Assessing Appropriate ICT with ARIS case in Mozambique

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ICT projects in developing countries need to integrate requirements of the local context in order to be successful. Appropriate Technology (AT) has been applied in many domains to deliver technological solutions that are suitable to the local contexts for which they are intended. The Appropriate ICT framework has adopted the principles of AT within the domain of ICT. This paper assesses the Appropriate ICT framework in the context of developing and implementing an Academic Registry Information System (ARIS) in Mozambique, and proposes an enhancement to the Appropriate ICT framework in order to facilitate further research on appropriate ICT tools and methods.

1. Introduction

The difficulties reported in Information and Communication Technology (ICT) projects in developing countries [Heeks 2002; Averrou 2008] suggest a need to improve our implementation of ICT projects. These difficulties include weak sustainability and scalability and missing organizational capacity to pursue change, and lead to underutilized and abandoned projects. In this paper we will examine how the Academic Registry Information System (ARIS) was implemented in Mozambique in order to assess whether or not the Appropriate ICT Framework can resolve some of these difficulties.

Appropriate ICT has been formulated by Van Reijswoud [2009] based on the principles of Appropriate Technology as stated in the AT source book [Darrow & Saxenian]. Appropriate ICT is an attempt to facilitate suitable technologies for ICT projects in developing countries and consists of three components: hardware, software and organizational change management. Many AT artifacts in domains such as energy and water supply are hardware artifacts. The software component has different characteristics. Some of these characteristics fit in well with the AT concept, while other characteristics pose special challenges. Implementing an ICT artifact in an organization is a process during a certain period of time and brings organizational change with it.

All three components - hardware, software and organizational change management - play an important part in the ARIS case study. Guided by the experiences of ARIS up to now, we show that Appropriate ICT is a useful perspective throughout the project lifetime to reflect on challenges and aid in the selection of appropriate tools. Finally, we encourage further research on appropriate tools to provide practitioners with best practices suitable in specific contexts.

The next section will introduce the concept of Appropriate Technology (AT) and the Appropriate ICT Framework. Then the study and the context of the ARIS case are
described. This is followed by observations of the relationship between software and Appropriate Technology principles. After this the study results are presented. Finally recommendations and conclusions are given.

2. Appropriate Technology and Appropriate ICT

Appropriate Technology (AT) is defined by Wiser Earth as follows [2009]:

“Appropriate Technology (AT) is an applied engineering science suitable to the level of economic development of a particular group of people. Ideally, AT is decentralized, can be used and operated by most of the concerned citizens (i.e. does not require outside operators), uses local or regional fuels and materials in an efficient manner, and involves machines that can be locally repaired. It is sometimes called ‘alternative technology’ and sometimes used for the ‘best choice’ of a technology no matter how complex (‘green technology’)”.

Appropriate Technology has been applied in many domains such as architecture, building, energy and water supply [Darrow & Saxenian, 2009]. There have been a few Appropriate Technology initiatives in the domain of ICT, such as One-laptop-per-child (laptop.org) and the Simputer (www.simputer.org) have tried to provide appropriate hardware, Damn Small Linux (www.damnsmalllinux.org) and UbuntuLite (www.u-lite.org) try to provide software solutions for low-cost hardware. The aspect of organizational change has not received much attention in AT. Appropriate ICT takes a closer look at the complexities of ICT projects and integrates organizational change.

Appropriate ICT is defined by Van Reijswoud [2009] as “the integrated and participatory approach that results in tools and processes for establishing Information and Communication Technology (ICT) that is suitable for the cultural, environmental, organizational, economic and political conditions in which it is intended to be used”. The theoretical considerations on which the Appropriate ICT framework is based consist of the distinction between product - the technical artifact itself - and process of introducing this artifact into the target organization or the respective environment. The process perspective is vital during the implementation phase and is guided by Community Informatics (CI) practices, involving the community itself in the adaptation of the ICT artifact.
The proposed Appropriate ICT Framework is based on the traditional Systems Development Life Cycle (SDLC) and extends it with tools and approaches which shall guide the ICT solution to greater appropriateness and thus effectiveness in implementation. A basic set of tools is given and the Appropriate ICT Framework encourages to propose further tools which address cultural, environmental, organizational, economical and political aspects of ICT projects. Figure 1 shows the Appropriate ICT framework extended with possible tools that can support the process. Furthermore, a set of key guiding questions integrate the 10 rules of AT and are structured along the phases of the Systems Development Life Cycle (see Table I).

Table I: Key guiding questions

<table>
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<tr>
<th>Hardware</th>
<th>Software</th>
<th>Change mgmt.</th>
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<tr>
<td>- Specific HW requirements in terms of climatological and environmental conditions?</td>
<td>- What are the needs?</td>
<td>- What ICT knowledge levels?</td>
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<td>- What are the possibilities in terms of enabling factors (Internet connectivity, electricity)?</td>
<td>- What are the expectations?</td>
<td>- What the financial constraints?</td>
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<td>- What is the cultural context?</td>
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<td>- What added value is created?</td>
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<td></td>
<td></td>
<td>- How is the economic equilibrium affected?</td>
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<tr>
<td></td>
<td></td>
<td>- What new ways of working are introduced?</td>
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<td>- What will the impact be of the system in terms of organizational change?</td>
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<td>- What is the involvement in the idea generation of key decision makers (political leaders, religious leaders)?</td>
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### Design phase

- What is offered on the local market?
- What are physical constraints?
- What are the financial constraints?
- What interoperability needs?
- What localization is needed?
- What flexibility is expected?
- What are the information needs of the various target groups?
- How will these needs evolve?
- How do the expectations change?

### Construction phase

- What local skills are available?
- Is the equipment protected against physical conditions?
- What local skills are available?
- Are features in line with skills?
- Are free and open source alternatives considered?
- Are the systems well documented?
- Are local skills and knowledge being developed?
- Are stakeholders actively involved?
- What new ways of working are introduced?
- What will the impact be in terms of organizational change?

### Installation phase

- Is all the equipment well protected?
- Has the system been tested with all stakeholders?
- Are all stakeholders involved in training program?
- Is the added value made clear?

### Operation / maintenance phase

- Is local capacity sufficient?
- Are spare parts easily available?
- Are software maintenance skills available?
- Is a support organization in place?
- Is the support organization able to support all stakeholders (e.g. Gender issues)

### 3. Description of the study

This study builds upon a single-case study of the development and implementation project of the Academic Registry Information System (ARIS) in Mozambique. The functionality of the system is to manage academic information including studies, students, exams and marks, taking into account the specific Mozambican reality and requirements. The project has started in 2005 and this study was conducted at the final stages of the project in 2009. The project has run through all stages of the software development life cycle and at the time of writing the software product is in use. Since the Appropriate ICT framework has been only recently presented by van Reijswoud [2009], it has not been applied during the ARIS project. Through a reconstruction of events of the project, the Appropriate ICT framework is assessed.

The objective of this study is to evaluate the usefulness of Appropriate ICT framework, including its “guiding questions”. The study questions are:

- In which way is the Appropriate ICT framework useful during project lifetime?
- How would the use of the Appropriate ICT framework during the ARIS project have improved the outcome?
• Is the set of guiding questions complete? Can we find suggestions for improvement?
• How can we guide tool development in order to facilitate reuse between ICT projects?

To investigate the study questions, the study made use of the “guiding questions” as formulated by the Appropriate ICT framework. These guiding questions are the means of the Appropriate ICT framework to address relevant issues related to hardware, software and organizational change management. The questions were therefore answered to reflect project challenges. In a second step this picture was contrasted with the actual situation in the ARIS project to evaluate the usefulness and completeness of the picture drawn by the Appropriate ICT framework.

The results of this comparison were strong enough to be used to suggest some improvements to the Appropriate ICT framework.

The sources of evidence for answering the guiding questions for the ARIS project were documents, interviews and participant observation – the latter by assuming a role as a technical expert in the project.

4. The ARIS case

In the following the case of the development and implementation of an Academic Registry Information System (ARIS) at the Catholic University in Mozambique (UCM) will be presented, with the intention to verify the usefulness of the Appropriate ICT framework. This section consists of a description of the context of the case, followed by responses to the guiding questions of the Appropriate ICT framework to verify that a complete picture of project complexity can be developed. Then, the tools which were used during the various cycles of the system development life cycle are described. Finally, some observations are made on the special characteristics of the software development part of the project.

4.1 Context of the case

The case described here focuses on the development and implementation of an Academic Registry Information System (ARIS) at the Catholic University of Mozambique (UCM). The objective of the system to manage academic registry information at Higher Education institutions. The data is stored in a database and can be used to automatically retrieve reports like student lists, certificates, student cards and statistics. The need for such a system has been expressed by several Mozambican universities, since data has been managed mainly with spreadsheets which is labor-intensive, error-prone and not scalable enough for increasing student numbers.

The incremental development model [Davis et al. 1988] was used as the basic software development methodology. After the construction of a partial system, all stakeholders were involved on a regular basis to review progress and provide feedback for further system development.

The information system has been developed by a combined effort of several Mozambican universities, the Ministry of Education and Culture (MEC) and two Dutch
universities. These stakeholders worked together within a development cooperation project funded by the Dutch government and locally coordinated by the MEC. The UCM was one of the beneficiary universities because of its presence in the central and northern provinces of Mozambique. The viewpoint of this case is mainly from the perspective of the UCM as one of the target organizations, but the whole effort was a collaboration between all involved actors, whose input was important for the success in each of the Mozambican target universities. The software development has been done mainly on the Dutch side, in order to provide the necessary competence which was lacking on the Mozambican side. The coordination of most activities like workshops was done by the MEC in Mozambique.

4.2 Hardware, Software and organizational implementation

ARIS has been designed as a client-server architecture and built on Open Source components. Data is stored in a central database. The application logic runs on an Apache Tomcat server providing HTTP content to clients. The clients use a web-browser to access the server. Each user has a separate login and password, and an associated user role to limit the user’s privileges in the system.

The system is based on Open Source components. PostgreSQL is used as the database and Apache Tomcat as the web server. Furthermore Open Source frameworks like Spring and iBatis are used as building blocks of the software system. Furthermore the system has a modular architecture which comprises a kernel, a reporting module, a scholarship module, a fee module and university specific extension modules.

UCM leased a virtual Linux server from a provider in the United States on which ARIS is deployed. This allows client access from any Internet connected computer via a web browser. Clients use Mozilla Firefox or Internet Explorer to access the ARIS application. The hardware requirements on the client side are a computer with connection to the Internet. All users used Microsoft Windows as an operating system, although this is not a requirement.

UCM has faculties in different cities in central and northern Mozambique. Each faculty has academic registry staff which is trained in common workshops and by on the job. The process is further facilitated with the help of technical experts by importing existing academic data into ARIS, so that the benefits of the new system are more obvious to users. These benefits include automatic creation of certificates and statistics built on data existing in the database.

4.3 Tools used

During the various stages of the SDLC many tools have been applied in order to achieve project results and to deal with the given reality. These are illustrated in Figure 2.
5. Observations of SW characteristics

ARIS has a strong software component, so it is pertinent to make some observations about software in relation to Appropriate Technology principles. Many AT artifacts are “hardware” artifacts; for example, appropriate cooking stoves. There are several factors unique to software artifacts, as observed in the ARIS case. Some examples are:

- Software production is rather complex [Xia and Lee 2004], which does not easily fit with the AT emphasis of simple technologies. Nauman et al. [2005] give a case study of the complexity of a software development project in a developing country in which they demonstrate considerable complexity in a seemingly simple information system project.

- Because they are complex and need a lot of resources, software systems should not be reinvented by each organization which needs a certain type of software. Uwadia et al. [2006] describe a case study of the collaborative development of information systems with the university environment in Nigeria. The collaborative approach was viewed appropriate for Nigeria because of a high degree of similarity in the core functions and activities needed to support the administration and management of the universities. In such a context, uniform software can be developed at a cost shared by all participating institutions, which can easily be customized to suit each institution’s individual needs. In addition, many universities in developing countries do not have the capacity to develop the required software on their own. For software systems, collaboration should be emphasized and investigated further. But collaborative work without face-to-face contact and without immediately visible benefits for the community involved is not common behavior, so proper ways of organizing collaborative software development need to be investigated and developed.
• There is a design challenge for software systems to allow adapting the system to specific needs of each implementing organization.

• Software needs constant, ongoing development to respond to changing organizational needs [Lehman and Ramil, 2001].

• AT has a "village" orientation [Darrow and Saxenian] but software systems are not typically developed and used in remote villages (which often do not have electrical power). Eventually, the village in this case can be reinterpreted - as organizational communities which, according to AT, shall seek to understand their own needs and how to solve them by their own means.

These observations show the importance of community networking – which is an important aspect of the AT concept. Appropriate ICT orients itself more particularly at the field of Community Informatics [Gurstein 2000], and further tools and methods should be investigated for the community networking aspect, i.e. for the coordination of inter-organizational collaborations for the development and maintenance of ICT systems.

However, software also has characteristics that fit in well with the AT concept: Software production needs small amounts of initial capital; computers and Internet connections are the only investment. It is labor-intensive and has the potential to offer more productive solutions than traditional information management technologies such as pen and paper and plain office applications like word processors and spreadsheets. Furthermore, collaborative software development offers possibilities for local experts and entrepreneurs to get involved if organized properly, e.g. in an Open Source Software approach.

The ARIS case has a strong software part, and one of the conditions for success is that the system is reliable and not error-prone which is a condition for user acceptance of the system. To maintain the code-base constantly in good shape needs experienced software developers. This is a challenge to be achieved in a compatible way to the Appropriate Technology principle that the technology should be maintained by local stakeholders without the need for external expertise.

The high level of skills required to develop and maintain the code-base of a software project bring some serious challenges for sustainability and support. In the ARIS case, no single university is likely to have both the capacity and the acceptance of the other universities to maintain a software system like ARIS on its own. This makes the question of appropriate support and sustainability a crucial one. Donor funding with the development cooperation project was limited to the time needed to develop the system and to do a certain amount of user training. The knowledge transfer and the building of appropriate local structures with accompanying negotiations between the stakeholders will take a longer time. To summarize, the complexity of the system itself is a big challenge for the sustainability of the system and its necessary accompanying support units.
6. Results
In the following the results of the study are presented. First the overall usefulness of the Appropriate ICT framework is reported. Then the two elements of the framework are viewed separately: the “guiding questions” are analyzed for completeness, and guidelines are presented for appropriate tool development.

6.1 Usefulness of Appropriate ICT framework
In our study we have found the following arguments in favor of the usefulness of the Appropriate ICT framework in the ARIS context:
- It gives a good picture of the project reality as it helps to discover ignored aspects.
- The guiding questions can be applied repeatedly throughout the project lifetime to react on changing project realities.
- Analysis through guiding questions aids in proper tool selection.

6.2 Completeness of guiding questions
The guiding questions comprise questionnaires in three areas: hardware, software and change management. The completeness of the questionnaires is considered as follows:
- The hardware guiding questions gave a complete picture of project reality by revealing given challenges with Internet connectivity, environmental factors and staff competency.
- The software questionnaire covered many important aspects. The following should be considered and integrated:
  • In order to analyze the complexity of a project it is important to distinguish if existing software is used or software is developed as a part of the project. In the latter case the complexity of the project is increased and proper staff is needed, even after the construction phase has finished, during operation and maintenance.
  • Software requires skills in three different areas: user skills, technical skills for system maintenance and software development skills. This distinction is not present in the questionnaire.
- While in the area of organizational change many challenges were revealed, some of which have not been properly dealt with in the ARIS project, the questionnaire gave a good picture in terms of completeness. The application of the questionnaire showed that the area of organizational change was undervalued in the project as it was set up in relation to hardware and software.

6.3 Tool description
The Appropriate ICT framework in its current form does not provide guidelines for the description of tools, while a good description of tools makes them easier understood and reusable in other projects. We found in the analysis of tools used in the project that there is a common set of characteristics that are helpful to give a concise description of tools, and we suggest to add to the Appropriate ICT framework a set of tool description questions as follows:
• What is the context for which the tool is appropriate?
• What is the problem to be solved by the tool and what is the goal to be accomplished?
• How does the tool relate to local culture, environment, organization, economy and/or politics?
• In which step(s) of the System Development Life Cycle (SDLC) is the tool used?
• What are the necessary preconditions, e.g. availability of resources?
• What potential difficulties can arise as a consequence of the application of the tool (risks)?
• Are there any indicators which can be used to measure the success of the tool?

Table II shows an example how a tool can be described based on the given set of questions.

### Table II: Example of a detailed description of a tool

<table>
<thead>
<tr>
<th>Tool: Involvement of local software developers during system development: Report and scholarship modules development on Mozambican side.</th>
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<tbody>
<tr>
<td>Context: Development cooperation project where a software development team in the developed country needs to transfer knowledge to a software development team in the developing country.</td>
</tr>
<tr>
<td>Description: The tool is about giving parts of the system development to the local side; at the beginning small parts and increasingly bigger parts. This is a form of knowledge transfer. The process needs to be initiated by a proper training of the relevant aspects of the system.</td>
</tr>
<tr>
<td>Phase: Construction</td>
</tr>
<tr>
<td>Problem addressed: Missing capacity of local software developers.</td>
</tr>
<tr>
<td>Goal of tool use: Local software developers shall be able to execute basic software development tasks for the application.</td>
</tr>
<tr>
<td>Potential difficulties:</td>
</tr>
<tr>
<td>• Local software developers need some guidance. This is difficult if the competent contact persons are far away in the developed country. This can be facilitated by the presence of a development worker who stays with the community of local software developers.</td>
</tr>
<tr>
<td>• Conditions for local software developers may not always be appropriate. They may have other duties besides their involvement in the project so they need the commitment by their superiors, sufficient time and proper equipment.</td>
</tr>
<tr>
<td>• The structure of the software system and its code base needs to allow that people in different locations around the world do not interfere with each other when working on the system. This can be facilitated by a modular structure and a central code repository.</td>
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</tbody>
</table>
The practical experience in ARIS is that local guidance and proper working conditions make a big difference. After a three-weeks developer workshop in the Netherlands one team of local software developers got the task to develop a scholarship module. Although the module was specified and designed, the local team did not achieve to continue their work once they team members returned to Mozambique. They had other duties and missing commitment from their superiors. Another example was the development of the reporting module which was successfully developed by another local team supervised by a development worker. After that many other tasks have been done by the same programmer under supervision and increasing communication with the team in the Netherlands via a mailing-list. In this case, the competency is present for the university to further adapt the ARIS for their own needs as well as being a resource for further development of ARIS in general.

7. Conclusions

The case study confirms that ICT projects in the developing world are confronted with major challenges. Scarcey of equipment, financial means and skills demand careful assessment of the needs and often require alternative approaches. The Appropriate ICT framework promises to be useful to tackle the complexity of ICT projects in developing countries.

In this paper we made observations of software characteristics in relation to Appropriate Technology principles, evaluated the usefulness and completeness of the Appropriate ICT guiding questions and suggested a framework for development of appropriate tools which fit into the Appropriate ICT framework. We recommend further development of appropriate tools in order to aid practitioners in successful ICT project implementations.

References


