Scalability factors in an ICT4D context

A literature review

Melchior Keijdener
Department of Information and Computing Sciences, Utrecht University
Utrecht, The Netherlands
M.N.C.Keijdener@uu.nl

Sietse Overbeek
Department of Information and Computing Sciences, Utrecht University
Utrecht, The Netherlands
S.J.Overbeek@uu.nl

Sergio España
Department of Information and Computing Sciences, Utrecht University
Utrecht, The Netherlands
S.Espana@uu.nl

ABSTRACT

This research investigates possible scalability factors that influence an ICT4D project. By performing a literature study on four strands of literature, which include: technical literature (1), development studies (2), technology adoption (3) and ICT4D literature (4), it was found that there are seventeen factors that need to be accounted for in the development process. Furthermore, a general outline of an ICT4D development process is presented and scalability factors are related to phases in this ICT4D process. Future research could focus on validating these factors by using them in a development cycle and determining the precise influence, rather than determining an overall positive or negative influence.

KEYWORDS

Agile framework, Development process, ICT for development, ICT4D, Scalability

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1 INTRODUCTION

The failures in ICT for development (ICT4D) projects is a topic heavily discussed in the academic world. Although there are many possible explanations for these failures, they can be summarized into three categories: a lack of sustainability (1), evaluation (2) and scalability (3) [14]. First, Heeks [14] noted that many projects are not sustainable as ICT4D developers often aim for a quick-fix of the problem, but fail to deliver a complete and comprehensive system which lasts after the cooperation with the developers ends. Second, ICT4D projects are often not evaluated. Therefore, mistakes are repeated, lowering the quality of the development project. Third, scalability is not always accounted for. This results in many ICT4D projects that are aimed at a small community of not more than a couple of villages maximum. As ICT4D projects are hardly ever implemented on a provincial or national scale, this leaves a lot of untapped potential.

The issue of scalability is not a new one. Haikin [17] established parallels between the problems in ICT4D projects and problems that plagued the regular software industry several years ago. He states that the regular industry has dealt with a scalability problem as well, as the increase in size of software projects leads to the delivery of a system that becomes too big and too complex, thus becoming unusable. One important contributor to the solution of this problem has been the adoption of agile methods. Therefore, the use of agile methods will likely benefit ICT4D projects as well.

However, most of these current methods are tailored towards Western needs and knowledge which makes them incompatible with a development context [14, 31]. For example, it is not possible to perform pair programming when there is only one software developer on the team and it cannot afford more developers due to budget size. Therefore, to counteract this problem, different kinds of development methods are required. Fortunately, as ICT4D gains more interest in the scientific community, scholars like Haikin and Duncombe [11], Ferrario et al. [10], Bon et al. [5] and Doerflinger and Dearden [7], combine agile methods with development practices to create robust frameworks for ICT4D development.

However, these frameworks are no silver bullets. Issues as sustainability and scalability still remain a problem to be solved and this is not aided by the fact that the terms are interlinked in literature [18, 20]. As Haikin and Flatters [12] stress that a distinction should be made between the two terms, this paper will aim to focus on scalability only, which can be defined as the process of expanding the size and scope of an ICT project within a particular setting or incorporating it into other settings [29].

Despite that multiple authors already came up with sustainability factors and evaluation models [21, 26], to the best of our knowledge, no work exists that focuses on systematically identifying scalability factors in ICT4D projects. Therefore, the main goal of this paper is to identify multiple factors that help designing for a scalable ICT4D project. Additionally, it will propose a way of incorporating these factors in the agile development process, to prevent the return to a linear development process.

The paper is structured as follows. In section two, the concept of scalability is studied from four different fields. Then, section three provides an overview of all found scalability factors (groups) and proposes to incorporate these factors in a method. Next, section four discusses a related work. Finally, limitations are given in section five and the research is concluded in section six.

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2 SCALABILITY FACTORS

This research analyzes scalability in four different contexts and derives factors from those strands of literature. First, factors that technically limit growth are derived from technical literature (1). Then, as development studies (2) are oftentimes concerned with size growth in regular development projects, factors from this strand of literature are analyzed. Next, factors that might limit the acceptance of a new technology are found in literature on technology adoption (3). Finally, factors from existing ICT4D literature (4) are incorporated.

2.1 Technical literature

In technical literature, a system has a scalability problem when any resource is overloaded or exceeded [30]. Weinstock and Goodenough [30] have identified five kinds of bottlenecks that can occur. Administrative bottlenecks (1) occur when the workload on the system increases and the staff cannot keep up. Capacity limits (2) is a bottleneck that is often hard-coded, which can limit growth eventually. The user interface (3) can become a bottleneck in multiple cases. First, the change of the UI in case of an increased workload; more information in general means that there is more to communicate with the user. Second, a growth in information means a growth in waiting times for the user. The user might need some sort of selection/termination system to control the waiting times. Algorithmic performance (4) can become a bottleneck when the workload becomes larger than the algorithm can deal with. Finally, centralized control (5) can lead to resource bottlenecks. Therefore, a move towards decentralized control might be necessary for large scale systems.

2.2 Development studies

In development studies, an important requirement for achieving scalability is planning [9, 13, 16, 19]. Farrington and Lobo [9] suggested a couple of mechanisms that should be in place; for promoting the approach for political and administrative boundaries, and for channeling the funds as efficiently as possible. Also, cooperation with local parties and government is emphasized [8]. Mansuri and Rao [16] also suggest using a bottom-up approach, bringing change through incremental iterations. Hartmann and Linn [13] have developed a framework with several spaces and values. A key element of this framework is vision. To scale a project successfully, many actors must share an ideal or goal where they wish the technology to grow to. They define the following spaces: fiscal, political, economic, capacity, cultural, learning and partnership. All these spaces must exist, if there is a wish to grow the project. Additionally, it is important to start thinking about scaling from the beginning, as it takes time for scaling to have any effect [4]. Many of these thoughts have been incorporated in a scalability strategy [19]. In conclusion, a correct set of mechanisms, sufficient space for growth and a clear scalability strategy all have a positive influence on the scalability of a project.

2.3 Technology adoption

In the field of technology adoption, Rogers [22] was one of the first sociologists to formally describe technology adoption with his adoption model. This model identified five attributes that a technology needs to possess to be adopted. First, it should provide a clear advantage over the old technology. The technology should improve someone's life, otherwise people will not see the added value of it. Second, the technology must fit into the mindset of the consumer (compatibility). Especially in ICT4D projects this can lead to problems, as many of the rural poor are unfamiliar with ICTs and their capabilities. Therefore, a process of familiarization is required. Third, a technology should be easy to understand and use (complexity). If it is too hard to use or learn, people will not use it. Therefore, it is emphasized to use human centered design techniques when developing ICT4D solutions [14]. Fourth, a technology needs to be accessible and testable (trialability). People are more keen to adopt a technology they have tried before and can try without obligations. Finally, the more visible a technology is, the more likely it is to be adopted (observability). Interest in the technology will grow as more people are exposed to it while small technologies are likely to remain unnoticed. Therefore, the fulfillment of these attributes all increase the scalability potential of a project.

2.4 ICT4D literature

In ICT4D literature, there are already many known, positive factors that affect scalability. To begin with, there is a required level of technical competence of the staff [29], as a high competence is needed to successfully scale a product. Furthermore, the use of human centered design techniques should ensure a (simplified) fitting user interface [1]. A less complex product is easier to scale. Additionally, a reliable infrastructure is needed (i.e. hardware, electricity, Internet access). This can be done in three ways. First, using low-cost robust terminals that can withstand the harsh local conditions [25], second, keeping in mind the access to electricity [1] and third, using satellite (3g/4g) over land-based systems [14]. Next, the entry barrier to the market should be kept low and the project should be decentralized to enhance scalability potential, allowing it to run locally without interference from the development team [1]. Furthermore, Sæbø and Thapa emphasized that salient stakeholders are vital for scaling up a pilot study, as the lack of these stakeholders prevents a pilot study from being successfully replicated [23].

Additionally, high financial sustainability has been pointed to as an important positive factor in scalability [6, 15, 18, 29]. A viable business model is essential as donors only temporarily support a project. On the contrary to the positive factors, bureaucracy in developing nations might play a role. A high bureaucracy slows down the implementation of an ICT4D project [6]. Finally, Tongia and Subrahmanian have noted the importance of geographical location [27]. Some projects might work only in a specific culture or region, scaling is only possible if the esteemed area has similar institutions. High geographical limitations therefore reduce the scalability potential.

On a related note, much research has been performed to study the combination of information systems in (ICT) development context (ISDC). One noteworthy thing is that scaling is a term not often discussed in ISDC literature and when it is, it usually focuses on the technical artifacts rather than on social issues [24]. In this context, scalability can be defined as the extension of a project to a fully operational information system [3]. Here, a low technological complexity, high political support and sufficient human resources positively influence the scalability potential. Unanticipated effects can either positively or negatively influence the scalability potential, depending on the situation [3]. A final important aspect about the ISDC is impact [2]. Avgerou [2] defines two types of impact that ISDC have: progressive transformation and disruptive transformation. Progressive transformation considers ICTs as an enabler of innovation and welfare. These are accommodated with existing institutions and social order, thus improving the scalability potential. Disruptive transformation often brings change to the target audience, but also reveals conflicts of interests and struggles of power. Even though ICTs have potential to increase democratic structures within the world, countries with widespread bureaucracy and corruption might not be willing to accept them, thus decreasing the scalability potential.

3 TOWARDS A SCALABILITY MODEL

From the literature, it is evident that there are many factors that have an influence on the scalability of an ICT4D project. In table 1 an overview of these factors have been given. All factors have also been provided with an effect on the scalability in ICT4D projects; a positive one (+), a negative one (–) or one that is unknown or context depended (+/-).

Scalability factor	Effect
Use of human centered design [1]	+
Low entry barrier to market [1]	+
Decentralization of network [1]	+
Good application of algorithms [30]	+
High political support [3]	+
Sufficient human resources [29]	+
High financial sustainability [18]	+
Correct mechanisms in place [9]	+
Proper infrastructure [1]	+
Fulfillment of adoption attributes [22]	+
Use of robust hardware [25]	+
Sufficient space for growth [13]	+
Use of a well planned strategy [19]	+
Nature of transformation [2]	+/–
Unanticipated effects [3]	+/–
High geographical limitations [27]	–
High amount of bureaucracy [6]	–

Table 1: Scalability factors on ICT4D projects

3.1 Common ICT4D development phases

By analyzing the frameworks of Haikin and Duncombe [11], Ferrario et al. [10], Bon et al. [5] and Doerflinger and Dearden [7], an outline of a development method has been derived to clarify what phases and characteristics an ICT4D project generally has. The frameworks have been compared through the use of Process Deliverable Diagrams (PDD)[1] to create meta-models of the framework and to gain insight in what phases, activities, steps and deliverables are part of it [28].

[1]The PDDs can be found at: https://osf.io/ujpa7/

From analyzing these PDDs, it becomes clear that the frameworks have a similar structure. Most start with a phase of preparation, where the environmental factors and stakeholders are identified. The goal of this phase generally is to gain an understanding of how the environment works, to make initial partnerships and to get an idea of what the research team needs to cope with. Factors that correspond with this phase are e.g. the *analysis of political support* and the *assessment of infrastructure*. Bon et al. [5] and Doerflinger and Dearden [7] especially mention the establishment of a research team, so *human resources* should be gathered in this phase. This phase has been named understanding. The second phase is often one of requirement gathering. Its goal is to get an idea of what the local population needs, i.e. the project that the research team will design. This will include all scalability factors that relate to the needs of the local population. The third phase is therefore its formalization (design), where requirement analysis techniques are used to get clear requirements and formulate a design. Popular techniques are user interface drawings and prototyping. A relating scalability factor is the use of *human centered design techniques*. The fourth phase is often a sustainability assessment (sustainability analysis). A corresponding factor here is the *high financial sustainability*. The precise position in the process changes, where some place it before the requirements analysis [11], some between the requirement analysis [5, 7] and the build and some after the build [10]. The final phase is the build (development), where the prototype is iteratively developed into the final product and implemented. Here for example, it is determined which *algorithms are used*. After this, a feedback loop ensures that bugs can be fixed and the prototype is updated.

Scalability factor	Proposed phase
Low entry barrier to market [1]	Understanding
High geographical limitations [27]	Understanding
Sufficient space for growth [13]	Understanding
High amount of bureaucracy [6]	Understanding
High political support [3]	Understanding
Sufficient human resources [29]	Understanding
Correct mechanisms in place [9]	Understanding
Proper infrastructure [1]	Understanding
Use of human centered design [1]	Design
Nature of transformation [2]	Design
Fulfillment of adoption attributes [22]	Design
Use of robust hardware [25]	Design
Well planned strategy [19]	Sustainability analysis
High financial sustainability [18]	Sustainability analysis
Decentralization of network [1]	Development
Good application of algorithms [30]	Development
Unanticipated effects [3]	All phases

Table 2: Scalability factors and their corresponding phases

3.2 Applied factors to each phase

As discussed by Begovic et al. [4], it is important to start a plan to scale from the beginning. However, since not all factors are immediately relevant at the start of a development project, each factor has been classified on the specific characteristics of its corresponding phase, as shown in table 2. This is done by a single researcher but is reviewed by two others until an inter-reviewer agreement is reached. A notion is required for unanticipated effects (such as natural disasters), which can occur at any time in the development process, meaning that in all phases the research team should be capable to deal with them.

4 A RELATED WORK

Haikin and Flatters [12] discuss scalability and identify specific problems through an industry survey. They found that the biggest challenge to scalability is not the scaling of size or reach itself, but to keep it sustained over a longer period of time. An interesting notion is that there is a gap in literature and their survey results: around fifty percent of their sample admitted to scale their project successfully. However, even though they emphasize distinguishing scalability from sustainability, the paper does not provide a clear answer on what is meant with these terms.

5 DISCUSSION

As with every research, this one is not without its limitations. First, there is no way to check for the completeness of the factors. Additionally, the connectivity between the terms sustainability and scalability might cause these factors not to exclusively influence scalability, but sustainability as well. This also means that there can be factors which influence scalability, but are not mentioned as such in the literature. Next, this research does not answer the problem of factor trade-off. Even though it is estimated that a factor is negative or positive, it does not provide an answer to how big this impact is. Finally, these factors have not yet been sufficiently validated. This paper merely proposes the connection of the factors to the phases, but further research is needed to validate these links.

6 CONCLUSIONS AND FUTURE RESEARCH

The conclusions of this research are twofold. First, seventeen factors that affect scalability have been identified. Second, a proposition is given of when these factors affect a project and in which phase of the development process they should be dealt with. This way, developers of an ICT4D solution can incorporate these factors during the development process, resulting in an easier scaling of the solution if desired (assuming their project has successfully met local needs). Based on the discussion, there is some future work that can be performed. One, is to figure out how large the impact of each factor is on the scalability of a project, and how this might differ per project. Two, is to use these factors during an ICT4D development process to see if they fully cover the scalability aspect of the project, thus increasing their validity and completeness.

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