseline research, an e-procurement solution was designed, which could then be implemented and evaluated. The strategic objectives for developing the application were to:

- provide small-scale retailers (users) with a simple, easy-to-use, context-aware mobile e-procurement application that could be used to remotely place stock orders;
- ease challenges small-scale retailers face during the stock ordering; and
- enhance efficiency of supply of necessities to the entire community, and consequently improve the socio-economic status of the community.

The functional requirements and operating context for the proposed application were derived during the aforementioned baseline study. Open source software development tools were utilised to implement the application. The choice of open source was made to ensure the application's compatibility with the variety of other technologies running on the lower-end smartphones widely used in the community. Furthermore, use of open source tools was cost-effective for the development phase and would lower the application's cost of ownership for its intended users. Among the tools utilised for development of the application were: the Ruby on Rails framework, MySQL database management system (DBMS), PhP, Java, and Apache Geronimo.

Functionality of the application

Users of the application were able to access the mobile, web-based e-procurement application on any mobile browser such as Opera Mini or a proprietary mobile phone browser. The application enabled registered users to login and navigate through an online and up-to-date supplier product catalogue. The application interfaced with the suppliers' stock management system in the backend (providing up-to-date details on stock, prices, and availability), and an administration web interface was implemented for conducting system administration tasks. Stock suppliers were involved in the study as partners to the living lab.

During ordering, real-time pricing, stock availability and total cost to be paid for the quantities of selected items were displayed, which enabled retailers to budget stock purchases beforehand, without needing to travel long distances to suppliers' premises. The application also enabled collaborative ordering in which a number of the small-scale retailers could place orders weekly and the supplier could make a bulk delivery of all orders for a particular week to the community, saving the retailers' time and transport expenses and at the same time benefitting the suppliers, who could gain competitive advantage and bigger sales volumes.

Figure 4 shows the main user interface of the mobile e-procurement application implemented in Kgautswane, featuring the (i) main menu, (ii) product catalogue display, and (iii) order confirmation form pages.

Figure 4: Mobile e-procurement application interface

(i) (ii) (iii)

Factoring in usability considerations and context of use

The following features of the application were implemented and adapted to improve usability based on the determined specific classes of context (as per the context information classes outlined above in Figure 2). The basis of the adaptations was context obtained from the results of the baseline study within the living lab.

- *Look and feel:* The application's interface was developed to match the look and feel of the lower-end-smartphone menu items that were found to be popular among the users during the baseline study. A minimal grid design for the main menu was used for the interface, with all of the system's functionalities presented on the main screen upon successful log in (Figure 4). (During evaluation, it was found that this feature eased navigation of the application, allowing use even for users with little experience.)
- *Terminology and icons:* Because of the low literacy levels of the participants (as identified by the baseline study), simple terminology and meaningful icons were utilised for the system's functions. Furthermore, because the majority of the users were unbanked and had no credit cards, the application did not include an online payment module. Payment for purchases took place via cash on delivery method. (Evaluation results showed that these considerations improved the system's learnability and effectiveness, and user trust in the system.)
- *Catalogue display:* An easy-to-navigate, graphical product catalogue was implemented to assist users in recognising the products rather than having to spend time reading product information. The screen display also aimed to avoid cluttering the small device screen: an accordion view and tabbed designs were incorporated during development and run-time in order to achieve this goal.
- *Steps to complete the order process, and user input during ordering:* The application

supplanted the six steps involved in the traditional stock replenishment process, by requiring only two main steps after successful login. The first step involved perusing the product catalogue and selecting items for order; the second step involved confirmation and submission of the order. Received and aggregated orders were organised by the supplier, and collection of the orders took place weekly at a central delivery point. (This proved to require little effort from the user to effectively utilise the system for ordering, and users showed great satisfaction with use of this system to perform online remote ordering.)

- *Network connectivity:* Due to the absence of high-speed fourth generation (4G) mobile Internet connectivity in the community, the application was designed to respond (accordingly and favourably) to the network connectivity fluctuation challenges synonymous with the area. For example, in some instances during run-time images were replaced with text in order to improve the speed of the application in times of limited connectivity speed.

The living lab enabled determination and defining of community context, and usability considerations were tightly coupled to the identified context of the community and incorporated into the application in order to improve the potential sustainability of the application. Learning and validating mechanisms were implemented within the application to ensure that during run-time the context could be validated and necessary changes to context information could be captured and utilised. This mechanism worked as a feedback loop through which up-to-date context information was continuously collected from the run-time environment, including users' profiles, bandwidth variations, purchasing history, and updated in the system.

5. Evaluation of the intervention

The core element of our research was a usability evaluation of the intervention, aimed at determining the usefulness of the context-based solution that had been implemented via the living lab methodology. We also conducted an impact assessment that looked at the effects the intervention had on the whole community, i.e., the degree to which the application addressed social-economic challenges in the community.

Usability evaluation

According to standard ISO9241-11, usability is a process-oriented standard that states that a piece of software or system is usable when it allows the user to perform tasks effectively, efficiently and with satisfaction, in a specified context of use (Min, Li, & Zhong, 2009; Tullis & Albert, 2008). Thus, the standard consists of three elements:

- *Effectiveness:* The accuracy and completeness with which specified users achieve specified goals in a particular environment;
- *Efficiency:* The extent to which a software product enables tasks to be

performed in a quick, effective and economical manner; and
- *Satisfaction:* The degree to which a software product gives contentment or satisfies the user.

Our usability evaluation consisted of both a heuristic evaluation and usability testing (Min & Li, 2009; Min et al., 2009; Sharp et al., 2007). The heuristic evaluation was carried out by eight experts in mobile software development and usability, who identified the application's usability challenges prior to the usability testing. The feedback from the heuristic evaluation was utilised to improve and address any shortfalls in the system. The data collection tools for the usability testing consisted of a written questionnaire, observations, task performance measures involving 30 evaluation participants (users of the application, i.e., small-scale retailers). The 30 usability evaluation participants interacted with the application and completed the questionnaire over a period of five months, from June to October 2013. (Use of the system began before the evaluation.)

Impact assessment

The impact assessment was conducted over a period of 18 months, from June 2012 to December 2013, at times running in parallel, between June and October 2013, to the usability evaluation. It was aimed at assessing influences of the intervention in the community that went beyond the intervention's direct objectives. The following dimensions were assessed:
- *Economic and financial management:* This dimension aimed at evaluating the application's impact on growth in the sustainability of businesses in the community, e.g., growth in the retailers' ability to identify opportunities and grow existing businesses.
- *Information dissemination and access:* This dimension aimed at determining whether the application improved access to product information.
- *Organisational management:* This dimension aimed at evaluating the impact on the retailers' ability to organise themselves, learn from each other, and grow.

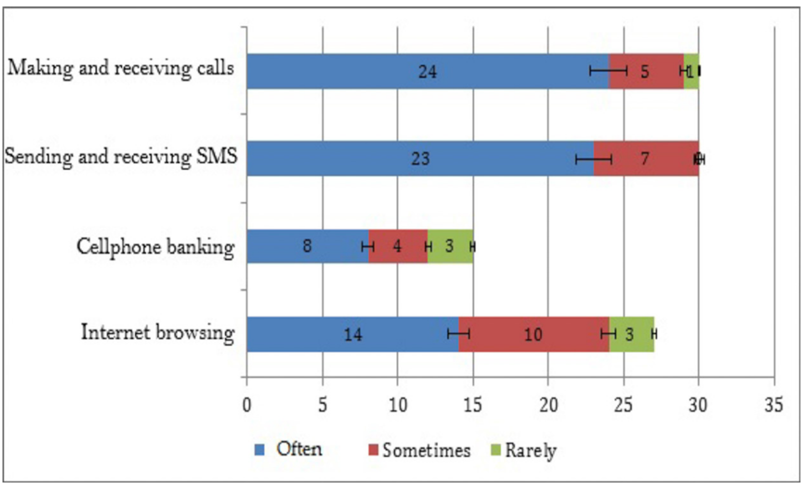
The impact assessment was conducted via interviews administered to a random sample of 10 households and to the same 30 small-scale retailers who participated in the usability evaluation. The retailers also completed an evaluation questionnaire. Two questionnaires were developed for the impact assessment: one to guide the interviews with the households and the second one to be completed by the 30 small-scale traders during assessment of each criterion. The second questionnaire, which was completed by the 30 participants, was included as part of the usability evaluation questionnaire. In addition, general observations of how things were working in the community, and self-reported metrics such as general comments obtained from the usability evaluation, were utilised to augment the impact assessment data (Tullis & Albert, 2013).

Usability evaluation results

The usability evaluation participants, recruited purposively on the basis of their having used the application, all indicated that they owned a smartphone. The majority of the participants owned low-cost, lower-end smartphones, with Internet browsing capability, from manufacturers such as Nokia, HTC, Huawei, Samsung, LG and Blackberry. A few indicated that they owned more complex mobile phones such as HTC Wildfire and Blackberry 9800.

Participants' existing experience in use of smartphones was assessed by analysing reported main uses. Figure 5 summarises the main uses reported by the 30 evaluation participants. The findings suggested that the sample owned suitable devices and could be presumed to have enough knowledge in using mobile phones to effectively use the e-procurement application and provide useful feedback during the evaluation.

Figure 5: Main uses of mobile phones by the usability evaluation participants (n = 30)



The users were asked to evaluate six usability dimensions of the application – navigation, learnability, efficiency, help provided, layout, and design – as well as "overall reaction". Figure 6 shows the results. The numerical scores were collected by participants selecting an option on a five-point Likert scale for each set of questions addressing each single dimension.

Figure 6: Usability ratings (n = 30)

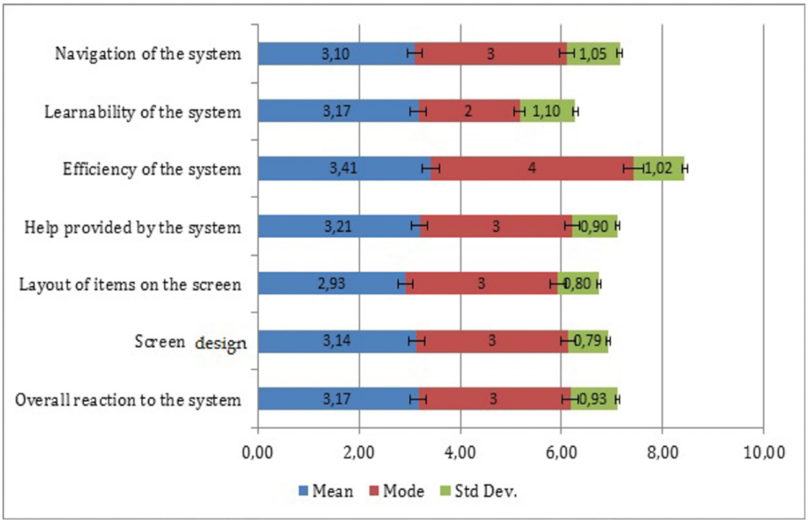


Figure 6 shows the mean (i.e., average) mode and standard deviation of the ratings for each aspect of usability that was evaluated. According to Tullis and Albert (2013), a usability score of less than 60% is considered poor, and a score between 60% to 80% is considered good, while a score above 80% is considered very good. The usability factors of the mobile e-procurement application scored "good" because the average ratings were between 58% and 68% (2.9 to 3.4). Most of the participants' rating values were very close to the mean, as indicated by the modes (frequency value) and a relatively small standard deviation. This means that participants had similar feelings about the usability aspects that were evaluated.

Impact assessment results

The following findings emerged from the impact assessment section of the questionnaire that the small-scale retailers completed:

Economic and financial management

Results from the impact assessment section of the questionnaire administered to the small-scale retailers indicated that 73% [n=22] of the 30 small-scale retailers reported that they had experienced an increase in customers visiting their shops since the beginning of the intervention. (The households interviewed indicated that there was improved confidence in finding various items at the small shops, a suggestion that was corroborated by the shop owners). Furthermore, there were clear indications of an increase in the volume of stock that the small-scale retailers ordered.

All 30 retailers stated that they were able to save on travelling costs because they could order stock remotely, and that some of these savings were used to increase the volume of orders. A smaller number of retailers, however, did say that for certain specific items, they still needed to travel to supplier premises in order to procure. Examples of stock for which retailers needed to travel were goods that sold quickly and thus needed to be replaced frequently, and items not supplied by the suppliers used in the project. (Suppliers who engaged in the e-procurement intervention made deliveries once a week.)

Information dissemination and access

Almost all retailers stated that the application helped them obtain items more easily and efficiently than through the traditional catalogues that used to be distributed in the community. A few retailers, however, mentioned that they still needed the traditional catalogues to complement their understanding and decision making, because traditional catalogues were more detailed than the mobile phone application catalogue. In addition, the small-scale retailers indicated that the paper catalogue was shared with customers, allowing the retailers to get input on other products customers may want stocked in the small shops. Thus, in general, it was concluded that the application was useful in disseminating timely product information to the retailers, though paper catalogues were still useful to both the retailers and the community.

Organisational management

While only 43% [n=13] of the retailers indicated that they were currently collaborating with other shops and exchanged business information, 23% [n=7] of the respondents indicated that they sometimes bought stock, via the application, in collaboration with other shop owners.

6. Conclusions

Our usability evaluation and impact assessment found that the living lab approach was effective in improving acceptance, usability and sustainability of an ICT4D application. The living lab allowed for broad learning of the context of use for the application, via direct interaction between intervention implementation teams (partners, stakeholders), users, and the users' environment. The living lab also allowed for context-based adaptation of the usability elements of the application, thus enhancing the application's effectiveness, efficiency and user satisfaction.

At a broader socio-economic level it was found that the savings the participating retailers made from cost reductions associated with the streamlined stock replenishment process enabled them to order more stock from the suppliers, helping them serve the Kgautswane community better. And the finding that 23% of the participating retailers had begun to cooperate with other retailers for cooperative use of the e-procurement application represented a potentially significant impact, because no evidence had been found, prior to deployment of the intervention, of efforts to form cooperatives or engage in group bulk-purchasing. Our findings thus suggest that adoption of a living lab approach can contribute to ensuring that an ICT4D intervention effectively addresses critical, tangible challenges that people face in rural areas of the developing world.

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