Research Article

Morphological Analysis: A Method for Selecting ICT Applications in South African Government Service Delivery

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Abstract

Successful ICT projects depend on complex, interrelated sociological and technical factors for which there are no standard theoretical framework for prediction or analysis. Morphological analysis is a problem-solving method for defining, linking, and evaluating problem spaces that are inherently nonquantitative. In this article, we show how our research team created a telephony impact model using morphological analysis to strategically select a national ICT telephony project for South Africa from several possibilities, based on non-quantitative, socio-technical criteria. The telephony impact model provides a rigorous framework to the diagnostic and planning phases of our action research that is a vast improvement over "best practices" guidelines. We believe that this approach takes a first step toward predictive models and theories for ICT deployment.

I. Introduction

1.1 ICTD and Action Research

Information communication technology (ICT) applications hold great promise in developing regions. However, it is hard to predict how an ICT carefully conceived in a laboratory will hold up once it is implemented in a developing region environment where assorted challenges—technical (e.g., humidity, heat, power outages, dust, bumpy roads, software infection, remote management), environmental (e.g., transportation, safety, customs, shipping, local manufacturing, danger, natural disasters), and cultural (e.g., staff, training, theft, corruption)—can mean immediate or eventual failure (Brewer et al., 2006). Successful information communication technology for development (ICTD) projects, on the other hand, can make a huge impact in people's health, their ability to find work or to make change in their community, and their overall income (Brewer et al., 2005).

Finding a fit between technology and user needs requires extensive knowledge of the relevant stakeholders, partnership with the community, evaluation metrics, and a plan for sustainability (Brewer et al., 2006; Dagron, 2001; Tongia & Subrahmanian, 2006). Most ICTD researchers begin with field assessments, site visits, interviews, and pilot studies to determine the socio-technical fit of a proposed project. ICT projects may also rely heavily on the successes and failures of previous projects to avoid common pitfalls. Best practices, which synthesize lessons learned from previous projects and which may even offer some predictors of success,

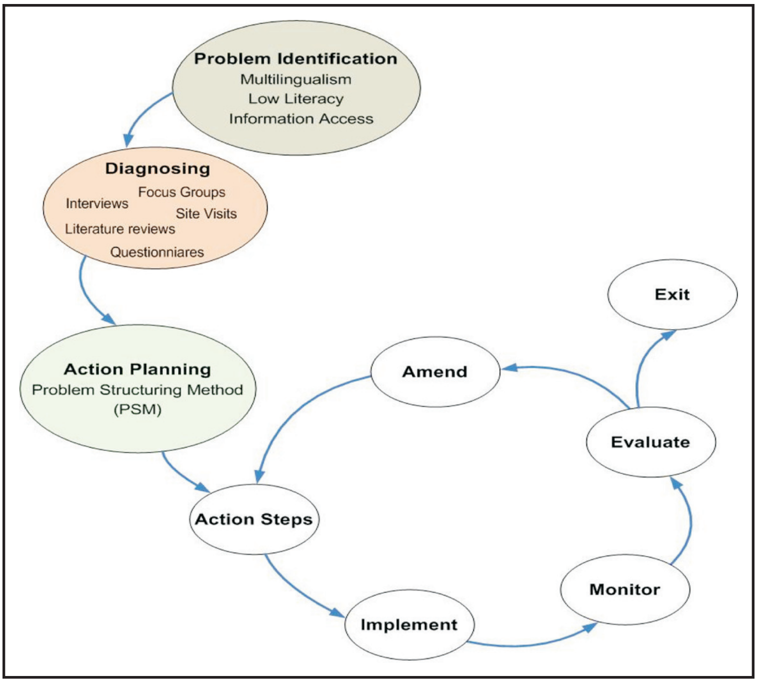

Figure 1. The Action Research Cycle highlights initial planning phases and features the specific methods used in the South African telephony project. Adapted from McCay & Marshall (2001).

may also guide ICTD researchers in the initial phases of project planning (cf., Maier & Nair-Reichart, 2007; Rothschild, 2008). However, the ICTD community has been challenged recently to move beyond simple descriptions to rigorous analysis: to put forth theories and models that can define the problem space and begin to predict results (cf., Heeks, 2006; Raiti, 2006).

Researchers have responded by applying to existing projects of ICTD the frameworks and theories adapted from the fields of social science (Bailur, 2006), development (Duncombe, 2006), media and communication (Raiti, 2006), and design (Tongia & Subrahmanian, 2006). Stakeholder theory, for example, offers practical strategies on how to manage all the stakeholders' conflicting needs, which is a critical, often unmentioned part of project planning in developing regions (Bailur, 2006). Stakeholder theory is especially useful for analyzing the use and impact of an existing project. Its utility in project selection, however, is less understood.

Duncombe's work (2006) addresses poverty and development in a broader sense than does most ICTD literature by showing how ICT projects can be understood in a *livelihoods framework*. The livelihoods framework assumes that groups and individuals use their own livelihood strategies within a context of vulnerability, and it analyzes ICTD efforts in the context of existing strategies. Duncombe claims that the livelihoods framework can be applied at any stage of an existing project from initial planning to impact evaluation, and, possibly, even when a project is first being considered. To our knowledge, use of the livelihoods framework as a means for selecting ICTD projects, however, has not been explored.

Another proposal frames ICTD projects within design theory, wherein each project is a *wicked problem* that demands an iterative, transparent approach to managing stakeholder needs throughout its planning and implementation (Tongia & Subrahmanian, 2006). The iterative, collaborative approach proposed by Tongia and Subrahmanian is reminiscent of *collaborative action research,* a process-oriented model used widely in the social sciences, and in particular, in information science. The action researcher assumes that a situation (such as abject poverty and lack of access to health and human services) is unacceptable and then seeks to understand this situation by introducing change, such as an ICTD project, and observing the effects (Baskerville, 1999). The action researcher does this, as illustrated in Figure 1, by engaging in an iterative cycle consisting of five phases: diagnosis, action planning, action taking, assessment, and learning (Davison, Martinsons, & Kock, 2004).

Action research breaks from the scientific method by involving the researcher as a part of the research and by relying heavily on qualitative data to understand the frame of reference and the underlying social values of the subjects. Like ICTD literature, action research (a) assumes a complex and multivariate social setting, (b) attempts to solve practical problems and expand scientific knowledge at the same time, and (c) includes the subjects and the researcher as collaborators. Unlike ICTD projects, which may adopt a cyclical, collaborative method out of pragmatism, action research fundamentally seeks to understand change processes in social systems (Baskerville, 1999). Action research and ICTD efforts also share the challenge of generalization through replication: Each project can never be replicated, as it is an intervention into a unique social setting. Action researchers instead consider results to be generalizable, if they are shown to be valid (in accordance with the initial hypothesis). In addition, action research is particularly suited to studying the effects of technology on humans (Baskerville & Harper, 1996), and offers a practical approach for the initial phases of a project, as well as its implementation and evaluation. For all of the above reasons, action research appears to offer ICTD researchers a theoretical basis for a system many are already using in the field.

1.2 Our Approach

We are particularly interested in the most initial phase of an ICTD project: the selection of a single ICT application from potential candidates. As such, we will leave open the larger debate of how action research might inform the burgeoning efforts to bring more rigor to the field of ICTD. Instead, we accept the iterative model of action research, but propose a nonquantitative problem structuring method for the action-planning phase, which entails the selection of a particular project, along with goals and plans for implementation. ICTD project selection involves multiple stakeholders with conflicting interests, relies on a deep understanding of complex social and technical factors, and results in a decision that will have a tremendous impact on the human and technical resources involved. With the exception of the livelihoods framework (Duncombe, 2006), theoretical models for ICTD have neglected to inform the project selection phase of project implementation. We will show how problem structuring methods (PSMs), when used during the initial phases of the action research model, can take complex social and technical factors as input and output a transparent, modifiable model that can guide researchers and other stakeholders to select an ICTD project that will most likely meet their needs. We believe that PSMs, such as morphological analysis (MA), which we discuss in this article, offer a replicable, rigorous method for ICTD project selection. Furthermore, this approach defines and brings transparency to the complex space of user needs, environmental concerns, technology inputs, and goals.

The Human Language Technologies group at the Meraka Institute in South Africa was tasked with creating an automated telephony system that would support government service delivery and have a great impact on citizens. Given this objective, our greatest challenge was to select a single telephony project from a wide range of domains and applications. Should the telephony system give the hours of nearby government offices? Should it allow an IsiZulu[1] speaker to check on the status of an application for a birth certificate? The research group developed a PSM model, using morphological analysis to facilitate the selection of an appropriate telephony project by allowing scientists, policy makers, and community members to define and analyze the potential impact and risks of multiple speech-based telephony applications in South Africa. The model focused our limited resources on those applications that would have the most impact by revealing weaknesses or gaps in the early phases of the project. Furthermore, it was invaluable for communicating with stakeholders, because it could easily be altered with new or modified input and it made all tradeoffs transparent. We believe that PSMs are extremely useful in the selection and early planning of ICTD projects, and their incorporation into the action research model can contribute to formulating predictive theories in the ICTD field.

This article (in Section 2) first presents PSMs, and in particular, morphological analysis, a nonquantitative PSM that integrates multiple nonquantitative variables into a logical framework (De Waal & Ritchey, 2007). It then provides the traditional data-gathering methods (key informant interviews, site visits, focus groups, pilot studies) that we applied to understand current South African health and government service delivery (Section 3). When these methods were combined with the MA model, we were able to evaluate and compare the potential telephony projects for their staying power, potential for uptake, ability to reach vulnerable populations, and other important factors (Section 4). Finally, we

1. Zulu, or IsiZulu, is an official language of South Africa and one of the most widely spoken languages of that country.

conclude by highlighting the strengths of PSMs for strategic decision-making and the theoretical gap that this approach fills in the field of ICTD (Section 5).

2. Problem Structuring Methods (PSMs)

Predicting the success of an ICTD project depends on complex, interrelated social and technological factors. Furthermore, decisions around these problems cannot be measured monetarily and offer no obvious, alternative ranking system. For these reasons, we agree with Tongia and Subrahmanian (2006) that ICTD design is a wicked problem, a term introduced by Rittel and Webber (1973) to describe complex social problems that are multidimensional and nonquantifiable. The multidimensional aspect makes it difficult to solve one part of the problem without affecting another part of the problem. The nonquantitative aspect of the problem makes it difficult to solve with traditional quantitative methods, as the problem cannot be described mathematically. Rittel and Webber defined wicked problems in the context of social planning with the following 10 characteristics (p. 161):

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule, because the solution to a wicked problem is not unique.
3. Solutions to wicked problems are not true or false, but better or worse.
4. There is no immediate or ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation," because there is no opportunity to learn by trial and error, as every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The planner has no right to be wrong (planners are liable for the consequences of the actions they generate).

Nonquantified problem structuring methods (PSMs) are alternatives to mathematical modeling that were developed to address complex problem spaces, such as socio-technical systems. PSMs facilitate group interaction and provide a transparent framework for finding consensus on the problem definition, which is the major challenge with wicked problems (Rosenhead, 1996). Some commonly used PSMs are hypergame analysis, interactive planning, metagame analysis, robustness analysis, soft systems methodology (SSM), strategic choice approach (SCA), and strategic options development and analysis (SODA). A summary of these methods can be found in Rosenhead.

Ritchey (2006) defines two general classification approaches for PSMs. The first approach structures the problem space around its *hierarchical* relationships. The second approach, called *typological* or *morphological* methods, structures the problem space according to *logical* relationships. Morphological analysis (MA) was developed by Fritz Zwickey at the California Institute of Technology in the 1930s and 1940s with the specific aim of constructing a parameter space and linking parameters by way of logical relationships, rather than by causal relationships (Ritchey, 2006). Zwickey applied MA to the classification of astrophysical objects (1948) and to rocket propulsion systems (1947). MA modeling was carried out by hand at the time, which limited its application to unrealistically small problem spaces. Since supporting software for MA has been developed, it has become possible to create larger fields and to perform inferencing in real time. Researchers in the United States and Europe have since applied MA to policy analysis, futures studies (Rhyne, 1981, 1995a, 1995b; Coyle & McGlone, 1995; Coyle & Yong, 1996), and disaster preparedness (Ritchey & Stenström, 2002).

All PSMs are well equipped to model data with strong socio-technical characteristics. Specifically, we found the logical approach of MA to be particularly well suited to the problem of selecting a telephony application for government service delivery in South Africa because the relationships between the relevant social and technical factors (e.g., user requirements, existing infrastructure, economic impact) are interlinked and overlapping, which makes causal or hierarchical structures difficult to define (De Waal & Ritchey, 2007). In a logical approach, specifically with the MA method, we need only specify the coexistence or consistency between each factor to model the problem. We describe our data and method for modeling the potential telephony projects for South African government service delivery in more detail in the following section.

3. Automated Telephony Service in South Africa

In 2006, the National Language Service (NLS) of the Department of Arts and Culture (DAC) in South Africa sponsored the Human Language Technology (HLT) Research Group to develop a multilingual, telephone-based system that would enable callers to access South African government services in the user's choice of any of the 11 official languages through a simple speech-oriented interface suitable for users with limited or no literacy. This system was termed *LWAZI,* which comes from the word for *knowledge* in IsiZulu.

One goal of LWAZI was the creation of key language technologies, including automatic speech recognition (ASR) and text-to-speech (TTS), in the 11 languages. Another goal was to create an automated telephony application for these technologies that would be both sustainable and visible, as well as make a positive impact in the lives of a large number of South Africans. The automated telephony service would be powered by a multilingual spoken dialog system (SDS), also known as an interactive voice response (IVR) system, that plays either recorded or synthesized speech as output and accepts either speech or button (touch-tone) presses as input. SDS systems are well established in the developed world and used in a variety of applications, such as buying airline tickets, checking bank balances, or retrieving messages. However, automated telephony services can also be useful in delivering low-cost, health-related interventions. For example, Migneault et al. (2006) showed that such services could positively influence a person's health behavior by modifying behavioral risk factors for disease, such as smoking and diet, and by promoting disease-related self-care behaviors, such as reminders for taking medications and attending scheduled clinical visits.

Access to information about entitled services alone has been found to improve the delivery of health and social services to resource-poor populations (Pandey, Sehgal, Riboud, Levine, & Goyal, 2007). In South Africa, however, multilingualism and illiteracy are both formidable barriers to access. Currently, the national government of South Africa disseminates most of its messages to the public in English, even though 47% of its citizens do not have a working knowledge of this language and therefore do not understand these messages (Heugh, 2007). There is no *lingua franca* for South Africa. Instead, several languages are dominant, depending on the region. Speakers of the two most widely used languages, IsiZulu and IsiXhosa, which are considered mutually intelligible, constituted only 41% of the population in 2001.

Even within a given linguistic region, low rates of literacy hinder the government's ability to inform citizens. In 2000, of all South Africans that constituted the "African" group of people (73.8%), only half could read and write (Gordon, 2005). In 2001, over 10% of the country's population had never been to school (Statistics South Africa, 2007). Pamphlets, newspapers, bulletin boards, flyers, and signs with the hours of operation of police stations and clinics then are not decipherable to many of the people who could most benefit from these services.

Throughout the country, however, there is extensive use and ownership of mobile phones. From 2001 to 2007, the percentage of households in South Africa with a mobile phone in working order more than doubled, growing from 32.3% to 72.9% (Statistics South Africa, 2007). Landline use has simultaneously dropped from 24.4% in 2001 to 18.6% in 2007. Given the high rate of mobile phone penetration, telephony was an ideal platform for delivering services to a wide cross-section of the population. Automated telephony services can cheaply and equitably transcend the language and literacy barriers. A further advantage of telephone-based services is the relatively low levels of infrastructure and user sophistication needed to operate such services. Useful services can be delivered by SDS technology to citizens equipped with only a basic telephone and require no more than the ability to understand and respond to spoken commands (Sherwani et al., 2007; Plauché, Nallasamy, Pal, Wooters, & Ramachandran, 2006). Such a verbal interface is thought to be highly appropriate in developing countries like South Africa, where there

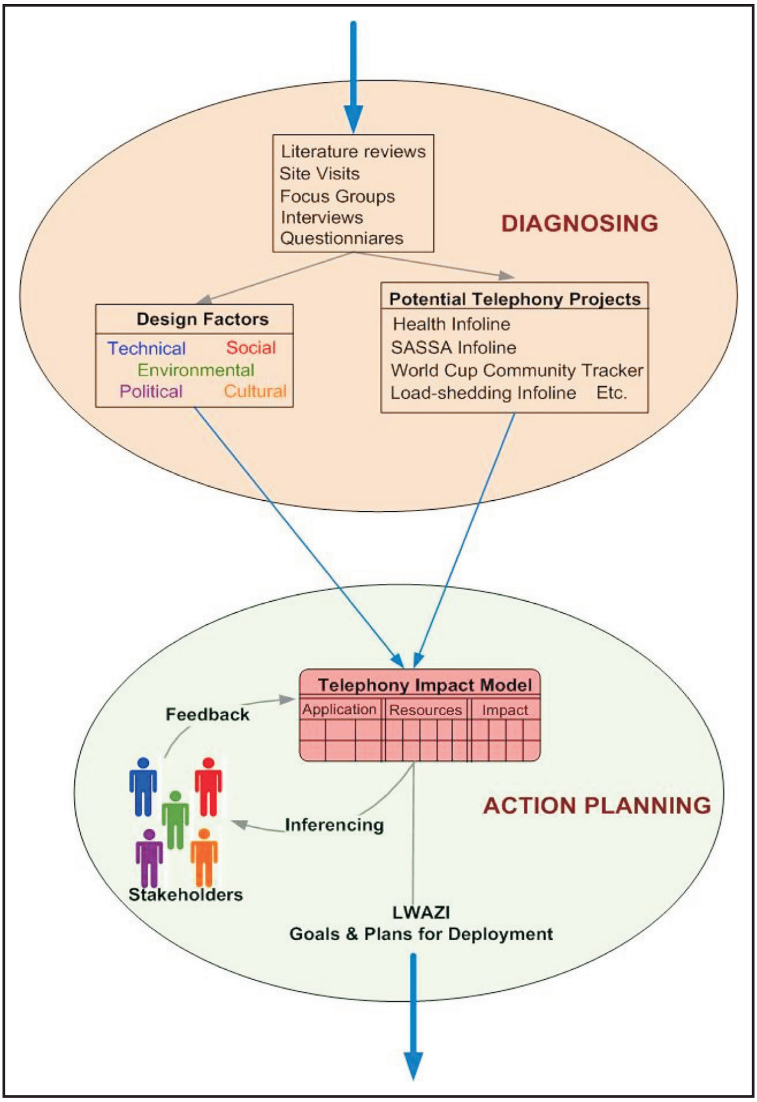

Figure 2. Diagnosing to action planning for the LWAZI project. (See Figure 1 for the complete action research cycle.)

This experience illustrated the importance that a single factor can have in planning a successful deployment. For LWAZI, we wanted to use a systematic method that would allow us to consider all socio-technical factors and then select an ICT project that would likely have the most success. Our approach followed the overall action research cycle (Figure 1), but also included the following innovation: A PSM would be used to model the potential impact of several telephony applications as a critical component of the planning phase of the cycle (Figure 2).

During the diagnosing phase, we used traditional techniques (e.g., site visits and interviews) to understand target users, technical requirements, quality of partnerships, and the greater context of government service delivery in South Africa. From our diagnostic fieldwork emerged (a) the important design factors for telephony in South Africa and (b) a list of potential telephony projects. During the action planning phase, we combined the design factors and the potential telephony projects into a telephony impact model (using a PSM) that allowed active inferencing and that was used during a series of workshops with a subset of relevant stakeholders to compare the proposed projects. After much discussion during the workshops, the stakeholders selected a domain and particular project to deploy for LWAZI and also specified the goals and plans for deployment.

In the following sections, we briefly describe the diagnostic fieldwork we conducted throughout the country, including data collected during interviews, site visits, questionnaires, and focus groups (Section 3.1). Then, we provide a short list of the proposed telephony projects (Section 3.2), along with the design factors and other factors critical to speech-

is a strong oral tradition and a growing use of mobile phones (ITU, 2003).

Our goal was to develop an automated telephony system that would continue to make a significant social impact long after its initial deployment. A recent deployment of an automated health infoline in Botswana for caregivers of children with HIV taught us that, although a telephony-based hotline was considered usable and helpful by both caregivers and nurses, the uptake of the project ultimately depended on whether the line was free to callers (Grover, Plauché, Barnard, & Kunn, 2009).

based ICT applications that emerged from this fieldwork (Section 3.3). Following that, we describe how we built a decision support model to aid in the evaluation of our shortlist of potential applications for automated telephony technology in South African government and health service delivery (Section 4).

3.1 Field Research

From February to May 2008, our team conducted an extensive investigation into the potential applications for automated telephony in South Africa. The investigation used site visits, surveys, and interviews to identify possible automated telephony projects and potential partners for their implementation. The assessment focused on how automated telephony technology could support current government service delivery for individuals throughout the country and make a measurable, positive impact in their daily lives. We investigated the following factors:

- Types of information needed by communities
- Sources for this information
- Relevant cultural and social factors (gender, age, geography, etc.)
- Technological sophistication of users (literacy, computer literacy, etc.)
- Potential for user uptake
- Suitability of the technology
- Sustainability of the technology

Beginning in the Gauteng province, the administrative seat of the national government, we held meetings with seven research groups at the CSIR (Council for Scientific and Industrial Research), three nonprofits in health and employment, and six government departments. All groups were currently working on ICT projects. In addition, we held a workshop with a community activist group in the KwaZulu Natal district, where we discussed how telephony, and ICT more generally, could better suit the needs of rural and disadvantaged people, especially those with disabilities. We found that little was known about language technologies and their potential. Although these technologies transcend language and literacy barriers, their widespread use as assistive tools, for example, is limited by affordability and the lack of electricity in remote areas. Most agreed that both technology and policy are needed to support the needs of disadvantaged people. Overall, these meetings resulted in many ideas for automated telephony projects, but there was mixed interest in partnering with us for their implementation.

Call centers were another target of our investigation, as language technologies can easily support multilingual directory assistance. Site visits, key informant interviews, observations, and focus group discussions with managers and telephone agents were arranged at three call centers in Gauteng province. One call center handled the customer service for municipal electricity delivery, including all queries relating to scheduled power outages. Another call center was run by a national nonprofit as a free emergency and support line for children, especially those who were homeless. The third call center operated a free hotline for questions about national government services, such as how to start a small business or where to get a birth certificate. The site visits revealed the need for local information and multilingual support. Most of the calls received at national hotlines were questions from callers who wished to know where their nearest clinic or social services office was located. In all of the call centers we visited, agents informally routed calls among the multilingual staff based on the language of the caller. In the cases where an automated SDS was in place, we noticed that many callers were often confused by the SDS, because it had not been designed for novice and multilingual users. We found many possibilities for automated telephony systems to support current call centers, either those run by government or by nonprofits.

We conducted site visits in seven rural villages that each housed a Thusong Service Centre (TSC), a multipurpose government center that represents four years of the government's effort to connect rural citizens to government services. TSCs are one-stop centers that provide integrated services and information to communities close to where potential users live as part of a comprehensive government strategy to better their lives. TSC objectives include improving access, making sure that infrastructure design caters to all vulnerable or marginalized groups, and ensuring that infrastructure is developed in a manner that caters to the needs of service providers. In each of the rural villages, a community survey was administered to a community development worker (CDW) who was often the most knowledgeable member of the community on the topic of citizen access to government. Interviews were conducted with TSC employees and community members.

Overall, we found that both of the rural government programs (TSCs and CDWs) were effective and that the staff and CDWs see the impact of their work daily, despite limited resources. CDWs used their cell phones as a powerful tool for community organizing, raising awareness about entitled services, and following up with citizens. When rural people are uninformed about entitled services, they miss opportunities for economic and social improvement, and they have to travel long distances for government and health services, often at great personal expense. The staff of TSCs and CDWs contributed many ideas for automated telephony projects that would support their efforts to keep rural South Africans informed. In addition, they informed our team about the importance of certain design factors, which will be discussed in more detail in Section 3.3, especially regarding content and language.

3.2 Proposed Telephony Projects

Based on our diagnostic fieldwork, we considered 12 potential telephony projects for South Africa government service delivery. Ideas for telephony applications came from interviews with government or nongovernmental workers, from existing text-based information services, or from observations of government workers involved in outreach and education. Most applications considered were *push* (vs. *pull*) services, where the caller, rather than the automated service, initiated the calls. Some applications pertained to immediate issues, such as the FIFA Soccer World Cup, to be hosted by South Africa in 2010. Others targeted social impact over a longer term, for example, those applications in the domain of education and training. Many of the applications were similar to one another. To demonstrate our method of application selection, we will examine only seven potential applications that illustrate the most variation from one another.

Automated Health Infoline

Callers who need access to health education in their own language navigate this hotline by pressing buttons on the keypad. General health information is provided in clear and accessible language to the caller. The main needs are strong partners in health, local content, and connectivity. When HLT researchers implemented such a system in Botswana, we found that a toll-free telephone number was critical to its success (Grover et al., 2009).

TES Loadshedding Infoline (Electricity Outages)

South Africans regularly experience planned electricity outages (loadshedding) that can affect their travel, their employment, and their access to resources. Callers in the Tshwane municipality could call our automated hotline at Tshwane Electricity Services (TES) and then provide their language preference and suburb using speech. ASR would then interpret caller input and use TTS in the caller's language to provide the updated schedule for planned electricity outages in the given suburb.

SASSA Infoline

Social service grants are a major source of income for many rural South Africans. Callers who live far from their nearest social services office (SASSA) could use touch-tone navigation by phone to hear the hours and nearest locations of the office, as well as eligibility requirements for specific grants in their own language. According to government workers and citizens in rural districts, such a hotline would save callers several trips to the SASSA office, which are costly and time consuming.

2010 World Cup Community Tracker

2010 World Cup Community Tracker is our most inventive idea for an automated telephony system. Modelled on self-tracking tools for individuals to alter their health habits, this community-level self-tracking tool would be used as part of a greater government effort to encourage communities to prepare to host the 2010 World Cup. Community members will call the tracker and use speech and keypad buttons to set community goals in areas of hygiene, crime prevention, event planning, and small business (for example, "Our community will prepare three events by next month"), and then later to report on their achievements. Communities across South Africa compete among one another, with members of the winning communities appearing on a nationally-aired TV show.

Child-Headed Household Infoline

The hundreds of thousands of South African children who are heads of households could use the telephone keypad to access information on grants, foster services, and free education, and perhaps most importantly, to connect to a Childline operator.

This information would be provided in the form of natural voice recordings in the child's language, because the nature of the content requires empathy and trust. The creation of this infoline is high risk, because inaccurate information or a confusing interface could be detrimental for the participating children. ASR would need to be adapted to children's speech, which differs from adult speech in its acoustics (smaller vocal tracts and resonant cavities), as well as in its discourse patterns (choice of words).

Community Development Worker (CDW) Mobilecast

CDWs are a successful effort by the South African government to connect rural citizens to government services. CDWs could use a telephony service as an audio tool for two major activities: broadcasting information about upcoming events and organizing community members to participate. CDWs could send a single message in their own trusted voice to several community members at once. Community members could call the same telephony service to leave audio voice mail for the CDW and to connect to them directly in the case of an emergency.

Sector Education and Training Authority (SETA) Audio Toolkit

At the time of our work, the South African government was piloting a Learnership Events Management Program, for which printed materials (toolkits) had been developed for the program's participating young adults. One technical deployment would allow learners to call an automated phone service for an audio version of these toolkits in their own language. The service could also support pairings between mentors and learners who work in the same industry, but not in the same geographic area.

3.3 Design Factors

In addition to the list of proposed telephony projects, our research and fieldwork across South Africa made us aware of several factors that were critical to the design and development of a telephony project. We discuss these design factors in detail in Section 4.1, as they form the building blocks of the telephony impact model. For now, we merely highlight the factors considered important to our design and development, many of which are well known in ICT literature (cf., Tongia & Subrahmanian, 2006).

A successful telephony service must meet community needs without disrupting current community patterns. For each telephony project, we must ask: What and whose needs does it serve? An ideal application should save time and money, or offer a service for which there is no equivalent. It should pose no risk or perception of risk to a person's privacy, health, or safety. It might serve hundreds of marginalized individuals, or tens of thousands of nonvulnerable citizens. In any case, the choice of language and the source of content are major factors in whether an application is well received in a particular community (Roman & Colle, 2003). This observation was also noted by the staff of rural TSC centers and by CDWs interviewed during our fieldwork.

Part of the decision to deploy a particular telephony project depends on its overall feasibility. We must ask: What resources are available to accomplish this project? Ideally, an ICT project is built on well-tested technology that suits and supports the final application. For example, in cases where the content is dynamically updated (e.g., train schedules or weather), TTS technologies, which can generate speech on the fly, should be used in lieu of prerecorded voice prompts. ICT projects, once deployed, must be maintained by a group or single organization. Success depends greatly on the strength of partnerships with stakeholders that provide skills, governmental support, or trusting relationships with potential users.

A large part of the design and development of a telephony project involves managing the needs of many stakeholder groups, including international and local funding agencies, governmental and nongovernmental agencies, telecommunications companies, researchers, and local champions. Stakeholders may contribute to the design by serving as content providers, advisors, benefactors, or end users. We agree with Tongia and Subrahmanian (2006), who argue that "greater inclusion of stakeholders in the design phase of solutions itself with formal mechanisms for feedback and trade-off elicitations will lead to far greater success in ICT for development than seen today." In the next section, we describe how to create a telephony impact model using morphological analysis (MA), which evaluates the impact of several proposed telephony projects based on a holistic analysis of factors. The model facilitates the inclusion of stakeholders and offers a formal mechanism for their feedback. Stakeholders can dynamically adjust variables and

Table 1. The MA process (Ritchey & Stenström, 2002).

Analysis phase: Define the problem complex in terms of variables and variable values.
Step 1: Identify the dimensions or variables that best define the problem complex or scenario. Each variable is represented in a column of the morphological field.
Step 2: For each variable, define the range of relevant possible values. The values are represented in the rows of the morphological field. The output of this step is illustrated in Figure 4. This step also concludes the analysis phase.
Synthesis phase: Link variables and synthesize an outcome space.
Step 3: Use a cross-consistency matrix to assess the internal consistency by considering only pairs of variable values that are internally consistent.[a]
Step 4: Synthesize an internally consistent outcome space. (MA software assists here by automatically "reducing" the solution space to contain only those solutions whose outcomes do not contain internal contradictions.)
At any stage in the process, revisit particular steps to adjust variables, values, and consistency measures.

a. Internal consistency evaluates the logical, rather than causal relationship between two variables.

outcomes of the model and thus guide the design process.

4. MA Model for Application Selection

In this section, we provide details on how we designed a framework, using MA for the task of selecting the telephony project that would likely make the most impact in government service delivery in South Africa. The MA model construction process consists of an analysis and synthesis phase, each with two steps (Table 1). During the analysis phase, we define the problem space and assign possible values and conditions to each factor in selecting a telephony project (Section 4.1). We then provide results from the synthesis phase in which we reduce the possible configurations of our problem space to noncontradictory possibilities (Section 4.2). Finally, we show how we use the model to evaluate and compare proposed projects (Section 4.3).

4.1 Analysis Phase

In the analysis phase, the dimensions of the problem complex to be investigated are defined (De Waal & Ritchey, 2007). A small, multidisciplinary team of researchers specified the dimensions of our particular problem complex: What telephony project should HLT embark on to make a significant, positive impact on South Africans? This team included researchers who had conducted the bulk of the field work and preliminary research, two senior research directors who had a great deal of experience with language technology applications in corporate and academic domains, and a researcher who acted as facilitator for the MA process. Together, the team contributed the list of factors in Table 2, based on observations from fieldwork, contributions from potential community stakeholders, and the collective wisdom of our particular team. When there were conflicts of opinion, the team discussed the issue until consensus was reached. Other researchers who use the MA framework will likely choose dimensions that more closely align with their particular research question.

We noted that our list of factors fell into three interlinked categories: application, resources, and impact. Our MA framework, therefore, will allow us to compare the potential telephony projects by asking two questions: For each telephone application, what resources are required for deployment, and what is its potential impact once deployed? The dimensions of these categories become variables in the framework that are placed in columns of the morphological field. Table 2 provides a description of the design and development factors (e.g., stakeholders, size of user group). For each factor, the core research team defined a range of all possible values or conditions. The possible values are often quantitative or nonexclusive, or ranges of values that reflect categories relevant to our needs (e.g., size of user group).

Figure 3 is a visual representation of the telephony impact model, using the MA framework. Each column corresponds to either an application (grey), resource (yellow), or impact (turquoise) factor, with each of its possible values listed in a column below. The first column on the left (Application: Telephony Projects), for example, is a factor of the

Table 2. Description of factors and their possible values in the MA framework.

APPLICATION	
Telephony Projects	Name and description of specific telephony projects (see Section 3.2).
Domain	Possible domains for the LWAZI telephony project are *Health, Education, Social Services, Employment, Tourism,* and *Infrastructure.*
RESOURCES	
Stakeholders	We classified the type of stakeholders likely to participate in a technological deployment along the following categories: *Government, Funding Agencies, Industry* (telecommunications or banks), *NGOs,* and *Community Organizations.*
Content	The quality and type of content resources determine the success of the project, so we categorized content by whether it was *Local, Accurate,* and *Relevant.* Also of interest is whether the content was *Accessible* to all target users and whether it came from a single or multiple sources *(Diverse).* In addition, we knew we would either have to create the content ourselves or adapt it from an *Available* source.
Strength of Partnerships	We rated our partnerships for each potential project as *Excellent, Good, Medium,* or *None,* based on the strength of our relationship with partners, their capabilities, and the skills they would provide, including technical skills, locally created content, or access to the targeted user group.
Critical Technology	Each application would require one or more of the following technologies from HLT: *Advanced* or *Basic Speech Recognition (ASR)* (multiple vs. single word recognition), *Advanced* or *Basic Text-to-Speech (TTS)* (multiple vs. single domain synthesis), *Language* or *Speaker Identification, User Interface Design,* and *Telephony.* Advanced levels of HLT technologies generally referred to large domains of synthesized or recognized speech or to noisy conditions.
IMPACT	
Vulnerability of User Group	One way to gear technology deployment toward social impact is to target vulnerable or marginalized population groups. The categories we considered for this variable were *Youth, Elderly, Poor, Nonliterate,* or people with disabilities *(Disabled),* or a *Long-term Illness* that prevents them from functioning wholly in society. *Nonvulnerable* users were also included.
Size of User Group	We categorized applications as likely to be applicable to the *whole country, 10,000 to 1 million* people, *1,000 to 10,000* people, or *less than 1,000* people.
Languages	An application could support *All* 11 official languages, *Local* languages of a specific deployment site, or the *Dominant* languages of South Africa (English, Afrikaans, a Nguni language, such as IsiZulu or IsiXhosa, and a Sotho language, such as Sepedi or Setswana).
Geography	Applications focused on *Rural, Peri-urban, Urban,* or specifically the *Gauteng* province. Geography is a factor that characterizes the potential user, as well as the difficulty in implementing a project: A deployment in Gauteng province, where HLT is located, will be easier and cheaper to initialize and monitor.
Risk of Negative Impact	We define risk as a direct consequence of the HLT technology involved in the project. A risk of *High* negative impact may refer to death, compromised privacy, or major financial loss to the individual (loss of one year's salary). *Medium* negative impact refers to a minor financial loss (loss of one month's salary) or a major inconvenience. *Low* refers to a minor inconvenience. Negative impact might also surface as problems of trust, privacy, or credibility of the HLT group or the technology project.
Potential for Positive Impact	The same rough economic metric was used for the potential for individual impact. Categories include *Life-changing, Significant* (gain of one month's salary), *Substantial* (gain of one day's salary), and *Some,* typically consisting of mere enjoyment for the individual.

APPLICATION: Telephony Projects	APPLICATION: Domain	RESOURCES: Stakeholders	RESOURCES: Content	RESOURCES: Strength of Partnerships	RESOURCES: Critical Technology	IMPACT: Vulnerability of User Group	IMPACT: Size of User Group	IMPACT: Language	IMPACT: Geography	IMPACT: Risk of negative impact	IMPACT: Potential for individual impact
Automated Health Infoline	Health	Government	Local	Excellent	ASR advanced	Youth	Whole country	All	Rural	High	Life changing
TES Loadshedding Infoline	Education	Funding agencies	Accessible	Good	ASR basic	Elderly	10,000 - 1 million	Local	Peri-urban	Medium	Significant
SASSA Infoline	Social Services	NGOs	Relevant	Medium	TTS advanced	Disabled	1,000 - 10,000	Dominant	Urban	Low	Substantial
World Cup Community Tracker	Employment	Industry	Available	None	TTS basic	Poor	Less than 1,000		Gauteng	None	Some
Child-headed households Infoline	Tourism	Community Organizations	Accurate		Langauge ID	Nonliterate					
CDW Mobilecast	Infrastructure		Diverse		Speaker ID	Nonvulnerable					
SETA Audio Toolkit					UI Design	Long-term illness					
					Telephony						

Figure 3. Telephony impact model, with each column representing an evaluation factor and its possible values.

application category. In this column, all seven of the proposed telephony applications are listed by name. The fifth column from the right (Impact: Size of User Group) includes four categories to represent how many users might be affected by any given telephony project. Note that Figure 3 is not a true table, as the rows do not correspond logically with one another. Instead, the visual representation must be viewed as a series of columns arranged side by side.

In our telephony impact model, telephony projects within a given domain shared many properties, such as the type of stakeholders involved and the vulnerability of the user group impacted. Therefore, the general application domain (e.g., social services) serves as a first-order filter for the more specific application variables (e.g., CDW Mobilecast). As we will see in the following section, once an application of its domain is selected, interesting trade-offs between the resources and impact categories can be observed.

4.2 Synthesis Phase

The MA framework in Figure 3 results in millions of possible combinations of factor values, which makes it impossible to examine each one individually. To reduce the number of possible combinations, a cross-consistency assessment (CCA) is introduced in the MA process. All the values between factors are compared with one another pair-wise and checked for internal consistency by asking the question: Can these two conditions coexist in the context of the problem complex? If the answer is *yes,* a hyphen *(-)* is assigned to the combination. If the answer is *no,* an *X* is assigned to the combination. Alternatively, if the answer is *maybe,* a *K* is assigned (from *kanske,* meaning *maybe* in Swedish). Using this technique, the number of configurations is reduced by 90% or more, depending on the problem structure. Consequently, the number of possible combinations becomes more manageable for an observer (Ritchey, 2006).

Each specific telephony project is evaluated against all other factors in the CCA process (Table 3). In this case, the authors and their two research directors performed these evaluations as a group during two four-hour sessions. The reduction in number of possible combinations resulting from the synthesis phase was from more than 216 million combinations to 7,568. Table 3 illustrates the results of the CCA process for the resources and impact factors (columns) for each proposed telephony project (rows).

The first row of the table shows our evaluation of the resources and impact factors for the proposed Automated Health Infoline model. An Automated Health Infoline would require stakeholders in government, funding agencies, NGOs, and communities. The box on the first row corresponding to each of these columns was marked with a hyphen *(-).* A health infoline would not necessarily require stake-

Table 3. Cross-consistency matrix for the telephony impact model.

	RESOURCES: Stakeholders					RESOURCES: Content						RESOURCES: Strength of Partnerships				RESOURCES: Critical Technology							
	Government	Funding agencies	NGOs	Industry	unity Organizations	Local	Accessible	Relevant	Available	Accurate	Diverse	Excellent	Good	Medium	None	ASR advanced	ASR basic	TTS advanced	TTS basic	Langauge ID	Speaker ID	UI Design	Telephony
Automated Health Infoline	-	-	-	X	-	X	-	-	-	-	-	X	-	X	X	X	X	X	X	X	X	-	-
TES Loadshedding Infoline	-	X	X	-	X	-	-	-	-	K	X	-	X	X	X	X	-	X	-	X	X	-	-
SASSA Infoline	-	X	X	X	-	-	-	-	K	K	X	X	X	-	X	X	-	X	-	X	X	-	-
World Cup Community Tracker	-	X	X	X	-	-	-	-	K	-	-	X	-	X	X	X	-	-	X	-	X	-	-
Child-headed households Infoline	-	-	-	X	X	-	-	-	K	K	-	X	X	-	X	X	X	X	X	X	X	-	-
CDW Mobilecast	-	X	X	X	-	X	-	-	-	-	X	X	-	X	X	X	X	-	X	X	X	-	-
SETA Audio Toolkit	-	X	X	X	-	X	-	-	-	-	X	-	X	X	X	X	X	X	X	X	X	-	-

	IMPACT: Vulnerability of User Group							IMPACT: Size of User Group				IMPACT: Language			IMPACT: Geography				IMPACT: Risk of negative impact				IMPACT: Potential for individual impact				APPLICATION: Domain					
	Youth	Elderly	Disabled	Poor	Nonliterate	Nonvulnerable	Long-term illness	Whole country	10,000 - 1 million	1,000 - 10,000	Less than 1,000	All	Local	Dominant	Rural	Peri-urban	Urban	Gauteng	High	Medium	Low	None	Life changing	Significant	Substantial	Some	Health	Education	Social Services	Employment	Tourism	Infrastructure
Automated Health Infoline	-	X	X	-	-	X	-	X	X	-	-	X	-	X	-	X	-	X	X	X	-	X	X	-	-	-	-	X	X	X	X	X
TES Loadshedding Infoline	X	X	X	-	-	-	X	X	-	X	X	X	-	X	X	X	X	-	X	X	-	X	X	X	-	-	X	X	X	X	X	-
SASSA Infoline	X	-	-	-	-	X	-	X	X	-	X	X	-	X	-	X	X	X	X	-	X	X	X	X	-	-	X	X	-	X	X	X
World Cup Community Tracker	-	X	X	-	-	X	X	-	X	X	X	-	X	X	-	-	-	-	X	X	X	-	X	-	-	-	X	X	X	X	-	X
Child-headed households Infoline	-	X	-	-	X	X	X	-	X	X	X	-	X	X	-	-	-	-	-	X	X	X	-	-	-	-	X	X	-	X	X	X
CDW Mobilecast	X	X	X	-	-	X	X	X	-	-	-	X	-	X	-	X	X	X	X	X	-	X	X	X	-	-	-	-	-	X	X	-
SETA Audio Toolkit	-	X	-	-	X	X	X	X	X	X	-	X	-	X	-	X	X	-	X	X	-	X	X	X	-	-	X	X	X	-	X	X

holders in industry, however. The box on the first row corresponding to "Industry" was marked with an *X.* An Automated Health Infoline would likely need to disseminate accessible, relevant, and accurate content. In this application, local content may not be critical. Existing partnerships in the health domain were considered "good" by our research team. Finally, the technology required for such a project includes basic ASR, user interface (UI) design, and telephony.

Continuing along the first row of the matrix, we come to "Impact: Vulnerability of User Group" and to "Impact: Size of User Group." An Automated Health Infoline would likely have an impact on 10,000 to 1 million people in South Africa, including vulnerable groups such as the youth, the poor, individuals with long-term illnesses, and those who cannot read or write. Although its services would include information for the elderly and the disabled, the health infoline would not specifically target these groups. An Automated Health Infoline should be available in local languages, not only in the dominant ones (IsiZulu, IsiXhosa, Sepedi, English, Afrikaans). Depending on how many provinces will host such a system, it might be necessary to support all 11 official South African languages, but it was not known whether all provinces would participate. The corresponding box was marked with a *K.* The Automated Health Infoline would be designed to support individuals living in rural, urban, and peri-urban settings.

Our team predicted that an Automated Health Infoline could significantly impact an individual. For example, a telephony application that reminds a person with HIV to take one's antiretroviral (ARV) medication could impact that person's life by ensuring that the medication works effectively. This would avoid the need for a second, stronger strand of a more costly ARV with stronger side effects, or avoid a situation where all medications fail to work for the patient. However, the same health infoline runs a medium risk of negative impact if it provides incorrect or confusing advice, the results could be dangerous for the caller.

All seven potential telephony projects were evaluated in this way.

We observed several interesting trends during the synthesis phase. For example, "Resources: Content" was often marked with a *K.* This tag was especially frequent for the values of "Availability" and "Accuracy," which revealed a gap in our fieldwork investigations. During future meetings with stakeholders, we asked many more questions regarding content availability and devised means to evaluate its accuracy. In addition, we actively sought additional partnerships with NGOs whose primary goal was the creation of quality content (both print and mixed media) in local languages of South Africa.

During the synthesis phase, we agreed that high-risk applications should use keypad input (touch-tone) over speech input. Applications designed for vulnerable youth have the highest risk of negative impact and may cause the most challenge to the technology (ASR models and UI design would need to be carefully customized for this population). In our fieldwork, we noted that information hotlines as a whole are unlikely to be used by most South Africans unless they are free of charge. Acquiring a toll-free number for an application, however, requires strong partnerships with industry. Despite the importance of stakeholders in project success, the "Resources: Stakeholder" factor was not a strong criterion for the telephony impact model, as its values varied little according to the application.

APPLICATION: Telephony Projects	APPLICATION: Domain	RESOURCES: Stakeholders	RESOURCES: Content	RESOURCES: Strength of Partnerships	RESOURCES: Critical Technology	IMPACT: Vulnerability of User Group	IMPACT: Size of User Group	IMPACT: Language	IMPACT: Geography	IMPACT: Risk of negative impact	IMPACT: Potential for individual impact
Automated Health Infoline	Health	Government	Local	Excellent	ASR advanced	Youth	Whole country	All	Rural	High	Life changing
TES Loadshedding Infoline	Education	Funding agencies	Accessible	Good	ASR basic	Elderly	10,000 - 1 million	Local	Peri-urban	Medium	Significant
SASSA Infoline	Social Services	NGOs	Relevant	Medium	TTS advanced	Disabled	1,000 - 10,000	Dominant	Urban	Low	Substantial
World Cup Community Tracker	Employment	Industry	Available	None	TTS basic	Poor	Less than 1,000		Gauteng	None	Some
Child-headed households Infoline	Tourism	Community Organizations	Accurate		Langauge ID	Nonliterate					
CDW Mobilecast	Infrastructure		Diverse		Speaker ID	Nonvulnerable					
SETA Audio Toolkit					UI Design	Long-term illness					
					Telephony						

Figure 4. Predictive Mode: Properties of the Child-Headed Household Infoline.

By reading the rows corresponding to each telephony project, one can perform a rough comparison along each of the factors. For example, the World Cup Community Tracker is a little or no risk project that would showcase many language technologies, whereas the Child-Headed Household Infoline is a high-risk project that only uses two language technologies. For more complex evaluations than a simple line-by-line comparison, the Swedish Defense Research Agency (FOI) has developed the proprietary software Casper[2] (Computer Aided Scenario and Problem Evaluation Routine) to support the MA process. With this software support, an internally assessed morphological field becomes a flexible model in which anything can be selected as "input," and all values and conditions that are consistent with the selected input are highlighted as "output" (De Waal & Ritchey, 2007). The result is a model that allows inferencing, where any combination of "if-then" scenarios may be observed.

4.3 Inferencing

The MA model enabled the research team to systematically evaluate the potential telephony projects for government service delivery in South Africa using a predictive mode, a prescriptive mode, and a diagnostic mode (De Waal & Ritchey, 2007). The three modes of inferencing were primarily used by the research team to select a telephony project for LWAZI whose funders were invited to view the framework to see our selection process and our metrics for impact. Community stakeholders were not included in this phase, as it involved selecting which community would be involved. In the following subsections, we provide examples of how we performed each mode of inferencing, along with our major findings.

Predictive Mode: Evaluating Telephony Projects

The most natural way to use the telephony impact model is the predictive mode, which asks: Given a selected telephony project, what are the critical resources and the potential for impact? The telephony impact model allows one to view all the nonquantitative properties of each potential telephony project at once (Figure 4). For example, when the Child-Headed Household Infoline is selected (red), all values and conditions that were judged to be consistent with its selection are highlighted (blue). The predictive mode is equivalent to reading across any given row of the CCA in Figure 3.

From Figure 4, we can easily observe that the Child-Headed Household Infoline targets youth, the

2. CASPER software is not commercially available, but an alternative suite of methods in the Parmenides EIDOS software package (http://www.parmenides-foundation.org/content.phtml) is available for free download.

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SASSA Infoline	Social Services	NGOs	Relevant	Medium	TTS advanced	Disabled	1,000 - 10,000	Dominant	Urban	Low	Substantial
World Cup Community Tracker	Employment	Industry	Available	None	TTS basic	Poor	Less than 1,000		Gauteng	None	Some
Child-headed households Infoline	Tourism	Community Organizations	Accurate		Langauge ID	Nonliterate					
CDW Mobilecast	Infrastructure		Diverse		Speaker ID	Nonvulnerable					
SETA Audio Toolkit					UI Design	Long-term illness					
					Telephony						

Figure 5. Diagnostic Mode: Projects that impact nonliterate South Africans.

poor, and the disabled. It is the only application that is both high-risk and potentially life changing for the individuals who use it. Funding agencies, NGOs, and government, in particular Social Services, are likely to be involved in the deployment in some capacity. The Child-Headed Household Infoline would, even at its first inception, impact the whole country and support all 11 official languages of South Africa. The content would need to contain local information (e.g., location of the nearest social worker's office) to be accessible to children and to be relevant to their daily needs. As the content is not currently available, HLT would need to develop it from diverse sources (books, brochures, expert advice, focus group discussions). The development of a Child-Headed Household Infoline would require UI design and telephony implementation. However, it would not showcase our newest technologies: speech recognition and speech synthesis for South African languages. Partnerships would need to be strengthened to ensure sustainability and usability of this system.

Performing the predictive mode of inference across all potential telephony projects led to several high-level observations. Every telephony project that we considered required accessible and relevant content. Every potential telephony project would require telephony technologies and user interface design. These observations allowed the research team to focus efforts in these areas well before the final project had been selected for LWAZI. All the telephony projects had at least a substantial potential for individual impact and targeted the poor, a fact that clarified our minimum impact goals for LWAZI. Finally, we noted that most of the projects fell into one of two categories: (a) ambitious, high-profile projects that would be a challenge for the HLT team and (b) less challenging projects in well-explored domains.

Diagnostic Mode: Selecting Projects Based on Impact

Using the telephony impact model in the diagnostic mode (or analytic mode) asks the question: Given an impact goal, what are the resources and the application that can achieve this goal? The MA model can be used to show all the telephony projects that satisfy any number of specified impact properties (Figure 5). For example, speech-based systems are thought to be particularly useful for nonliterate populations who do not speak a dominant language, such as English. Using our model, we can select *nonliterate* as a section of the South Africa population to be targeted and *local* as the number of languages we wish to support. We want to impact the largest size of the user group possible, which, in this case, is 10,000 to 1 million. In Figure 5, we show the three criteria we selected (red), along with the

APPLICATION: Telephony Projects	APPLICATION: Domain	RESOURCES: Stakeholders	RESOURCES: Content	RESOURCES: Strength of Partnerships	RESOURCES: Critical Technology	IMPACT: Vulnerability of User Group	IMPACT: Size of User Group	IMPACT: Language	IMPACT: Geography	IMPACT: Risk of negative impact	IMPACT: Potential for individual impact
Automated Health Infoline	Health	Government	Local	Excellent	ASR advanced	Youth	Whole country	All	Rural	High	Life changing
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World Cup Community Tracker	Employment	Industry	Available	None	TTS basic	Poor	Less than 1,000		Gauteng	None	Some
Child-headed households Infoline	Tourism	Community Organizations	Accurate		Langauge ID	Nonliterate					
CDW Mobilecast	Infrastructure		Diverse		Speaker ID	Nonvulnerable					
SETA Audio Toolkit					UI Design	Long-term illness					
					Telephony						

Figure 6. Prescriptive Mode: The Automated Health Infoline is the project that both requires ASR and has the biggest impact in rural areas.

two projects that meet these criteria and the resources required (blue).

Only two projects satisfy the criteria for a large, nonliterate user group and the use of local languages: TES Loadshedding and CDW Mobilecast. The resources necessary include partnerships with government, industry, and community stakeholders that we consider to be good or better. The project will also require the acquisition or development of local, relevant content, as well as core and advanced language technologies (ASR, TTS, UI design, telephony). Either project is predicted to have a low risk of negative impact and a potential for substantial positive impact.

Analysis of the telephony impact model in the diagnostic mode facilitated discussions for what type of impact we hoped to make with LWAZI. For example, did we prefer to make a small impact for a large number of people or a large impact for a small number of people? We observed an important impact tradeoff: All projects that offered a life-changing, positive impact also yielded a high risk for negative impact. Lower-risk projects also offered more modest positive impact for users. The diagnostic mode also revealed our unwillingness to implement challenging technology on projects with a high risk for negative impact. In cases of high risk for users, we preferred to limit project technology to UI design and telephony, instead of attempting innovative, yet relatively untested technology, such as advanced TTS.

Prescriptive Mode: Selecting Projects Based on Resource and Impact Constraints

The MA model in the prescriptive (or synthetic) mode shows which telephony applications are possible, given certain constraints on the available resources and desired impact. The question, therefore, is this: Given a set of resources and a desired impact, which applications are possible? The MA model can show all the telephony projects that satisfy specified resource and impact properties. For LWAZI, we were especially interested to know which applications would have at least a significant impact on individuals in rural areas, but would require only basic ASR technology. Therefore, we constrain the model by selecting *significant* for impact, *rural* for geography, and *basic ASR* for technology (Figure 6).

Only one telephony project meets the three constraints (red): The Automated Health Infoline (blue, first column). The health infoline would provide general health education information to a large number of people in rural areas, including youth, the poor, nonliterate South Africans, and those with long-term illnesses. In addition to basic ASR, the project would require the development of content that is accessible, relevant, and accurate. Fortunately, such content is currently available in English and other dominant languages. A project in the health domain carries a certain amount of risk; but such a risk can be mitigated by working closely with stakeholders in government, funding agencies, NGOs, and community organizations. Any single constraint or set of constraints can be selected and its results viewed in this manner.

Using the telephony impact model in the prescriptive mode gave us the most information about planning our deployment. The model provided a visual aid to weighing benefits and drawbacks of the potential projects against one another. It was easy to systematically evaluate each what-if scenario our team could envisage until all were exhausted. Without the model, the same discussion would have been circuitous, tedious, and would have likely missed a scenario. We found, for example, that if we wanted to make our work easier by planning a low-risk project in Gauteng, we had two choices: TES Loadshedding Infoline and the SETA Audio Toolkit. Both of these telephony projects offered strong partnerships with stakeholders, but targeted different user groups and sizes of user groups. Finally, during our analysis of the telephony impact model in the prescriptive mode, the importance of certain properties over others began to emerge. In earlier definitions of *impact,* our team agreed that a substantial impact for a small number of people was just as important as a small impact for a large number of people. In theory, that still holds true. However, during this phase of our analysis, it became clear that our research team was less interested in the projects that would impact less than 1,000 people, regardless of the other benefits they offered.

4.4 Final Selection

After the LWAZI project selection team completed the telephony impact model and analyzed it, using the predictive, diagnostic, and prescriptive modes, a workshop was organized for experts in a variety of HLT domains who gave their input on both resource and impact constraints. The participants were presented with the predictive description of each potential telephony project and several key what-if scenarios, then asked to rank the projects based on their strengths and weaknesses. Although no changes were suggested, if participants had offered a correction to the factors or their values at this point, the MA model could easily have been modified and new results viewed at this stage. The core team convened a follow-up meeting during which it selected two applications based on expert feedback from the workshop: TES Loadshedding Infoline and CDW Mobilecast. The MA models of these telephony projects have since been used in meetings with stakeholders (funders, government partners, CDWs, and community members) to facilitate collaboration and co-design, with positive results. Both projects are being simultaneously developed by HLT groups in South Africa.

Results from the deployment of these two telephony applications will lend further insight into the possible predictive power of the MA model when applied to ICT project selection. As always, there are on-the-ground realities that will no doubt challenge the subjective input on which the telephony impact model is based. Once community members are involved, we also expect a need to represent more detail. For example, we have identified the need for accurate, relevant content, but different community stakeholders will likely disagree about what specific content satisfies those criteria. At this stage, we plan to modify the telephony impact model as the problem complex and the key stakeholders shift. In this way, the MA framework will continue to facilitate problem solving by serving as a flexible, transparent tool that reflects the wisdom and goals of those involved at each stage.

5. Conclusions for ICTD Projects

In this article, we describe the creation of a telephony impact model by our multidisciplinary team to select the ICT project that would most likely meet our research goals in South Africa. We believe that integrating the MA model into the initial phases of the action research cycle is a first step in formalizing ICTD approaches. Although the MA model cannot truly predict project impact or uptake (unless such parameters are included as properties), it will aid in the efforts of the ICT community to develop theories and models that can begin to predict results. In our case, whatever predictive power the telephony impact model may hold will only be known after the deployments are conducted and evaluated. Certainly, the integration of the MA model with the early phases of the ICTD research cycle is a vast improvement over methods for technological deployment, which depend solely on best practices or previous case studies to predict their success or failure. By optimizing early planning of ICT project deployments, MA modeling will help ICT better measure up to its promise to improve people's lives in developing regions.

The practical advantages that the MA model offers early ICTD planning are numerous. First, the MA model offers a step-by-step approach to the most initial phases of technology deployment. The initial phases are arguably the most important for successful ICT deployment, because it is essential to understand the broader social setting in order to implement an appropriate solution. The initial phases can be challenging, however, especially for researchers new to the field of ICTD, as these early steps require careful coordination among participants who often represent a wide range of wisdom and interests. This article offers instructions that any interested researcher can follow on how to select an ambitious, large-scale ICTD project that will most likely meet specified research goals.

Second, the MA model reveals the characteristics unique to each research setting. In the field of ICTD, there is no one-size-fits-all solution. The MA model highlights the most relevant socio-technical factors for a given setting by representing the combined knowledge of all participants at a given point in time. If a different set of experts constructed a model with the same objective, the model would be different. Furthermore, if that same group of experts constructed the same model a few months later, again the model would be different. Although much can be learned by reading about ICTD projects around the world, the MA model clearly reveals the relevant goals and resources of the particular region, research team, and technology under consideration.

Additionally, the approach we describe in this article is extremely helpful in coordinating research efforts during early planning. The MA model allowed us to clearly see the interdependence of factors and the *who* and *how* of the potential impact of each telephony project. In our case, the MA model revealed gaps in fieldwork while there was still time to plan additional site visits. Our MA model revealed the need for certain technologies, which could be communicated to those researchers responsible for technology development, well before a final application was chosen by the selection team. The initially broad impact goal for our project—to make a positive social impact—became focused to specific, measurable goals by the MA model, which clarified the combined interests of the relevant participants.

Finally, the MA model is a transparent framework that facilitates the management of multiple stakeholder interests. The MA process itself demands clarity, traceability, and consensus by participants. The MA framework defines a subjective parameter space with many inputs and multiple alternative outputs, rather than a single solution. The result is an interactive what-if laboratory that allows active inferencing by researchers and stakeholders (Ritchey & Stenström, 2002). Based on our use of the MA model to facilitate planning with researchers, funders, and select community members, we believe the framework has potential to serve as an inclusive tool for stakeholder management throughout the research cycle of an ICTD project. Supporting software facilitates the sharing and ownership of the model by experts and stakeholders. The more people who share and debate the model, the more feedback there will be that can be considered for each decision. As with all problem structuring methods and models, however, the output of the process is no better than the quality of the input, and care must be taken when choosing the participant group. ■

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References

Bailur, S. (2006). Using stakeholder theory to analyze telecenter projects. *Information Technologies and International Development, 3*(3), 61–80.

Baskerville, R. L. (1999). Investigating information systems with action research. *Communications of the Association for Information Systems, 2*(19), 1–32.

Baskerville, R. L., & Harper, A. T. (1996). A critical perspective on action research as a method for information systems research. *Journal of Information Technology, 11,* 235–246.

Brewer, E., Demmer, M., Du, B., Fall, K., Ho, M., Kam, M. et al. (2005). The case for technology for developing regions. *IEEE Computer, 38*(6), 25–38.

Brewer, E., Demmer, M., Ho, M., Honicky, R. J., Pal, J., Plauché, M. et al. (2006). The challenges of technology research for developing regions. *IEEE Pervasive Computing, 5*(2), 15–23.

De Waal, A., & Ritchey, T. (2007). Combining morphological analysis and Bayesian networks for strategic decision support. *ORiON, 23*(2), 105–121.

Coyle, R. G., & McGlone, G. R. (1995). Projection scenarios for South-east Asia and the South-west Pacific, *Futures, 27*(1), 65–79.

Coyle, R. G., & Yong, Y. C. (1996). A scenario projection for the South China Sea. *Futures, 28*(3), 269–283.

Dagron, A. G. (2001). Prometheus riding a Cadillac? Telecentres as the promised flame of knowledge [Special issue on telecentres]. *Journal of Development Communication, 12*(2).

Davison, R. M., Martinsons, M. G., & Kock, N. (2004). Principles of canonical action research. *Journal of Information Systems, 14,* 65–86.

Duncombe, R. (2006). Using the livelihoods framework to analyze ICT applications for poverty reduction through microenterprise. *Information Technologies and International Development, 3*(3), 81–100.

Gordon, R. G., Jr. (Ed.). (2005). *Ethnologue: Languages of the world,* 15th ed. Dallas: SIL International. Retrieved July 2007, from http://www.ethnologue.com/

Grover, Sharma A., Plauché, M., Barnard, E., & Kunn, C. (2009, April). HIV health information access using spoken dialogue systems: Touchtone vs. speech. *Proceedings IEEE International Conference on Information and Communications Technologies and Development '09 (ICTD 09),* Doha, Qatar, 95–107.

Heeks, R. (2006). Theorizing ICT4D research. *Information Technologies and International Development, 3*(3), 1–4.

Heugh, K. (2007). Language and literacy issues in South Africa. In Naz Rassool (Ed.), *Global issues in language, education and development: Perspectives from postcolonial countries* (pp. 190–196). Clevedon, UK: Multilingual Matters.

International Telecommunications Union (ITU). (2003). Mobile overtakes fixed: Implications for policy and regulation. Retrieved August 2007, from http://www.itu.int/osg/spu/ni/mobileovertakes/Resources/Mobileovertakes_Paper.pdf

Maier, S., & Nair-Reichert, U. (2007). Empowering women through ICT-based business initiatives: An overview of best practices in e-commerce/e-retailing projects. *Information Technologies and International Development, 4*(2), 43–60.

McKay, J., & Marshall, P. (2001). The dual imperatives of action research. *Information, Technology and People, 14*(1), 46–59.

Migneault, J. P., Farzanfar, R., Wright, J. A., & Friedman, R. H. (2006). How to write a health dialog system for a talking computer. *Journal of Biomedical Informatics, 39*(5), 468–481.

Pandey, P., Sehgal, A. R., Riboud, M., Levine, D., & Goyal, M. (2007). Informing resource-poor populations and the delivery of entitled health and social services in rural India: A cluster randomized controlled trial. *Journal of the American Medical Association, 298,* 1867–1875.

Plauché, M., Nallasamy, U., Pal, J., Wooters, C., & Ramachandran, D. (2006, May). Speech recognition for illiterate access to information and technology. *Proceedings IEEE International Conference on Information and Communications Technologies and Development '06,* Berkeley, CA, 83–92.

Raiti, G. C. (2006). The lost sheep of ICT4D literature. *Information Technologies and International Development, 3*(4), 1–8.

Rhyne, R. (1981). Whole-pattern futures projection. *Using Field Anomaly Relaxation, Technological Forecasting and Social Change, 19,* 331–360.

Rhyne, R. (1995a). Field anomaly relaxation—The arts of usage, *Futures, 27*(6), 657–674.

Rhyne, R. (1995b). *Evaluating alternative Indonesian sea-sovereignty systems: An exercise in soft tech-*

nology transfers. Informs: Institute for Operations Research and the Management Sciences, Linthicum, MD.

Ritchey, T. (2006). Problem structuring using computer-aided morphological analysis. *Journal of the Operational Research Society, 57,* 792–801.

Ritchey, T., & Stenström, M. (2002). Using morphological analysis to evaluate preparedness for accidents involving hazardous materials. Study for the Swedish Rescue Services Board presented at the *4th International Conference for Local Authorities,* Shanghai. Retrieved July 2007, from http://www.swemorph.com/downloads.html

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Science, 4*(2), 155–169.

Roman, R., & Colle, R. D. (2003). Content creation for ICT development projects: Integrating normative approaches and community demand. *Information Technology for Development, 10*(2), 85–94.

Rosenhead, J. (1996). What's the problem? An introduction to problem structuring methods. *Interfaces, 26*(6), 117–131.

Rothschild, C. (2008). *Incorporating predictors of success for telecenter projects: A qualitative analysis of 17 developing countries.* Master's thesis. Henry M. Jackson School of International Studies, University of Washington, Seattle, WA.

Sherwani, J., Tongia, R., Rosenfeld, R., Memon, Y., Karim, M., & Pappas, G. (2007, January). Towards speech interfaces for health information access by semi-literate users. *Proceedings of Artificial Intelligence in ICT for Development,* Bangalore, India.

Statistics South Africa. (2007). Community survey: Statistical release P0301. Retrieved July 2008, from http://www.statssa.gov.za/community_new/content.asp

Tongia, R., & Subrahmanian, E. (2006, May). Information and Communications Technology for Development (ICT4D)—A design challenge? *Proceedings of IEEE International Conference on Information and Communications Technologies and Development '06,* Berkeley, CA, 243–255.

Zwickey, F. (1947). Morphology and nomenclature of jet engines. *Aeronaut Engine Review, 6*(6), 49–50.

Zwickey, F. (1948). Morphological astronomy. *Observatory, 68*(845), 121–143.