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ICT for Development in a Post-2015 World:
How to conceptualise ICT4D in the context of the Sustainable Development Goals

Franz-Ferdinand Rothe
Vrije Universiteit Brussel (VUB)
Pleinlaan 9
1050 Ixelles, Belgium
+32 026148617
rothe.franz-ferdinand@vub.be

ABSTRACT
The understanding of the notion of ICT4D (ICT for Development), strongly depends on what is understood by *development* itself. Hence, this article argues that the introduction of the Sustainable Development Goals (SDGs) in 2015 must be understood as a caesura not only for conceptualising development, but, in turn, for conceptualising ICT4D, as well.

On the basis of literature review, this paper analyses the SDG framework and applies it to theories of ICT4D, outlining the implications of transitioning to the post-2015 concept of *sustainable development*, beyond the cosmetic reflex of adding an 'S' to the acronym. In doing so, this article aims to sensitise the reader towards the challenges and potential dilemmas emerging from this transition, which go far beyond the Agenda's new topical areas, and to spark debate on how to conceptualise ICT4D in response.

Keywords
ICT4D; Sustainable Development Goals; policy coherence

1. INTRODUCTION
The notion of ICT4D (Information and Communication Technologies for Development), encompassing the role of ICTs in development, has evolved alongside the shifting paradigms of development itself [1]. Having advanced from a modernist focus on North-South ICT transfer for economic growth, ICT4D has been attributed increasingly multi-dimensional potential, as the international community has embraced concepts such as human or sustainable development [2,3]. Analogously, coming from the early enthusiasm around, for example, colourful laptops that promised to automatically modernise not only the African classrooms but also the continent's economies and societies, theorists have reached a more nuanced conception of ICTs being only as valuable (or harmful) as the interventions in which they are embedded.

Given that what we mean by ICT4D thus depends on what we mean by development, this paper argues that the introduction of the United Nations' Sustainable Development Goals (SDGs) in 2015 must be understood as a caesura not only for conceptualising development, but, in turn, for conceptualising ICT4D, as well. On the basis of literature review, this paper analyses the SDG framework and applies it to theories of ICT4D, outlining the implications of transitioning to the post-2015 concept of *sustainable development*, beyond the cosmetic reflex of adding an 'S' to the acronym. In doing so, this article aims to sensitise the reader towards the challenges and potential dilemmas emerging from this transition, which go far beyond the Agenda's new topical areas, and to spark debate on how to conceptualise ICT4D in response.

2. WHY SDGs?
While there is a general consensus, at least among theorists, that ICT4D should relate itself to development that goes beyond pure economic growth and that takes account of the multiplicity of local realities [1] , the question of how to exactly define the *D* in ICT4D (and in general) is still debated. Zheng et al [1] argue that "ICT4D researchers often lack nuanced appreciation of what is development, both in terms of what constitutes a developmental outcome and which development processes are involved."

Literature theorising the *D* is ample [1] and works such as Kleine's adoption of Sen's Capability Approach [4] undoubtedly enrich the debate, offering crucial foundations for research. When considering ICT4D as a practice, however, it can be argued that this multitude of theoretical approaches also adds to the fragmentation of the field, increasing the blurriness of what ICT4D actually means. A fragmented definition of *development* bears a number of risks.

2.1 The risks of a 'bubble life'
If, following Heeks [5], we define ICT4D by "technology [being] used to help deliver on the international development agenda" [5], the understanding of the *D* should be aligned with that of the international development community. Misalignment, on the other hand, could first of all potentially side-line ICT4D as a disconnected bubble, not being integrated in the efforts of international organisations and governments. This disconnection, in turn, puts the notion of ICT4D at risk of being appropriated or 'hijacked' by players, who - by fault of flawed concepts or vested interests - fail or even undermine the global development efforts.

In practice, this appropriation can entail what Tim Unwin dubbed "'Development for ICTs' (D4ICT), where governments, the private sector, and civil society are all tending to use the idea of 'development' to promote their own ICT interests" [6]. Moreover, even with good intentions, ICTs can be used for interventions which are based on outdated development concepts and hence fail to improve or even end up worsening the issues they mean to tackle. This seems to be a particularly likely risk for ICT4D interventions, which have proven prone to lagging behind the shifting development paradigms, often still focusing on a modernist approach of "rather unilinear processes of technology transfer" [7].

2.2 The roadmap exists

If we want ICT4D to have an impact on and be integrated in global development processes, defining the notion of *development* should hence not be treated as a task for the ICT4D bubble. Much rather, its conception should be in line with the understanding agreed upon by the international community – and one does not have to look far to find this shared vision. When the SDGs were adopted with the 2030 Agenda for Sustainable Development in September 2015, the set of 17 goals encompassing 169 targets were the outcome of several years of consultations with governments, international organisations, the private sector, academia, and civil society [8]. As noted by Sachs [9], the goals "are meant to orient the world in clear, specific, measurable, concise, and understandable ways".

While critiques on the SDGs are plentiful, their mere existence makes them "the single most-important force shaping the future of international development and, hence, the single most-important force shaping the future of [ICT4D]" [10]. Considering that research indicates that ICT4D interventions have "not produced substantial and sustainable impact […], unless they are embedded in long-term development processes" [1], the SDG framework offers a clear roadmap to align ICT4D efforts with such processes.

3. WHAT IS NEW ABOUT THE SDGs?

In order to assess the implications of the SDG framework for ICT4D, we must consider the novel nature of the SDGs, in contrast to their predecessors such as the Millennium Development Goals (MDGs), which had guided development efforts since 2000. As LeBlanc [11] synopsises, "[t]he novelty of the SDGs […] is that they aim to cover the whole sustainable development universe, which includes basically all areas of the human enterprise on Earth."

The obvious novelty of the SDGs' widening scope of goals concerning "people, planet and prosperity" [8] might suggest that post-2015 ICT4D simply faces a widening 'playing field', which would be a short-sighted assumption. In fact, the holistic architecture of the SDGs goes far beyond these new topical areas.

The resolution adopted by the UN General Assembly [8] defines a "universal Agenda" of goals and targets that "are integrated and indivisible, global in nature and universally applicable," [8]. These notions represent three novel characteristics of the SDGs, which are (1) the holistic scope of targets, (2) their applicability for all countries alike, and (3) their essential interconnectedness and interdependence. While the former of these aspects has been subject to research from many sides, the latter two shall be central to the remainder of the paper. Section 4 will demonstrate the link between (1) the topical and (2) the geographical conceptual expansion before discussing their implications for (3) policy coherence in Section 5.

4. ICT4D AND UNIVERSALITY

The SDGs large amount of new goals, covering areas across the economic, social and environmental dimensions of sustainable development, can be understood as new opportunities for ICT to play a role in international development. ICTs, while recognised as integral drivers for sustainable development, are featured surprisingly little in the SDGs, being mentioned in merely four of the 196 targets. This striking absence was met by a significant amount of research, making the implicit potentials of ICT to support the SDGs explicit [12, 13, 14].

However, these new target areas in which ICTs can be utilised represent only one aspect of how the landscape for ICT4D changes in light of the SDGs. The holistic nature of the Agenda also widens the horizon of development in a geographical sense.

4.1 ICT 4 Global Development

As opposed to the MDGs, the SDGs acknowledge sustainable development as a global challenge, being "universal goals and targets which involve the entire world, developed and developing countries alike" [8]. In fact, this can be understood as a result of the widened topical scope.

The Global North might be more developed with regards to 'traditional' development issues such as absolute poverty or health. Areas such as climate change, sustainable production, or reducing inequalities, however, are as much a challenge for the Global North as they are for so-called developing countries. In the words of Jeffrey Sachs, "[t]he United States, just like Mali, needs to learn to live sustainably. The rich countries like the poor have to promote more social inclusion, gender equality, and of course energy systems that are low carbon and resilient" [9]. In a Post-2015 world, there is hence no longer such a thing as a *developed world.*

4.2 'Everything' is ICT4D?

This widened topical and geographic understanding of development leads to a number of potential dilemmas, when applied to ICT4D. Following the holistic and universal interpretation, ICT4D becomes a field going far beyond its traditional conception. To give an example, using big data to improve public transport in Brussels does, according to this definition, represent as much of an ICT4D intervention, as does a smart farming project in Burkina Faso.

On the one hand, this corresponds with the development challenges of our time. A better public transport, to stick with this example, does not only correspond to SDG11 on sustainable cities and, in turn, help reduce inequalities (SDG10) by improving mobility and thus increasing people's access to employment (SDG8), education (SDG4), and health care (SDG3), to name a few examples. Beyond their local impacts, such interventions also have an effect on climate change (SDG13), thus affecting the planet as such, including so-called developing countries, which carry the biggest burden of global warming.

On the other hand, however, it might be understandable if ICT4D practitioners question the practicality of such a definition of their field. While the old and largely overcome understanding of ICT4D as merely fostering economic growth in the Global South is clearly misaligned and counterproductive to the global development efforts, taking the SDG narrative literally could arguably pose the risk of diluting the notion into a meaningless catch-all term.

These two poles thus provide a spectrum, reaching from a clearly outdated development concept to an approach that might prove too idealistic to (yet) fully apply to ICT4D (see Figure 1). This paper

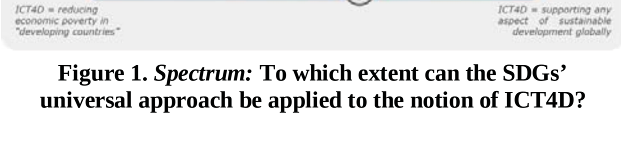

Figure 1. ***Spectrum:*** **To which extent can the SDGs' universal approach be applied to the notion of ICT4D?**

does not aim at providing an answer to this dilemma. Much rather it hopes to sensitise stakeholders towards this spectrum, along which ICT4D must consciously and rationally be situated.

5. ICT 4 INTEGRATED DEVELOPMENT

As indicated in Section 3, another defining novelty of the SDG architecture can be found in the "deep interconnections and many cross-cutting elements across the new Goals and targets" [8]. The network character of the goals adds another crucial element of complexity. As the goals and targets are "integrated and indivisible" [8], coherence must be ensured between all of the SDGs' 169 targets. The network architecture of the SDGs shall at this point briefly be outlined, before its implications for ICT4D are assessed.

5.1 A network of goals

In a Working Paper for the UN Department of Economic and Social Affairs, David Le Blanc [11] analyses the manifold links between the 169 targets, which spin a complex network between the 17 goals. As the intricacy of Figure 2 indicates, most areas of sustainable development are featured not only in their specific goal, but are highlighted in the targets of other related goals as well [11].

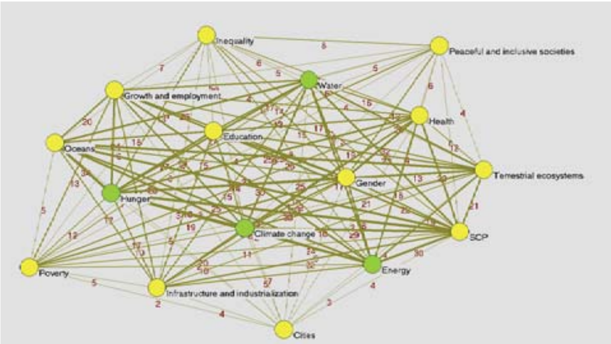

Figure 2. Links between SDG targets and other goals [11]

This network architecture responds to the fact that "[t]he interlinkages […] of the Sustainable Development Goals are of crucial importance in ensuring that the purpose of the new Agenda is realized." [8] To provide an example, sustainable economic growth (SDG8) cannot be achieved, unless women are allowed to work, linking it strongly to gender equality (SDG5). Women will not enter the work force, unless they receive proper education (SDG4), which in turn would positively affect issues such as maternal health (SDG3) and overcoming poverty (SDG1), just to name a few [15].

Acknowledging these interdependencies between the SDGs could "correct one of the drawbacks of the MDGs, in which 'silo' goals encouraged silo policies and did not make links and trade-offs across areas explicit" [11]. In a Post-2015 world, actors working in specific development sectors "will have to take into account targets that refer to other goals" in designing their interventions [11].

Translating this post-silo architecture into development action that does take the whole of the SDG Agenda into account, will represent one of the biggest challenges for development practicioners, including those working in ICT4D. As the following sections will demonstrate, this transition bears another potential dilemma for ICT4D, which should be debated within the community.

5.2 Coherence for Sustainable Development

On the one hand, the interconnectedness of goals indicates that an intervention in one of the areas of sustainable development can simultaneously support other goals as well. On the other hand, however, if the intervention is not coherent with the entirety of the SDG framework, its effects can undermine other objectives of the agenda. The work of Mackie et al. [16] on the transition from Policy Coherence for Development (PCD) to Policy Coherence for Sustainable Development (PCSD) explains why the struggle for coherence in the SDG context is becoming "infinitely more complex" [16].

Traditionally, the concept of PCD meant ensuring that domestic policies do not harm efforts of development policies. Its importance has often been illustrated by the prominent example of agricultural subsidies in Europe resulting in developing countries being flooded by European surplus products. Sold at dumping prices, these results of European agricultural policies had catastrophic effects on the economies and food security in the receiving countries, thus undermining Europe's development objectives [16].

In the framework of the SDGs, the relatively straightforward objective of considering a certain policy's potential effects on "the poor in developing countries" [16] turns into a far more complex challenge, assessing coherence with "many policy sectors, for all countries and for future generations as much as for the poor now." [16] As a result of the SDGs' holistic and universal approach, PCSD represents a multi-directional challenge, in which coherence must be achieved throughout the three dimensions of space, time, and the scope of development goals.

As opposed to the concept of PCD, PCSD in turn also acknowledges that the realm of *development* is no longer simply the protégé of policy coherence. Much rather, coherence must also be achieved within and between the various areas of development cooperation. If actors in certain areas of sustainable development disregard their potential effect on other goals, their interventions risk doing more damage than good. Without internal coherence, it will thus be impossible to deliver on the SDGs as a whole.

To quote an example used by Nilsson et al., "using coal to improve energy access (goal 7) in Asian nations, say, would accelerate climate change and acidify the oceans (undermining goals 13 and 14), as well as exacerbating other problems such as damage to health from air pollution (disrupting goal 3)." [15] For ICT4D projects in specific development areas, alignment with the SDGs thus means finding synergies with other areas, or, at least, preventing side-effects that may potentially undermine other SDGs.

5.3 SDGs as a Deadlock for ICT4D?

At first glance, the idea that measures to support one SDG should not undermine the rest of the goals appears self-evident and rather straightforward. On a closer look, however, the multi-directionality of coherence required for sustainable development presents another dilemma for ICT4D.

When practising ICT4D in line with the SDG Agenda, should projects hence be abandoned if they are incoherent with other goals? Clearly, this would be the logical consequence of the prior arguments laid out in this paper. When translating them into practice, however, it becomes obvious that a radical interpretation of these claims could put ICT4D, and arguably most other development sectors, into a deadlock.

Can practitioners be expected to forecast all potential "interactions within and between all the SDGs, everywhere, now and in the future" [16]? Is it even possible to have only ICT4D projects that use technology which has been produced sustainably and under fair conditions? Can we possibly guarantee a neutral environmental footprint for the technology that is used in ICT4D projects?

Mackie et al. argue that it is impossible to guarantee complete and absolute multi-directional coherence. However, while "trade-offs remain inevitable" [16], they must be addressed in a transparent manner, opting for the greatest possible coherence. ICT4D, like any other development sector, thus faces another spectrum, along which its position must be negotiated rationally and consciously.

Figure 3. *Spectrum:* What level of coherence can be granted without ICT4D becoming unworkable?

At one end of the spectrum, the outdated, yet not entirely overcome, approach of solely considering a project's desired direct outcome seems to offer a *road of least resistance* to achieving a specific goal. However, research on PCSD shows "the impossibility of delivering on all of the Agenda's commitments using a silo approach" [16]. At the other end of the spectrum, considering absolute coherence a requirement for any ICT4D project can be seen as a utopian approach, making ICT4D an almost impossible endeavour altogether.

This spectrum leads to the question, where a line should be drawn to avoid putting ICT4D in a deadlock? Arguably, ICT4D will never be entirely free from unintended side-effects, but does, for example, the energy consumption of Bitcoin, which already in 2014 matched that of Ireland [17], indicate that the e-currency should in fact not be used in the context of development? Or does a certain project empowering a certain group of people using ICTs actually enhance inequalities in a country or region, for example between those who have access to ICTs and those without?

When is a project's positive impact in its target area outweighed by its negative side-effects on others? Surely, there will not be a one-size-fits-all answer to this dilemma. Yet, it must be discussed how ICT4D actors can guarantee that these side-effects are being thoroughly and transparently assessed.

6. CONCLUSIONS

The introduction of the SDGs marked a caesura for conceptualising development. In turn, it must be understood as caesura for conceptualising ICT4D as well. As this paper demonstrated, defining ICT4D in a post-2015 world requires more than applying ICTs to the new areas of development and cosmetically tweaking the acronym to ICT4SD or ICT4SDG. The complexity of the SDG framework is mirrored in the complexity of challenges that must be faced in order to comply with it.

We cannot stop at the comfortable task of embracing the SDGs' new topical scope, which offers a new 'playing field' for ICTs to support international development. We must equally open the Pandora's Box of considering the complexity that results from this transition. Should ICT4D open up to the Global North, as development is no longer an exclusive challenge of the Global South? How close can ICT4D come to meeting the holistic and integrated SDG approach without becoming an unworkable utopia? How far can it afford to stay behind without failing or even undermining the SDGs by doing more damage than good? And how can practitioners, to whom these questions might not seem pressing or even relevant, be incentivised to acknowledge that sometimes no ICT4D project is the better choice for sustainable development?

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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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Improving ICT4D projects with Agile software development

Joost Dijkers
Utrecht University
Faculty of Science, Department of Information and Computing Sciences
Utrecht, the Netherlands
J.J.G.Dijkers@students.uu.nl

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

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

ABSTRACT

ICT4D seeks to bridge the digital divide in developing countries. Important requirements of ICT4D projects are a demand-driven approach and participation of the local community. The fact that user collaboration is a principle of Agile software development (Agile), triggers our interest on whether Agile practices can improve ICT4D projects. This paper aims to investigate if and how Agile can contribute to the success of ICT4D projects. In order to achieve this, existing literature was consulted and an interview was held. This paper provides an overview of the critical success factors for ICT4D projects and Agile, as well as of the advantages of Agile. Agile can only work successfully when ICT4D projects are demand-driven, and when both a cultural understanding and trust are built. Notable ways in which Agile can improve ICT4D projects are by facilitating user collaboration, improving team communication, enhancing organizational learning, and by frequently delivering software.

KEYWORDS

Agile, ICT4D, digital divide, user collaboration

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1 INTRODUCTION

The use of ICT in developing countries is the focus of an academic field called information and communication technology for development, or ICT4D for short [1]. ICT4D is aimed at how the benefits of ICT can be evenly divided between society to bridge the gap between the rich and poor. For example, ICT can improve creating, sharing, and enhancing knowledge, make production and transactions more efficient and cost-effective, and stimulate networking amongst parties (e.g. firms) [2]. However, high rates of failure exist for ICT4D projects [3, 4].

Agile Software Development (henceforth referred to as Agile) is a methodology for developing software and was found to increase the success rate of ICT projects [5]. Agile is collaborative, incremental, and iterative [6]. Collaborative development means that work is performed in teams rather than individually. For Agile, this also means that users should be included in the work process. Incremental development is a development approach in which the system is developed in a series of small steps. Iterative development means that the development activities, such as requirements engineering and software testing, are performed cyclically rather than sequentially. Furthermore, Agile is adaptive, which means that rapid change is supported [7]. Agile practices are summarized by Highsmith [7] as follows: 'short iterations, continuous testing, selforganizing teams, constant collaboration (...), and frequent replanning based on current reality'.

However, agile methods that have harvested success in western countries cannot be directly applied in ICT4D projects [8]. There exist multiple reasons for this. For example, increased user participation has proven to be essential in order to achieve ICT adoption [9]. Additionally, inhabitants of poor communities in developing countries often have no ICT or project management skills [10]. Furthermore, cultural barriers can limit or even prevent the cooperation of the local community [11, 12]. Research is thus necessary on to what degree Agile methods are compatible with ICT4D projects. In addition, research on the effects of using Agile methods in ICT4D projects is limited, as it is mainly focused on benefits of user collaboration. For example, using an Agile method was reported to allow developers to change the system in a natural way in response to unexpressed requirements and changes in business environment [13]. Furthermore, Agile methods make ICT more demand-driven and improve the involvement of users [14, 15]. This increased user participation of Agile methods also allows requirements to be elicited and knowledge to be created [14, 16]. To address these two problems, the following research question is formulated:

RQ: *To what degree can Agile software development improve ICT4D projects?*

The research question is answered by first performing a literature study on the critical success factors for ICT4D projects, the critical success factors for Agile methods, and the advantages of Agile methods. Then, the results of the literate study are analyzed.

The structure of this paper is as follows. In section 2 related work on Agile methods for ICT4D projects is discussed to find out why Agile is used in frameworks for ICT4D projects. In section 3 the method for arriving at an answer to the research question is given. In section 4 the results from the literature study on the critical success factors for ICT4D projects and Agile methods, and

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on the advantages of Agile methods are presented. In section 5 these results are analyzed to determine how suitable Agile methods are for ICT4D projects and in what ways they can improve ICT4D projects. In section 6 the analysis is discussed and related to existing literature. Finally, in section 7 an answer is given to the research question and suggestions for future research are given.

2 RELATED WORK

Bon, Akkermans, and Gordijn developed an ICT4D framework that is partially based on Agile [18]. Other inspirations of the framework are: Living Labs, use case analysis, and requirements engineering. The framework is specifically designed to address several ICT4D concerns, such as a lack of understanding of the local needs and the context. The discussed benefits of Agile are that it fosters creativity, personal commitment, and collaboration with the user.

Distributed Agile Methodology Addressing Technical Ictd in Commercial Settings (DRAMATICS) is an Agile method for commercial ICT4D projects [19]. The discussed benefit of Agile is the collaboration with users.

Speedplay is a framework for ICT4D projects which takes inspiration from Agile, Action Research, and Participatory Design [20]. Some of the inspirations from Agile are iterative development, flexibility, and collaborative development. The discussed benefit of Agile is the user collaboration.

The Nordic Model is a framework for ICT4D based on Nordic socio-cultural background and shared values, and is described as an Agile method [21]. The reasons for using an Agile method were frequent and immediate feedback from the users and informal communication to achieve equality and inclusion of all users.

These frameworks differ in terms of other inspirations (e.g. Participatory Design for Speedplay) or application (e.g. business ICT projects for DRAMATICS). However, all these frameworks have been tested in ICT4D projects with success. The success of Agile or Agile inspired frameworks suggests that Agile methods can be beneficial to ICT4D projects [22]. The primary reason for using Agile methods for ICT4D seems to be improved collaboration with the user.

3 METHOD

3.1 Research sub-questions

This paper aims to answer the main research question: 'To what degree can Agile software development improve ICT4D projects?'. It does so by answering the following research sub-questions (SQ):

SQ1: *Can Agile methods successfully work in an ICT4D project?*

An analysis is performed to determine if Agile can work successfully in ICT4D projects. It is essential for Agile to work successfully in order for the ICT4D project to succeed [24]. In order to analyze this, critical success factors for ICT4D projects and Agile are gathered. Critical success factors (CSF) are defined by Alias, Zawawi, Yusof, and Aris [23] as: 'Inputs to project management practice which can lead directly or indirectly to project success'. As such, CSFs give a good impression of where Agile methods might have an important effect.

SQ2: *How can ICT4D projects benefit from an Agile approach?*

The benefits Agile methods can bring specifically to ICT4D projects are discussed in order to understand how Agile can improve ICT4D projects. Data regarding the advantages of using Agile is gathered to answer this research sub-question.

3.2 Data gathering

These sub questions are answered by using existing literature. Google Scholar was primarily used as search engine, as well as IEEE Computer Society Digital Library and SpringerLink. Some common search terms that were used are: 'Agile software development', 'Agile software development advantages', 'Agile software development critical success factors', 'ICT4D', 'ICT4D critical success factor', and 'ICT4D Agile'. The forward snowballing technique was used as well.

CSFs for ICT4D projects were in literature referred to with the following terms: critical success factor, lesson learned, step (to ensure sustainable development), and activity (that led to success). For Agile, the following two terms were found and used to describe CSFs: critical success factor, lesson learned. Advantages of using Agile were sometimes also called benefits.

3.3 Data analysis

To answer the first research sub-question, the CSFs for Agile are discussed in the context of ICT4D projects and by relating these to the CSFs for ICT4D projects, resulting in a series of steps that need to be taken in setting up an ICT4D project before Agile can be applied. To answer the second research sub-question, a comparison between the advantages of Agile and the CSFs for ICT4D projects was made. For each CSF for ICT4D projects it was determined if Agile can improve the degree to which that CSF is satisfied.

3.4 Interview

In order to attain a greater insight into how Agile can improve ICT4D projects, an interview with ICT4D and Agile experts was held. A semi-structured interview is a good choice when the purpose of the interview is to elicit a person's viewpoint regarding a specific matter [25]. In a semi-structured interview, there are predetermined questions, but there is flexibility in asking these questions. For example, new questions can be added ad hoc. The results from the interview were used to validate the findings from the literature study, and are thus discussed in the Analysis section.

The interviewees are all part of the organization W4RA, of which the name stands for the Web alliance for Regreening in Africa. On its website, W4RA gives its mission as follows [26]: 'to support farmer-managed regreening activities specifically by enhancing information, communication, and knowledge sharing for rural development'. An example of an ICT4D project done by W4RA is RadioMarché [27], which is a voice-based market information system that allows farmers to advertise their products to communities in their local language. The interview was held with: prof. dr. Akkermans, who is the director; ms. drs. Bon, who is the program manager; and with ms. drs. Tuijp, who is the communication officer. When referring to their expertise, all three interviewees will be collectively referred to as 'the interviewees'.

4 RESULTS

4.1 Critical success factors for ICT4D projects

Monitor and evaluate project progress regularly (ICT4D-CSF1) [10, 28, 29]. Monitoring and evaluating project progress allows for the team members to measure the effects of ICT on development [29]. The goal of evaluation should be to discern changes in the welfare of the members of the local community, and to adapt the project accordingly. Evaluation should be an iterative and adaptive process. Monitoring and evaluating also allows for problems to be identified earlier, which, if acted upon, can ensure a more effective and efficient project [10].

An ICT4D project must be demand-driven (ICT4D-CSF2) [28–32]. The ICT4D project must satisfy the present needs while also allowing for the needs of future generations [31]. Furthermore, implementing an ICT4D project in an area where there is not sufficient demand will not result in a sustainable ICT4D project [28]. A critical element in achieving this is making sure that the stakeholders have ownership over the ICT4D project (ICT4D-CSF5) so as to increase their involvement in and acceptance of the ICT4D project.

Relevant skills must be built and trained (ICT4D-CSF3) [10, 28–31, 33]. Project management, implementation, and ICT skills are scarce in developing countries and need to be taught [10]. Illiteracy is also an important problem [34]. Building and training these skills can be expensive however, so mechanisms for knowledge sharing to reduce costs are recommended [31]. ICT training also helps overcome technophobia [35]. Finally, this training be a continuous process [28].

Efforts must be made to retain staff (ICT4D-CSF4) [10, 31]. The effects of talented staff leaving can be disastrous [31]. Other than traditional intrinsic (e.g. praise) and extrinsic (e.g. salary) rewards, project ownership (ICT4D-CSF5) can be a major motivational incentive due to the involvement it brings.

Project ownership must be given to local parties (ICT4D-CSF5) [28, 29, 31]. Local ownership is defined as the active participation of the local community in all phases of the development process [31]. Successful local ownership will result in the community viewing the ICT as an integral part of their daily lives [28]. Local ownership is related to two others CSFs: it improves the alignment of the ICT4D project to the needs of its stakeholders (ICT4D-CSF2) and it improves the motivation of staff (ICT4D-CSF4).

An ICT4D project must be economically self-sustainable (ICT4D-CSF6) [10, 12, 28–32]. Many ICT4D projects rely on donor money for their continued survival, which means these projects risk falling apart as soon as enthusiasm and funding from outside partners disappears [32]. Economic self-sustainability is therefore important to ensure the long-term success of ICT4D projects. However, donor money is important initially, because due to the experimental nature of many ICT4D projects it cannot be expected for these projects to be profitable from the get-go [18, 32]. One particular important aspect to ensure economic self-sustainability is marketing, because the inability to inform the community about the benefits of ICT4D projects is one of the main reasons why ICT4D projects fail [28]

Local partnerships must be built to achieve synergies (ICT4D-CSF7) [10, 28, 29, 31]. Ferguson and Ballantyne (2002) argue for the importance of building local partnerships (ICT4D-CSF7). A network of local partnerships will allow for the participants to gain access to resources they might otherwise not have had access to, such as skilled people or financial mechanisms [29, 31].

The creation of local content must be facilitated (ICT4D-CSF8) [10, 29, 30, 32, 33]. Local content is content being in local language as well as having inspiration from local culture, created by locals [32]. The reason for the importance of local content is that only a select portion of the population will be able to understand content from, for example, The United Kingdom, due to language and cultural barriers. An example of what local content can be is information for farmers regarding which vegetables can be grown on their fields [30].

The political context must be analyzed and considered (ICT4D-CSF9) [10, 29, 31–33]. The political situation in a country can affect an ICT4D project on two levels: micro and macro level [31]. On a micro level issues regarding ownership can arise due to a lack of defined ownership over processes and resources, or from unsuccessful transfers of ownership. On a macro level issues can arise due to increased bureaucracy or because the project is turned into a political statement.

An ICT4D project must have a project champion (ICT4D-CSF10) [10, 28, 29, 36]. Renken and Heeks [36] define an ICT4D project champion as follows: 'Any individual who makes a decisive contribution to the ICT4D project by actively and enthusiastically promoting its progress through critical stages in order to mobilise resource and/or active support and cooperation from project stakeholders'. Multiple ICT4D project champions are necessary, to reduce the risk of the project falling apart if an ICT4D project champion leaves the project [10].

The right technology must be chosen (ICT4D-CSF11) [10, 29–31, 33]. Ferguson and Ballantyne (2002) argue that the technology chosen plays an important role in the long-term success of ICT4D projects (ICT4D-CSF11). The reliability of ICT infrastructure, the availability of technology, and the maintenance and upgrading of ICT are key factors [31]. Technology also needs to be affordable for the people involved with the ICT4D project [10].

A cultural understanding of the local community must be developed (ICT4D-CSF12) [11, 33]. Cultural understanding can be necessary to avoid conflicts during the constant interaction between outsiders and the local community [11]. Cultural understanding can also be necessary to become accepted within the local community and gain their trust, as well as to gain access to their resources [12].

Trust between the local community and outside parties must be built (ICT4D-CSF13) [11, 12]. Trust can be a contributing factor to the willingness to cooperate with another party, and becomes necessary if that cooperation results in the trustor being put at risk [37]. In an ICT4D project the local community would be the trustor, and the outside party the trustee. There are two factors that determine the level of trust [37]: the trustor's propensity to trust and the trustee's perceived trustworthiness. The propensity to trust differs among individuals, but factors that influence the propensity are history with development, personality, and the culture. Trustworthiness has ability, benevolence, and integrity as antecedents. Ability refers to the skills and expertise of a party within a domain (e.g. knowledge about ICT). Benevolence refers to what degree the party desires to help the trustor without regard to extrinsic rewards. Finally, integrity refers the trustee's adherence to principles.

4.2 Critical success factors for Agile software development

A survey study to the CSFs of Agile projects on four dimensions to project success revealed six CSFs for Agile methods [24]. These four dimensions are quality (the quality of the delivered product), scope (to what degree the product meets the user's requirements), timeliness (whether the product is delivered on time or not), and cost (whether the real costs and effort put in were as projected). The six CSFs are discussed below.

Team environment (Agile-CSF1). A good team environment contributes positively to the quality of the product [24]. The entire team should be located in a single place, the team should be small, and the team should be self-organizing. If a project has multiple teams they should work collaboratively rather than independently. Teams should be small because as a team has more members, coordination becomes more difficult [38, 39].

Team capability (Agile-CSF2). Team capability positively contributes to the timeliness and cost of a project [24]. A good team member should have high competence, expertise, and motivation. A good manager should have an adaptive management style and possess knowledge on Agile. Additionally, relevant technical training should be provided to the team members. Highly competent team members are important to compensate for the smaller team size [38]. Finally, developers must possess domain knowledge in order to be able to communicate with the users [40].

User involvement (Agile-CSF3). User involvement positively contributes to the scope of the product [24]. To achieve good user involvement, a positive user relationship should be built. The user should have complete authority regarding the project. Finally, the user should have a strong commitment and presence.

Project management (Agile-CSF4). Project management processes positively contributes to the quality of the product [24]. Requirement management processes, project management processes, and configuration management processes should all be Agile. A working schedule should be put in place and followed. Progress should be tracked. There should be a strong focus on communication, for example with daily face-to-face meetings.

Agile software engineering techniques (Agile-CSF5). Agile software engineering techniques positively contribute to the quality and scope of the product [24]. These techniques are: coding standards, simple design, refactoring, limited but sufficient documentation, and integration testing.

Delivery strategy (Agile-CSF6). Delivery strategy positively contributes to the scope of the product, and the timeliness and cost of the project [24]. A good delivery strategy prioritizes the important features of the product first. Furthermore, software should be regularly delivered.

4.3 Advantages of Agile software development

More robust to changing requirements (Agile-ADV1). Requirements are inherently variable because both the developer and user acquire more knowledge about the domain of the application [41]. Requirements also change because the business environment in which the user is positioned is dynamic [42]. Agile methods are more robust to change than traditional methods because of two reasons [41]. First, Agile firms typically use a more simple software architecture, postponing any complex and binding changes as much as possible. This makes the architecture more robust to change. Second, Agile firms typically allow for requirements variability in the contract between the developer and the user. In those situations, users can specify or adjust requirements at the beginning of each iteration.

Improved communication with the user (Agile-ADV2). In Agile methods, face-to-face communication with the user instead of rigorous documentation is the norm [42]. The iterative nature of Agile allows for more frequent communication with the user. Furthermore, this more frequent face-to-face-communication allows for an improved elicitation and validation of requirements, which reduces the likelihood of requirements changing later on [42, 43].

Higher quality of software (Agile-ADV3). Software quality principles that quality professionals have been preaching for are included in Agile methods [6]. An example of such a principle is test driven development, which is an approach that suggests writing automated tests first, and code afterwards if the tests fail [44]. Frequent user feedback is also mentioned as a reason for improved software quality [39].

Increased user satisfaction (Agile-ADV4). There are several factors that contribute to this [45]: improved communication with users (Agile-ADV2), increased user involvement (Agile-CSF3), and the improved quality of software (Agile-ADV3).

Good, internal communication (Agile-ADV5). The required strong focus on internal communication (Agile-CSF4) results in an improved understanding of the requirements, tasks, project status, and resource allocation among all team members [43].

Improved employee job satisfaction (Agile-ADV6). Job satisfaction is higher for Agile methods for six reasons [46]: employees experienced less stress, felt more productive, enjoyed the internal communication (Agile-ADV5), found the job environment more pleasant and comfortable, were more motivated, and were more willing to continue using their software development method. The improved software quality (Agile-ADV3) also contributed to a higher job satisfaction [45].

A higher return on investment (Agile-ADV7). The return on investment (ROI) is higher in projects done with Agile methods for several reasons [47]: higher software quality (Agile-ADV3), increased user satisfaction (Agile-ADV4), lower costs, and higher productivity.

Increase in successful projects (Agile-ADV8). The more of the principles of the Agile approach is applied in the project, the higher the project success [5]. Hayes' study (as cited in [39]) attributed this occurrence to the iterative nature of Agile. An iterative cycle instead of a sequential cycle supposedly increases the visibility of the project. With this increased visibility the potential success of the project would then become clearer, which gives insight into whether adjustments can or have to be made, or if the project has to be cancelled entirely.

Improved control over projects (Agile-ADV9). Hayes (as cited by Mahanti [39]) argues that Agile methods improve the control over projects due to several reasons: 'Short iterations, multidisciplinary teams, knowledge sharing, continuous integration, and feedback'.

Improved organizational learning (Agile-ADV10). Agile methods focuses on teamwork and foster organizational learning within those teams [48], for example with pair programming [49].

5 ANALYSIS

5.1 Suitability of Agile software development for ICT4D projects

The suitability of Agile for ICT4D projects is analyzed by comparing the CSFs for Agile methods and for ICT4D projects.

A good team environment (Agile-CSF1) is also necessary in order for an ICT4D project to be successful. For ICT4D projects it is beneficial for all the team members to be located near each other, because an active presence within the local community can contribute to developing a cultural understanding (ICT4D-CSF12), and because ownership over the project by the local community requires their active participation (ICT4D-CSF5). However, this is not always possible for ICT4D projects. For example, according to the interviewees, members of W4RA go several times a year for extended periods. The goal is to do as much work as possible in those time frames, because it is not financially doable to remain there during the entire project. Another aspect of the team environment is that teams should be small, which fits with ICT4D projects because of budget restrictions.

User involvement (Agile-CSF3) requires cooperation with the local community, which is also important for ICT4D projects (ICT4D-CSF2). From the 'Critical success factors for ICT4D projects' section, important prerequisites for cooperation can be identified: developing a cultural understanding (ICT4D-CSF12) and building trust (ICT4D-CSF13). Multiple factors contribute to developing a cultural understanding. These factors are cultural interpreters, local partnerships, and a strong presence within the local community. For building trust the trustor's propensity to trust and the trustee's perceived trustworthiness are of importance.

An incremental Agile delivery strategy delivers software regularly, and prioritizes the most important features first (Agile-CSF6). Such a strategy allows for more user involvement [51], which subsequently means that cooperation is an important prerequisite.

The following three CSFs for Agile can be challenging to satisfy for similar reasons: team capability (Agile-CSF2), project management processes (Agile-CSF4), and Agile software engineering techniques (Agile-CSF5). Project management and ICT skills are often lacking in developing countries (ICT4D-CSF3). If people from the community are actively included in the software development process, they will need to be educated on Agile. This relates to both Agile processes in project management and Agile software engineering techniques. Furthermore, because ICT4D is a multidisciplinary field [50], not every team member may have a background in ICT. It is thus possible that people assigned to roles such as cultural interpreter or business strategy (to ensure economic self-sustainability) are not familiar with Agile either, and will also have to be educated. However, teaching Agile may not be difficult, or even necessary. According to the interviewees, it is not Agile that needs to be taught, but rather the principles behind Agile. So for example, the concepts of collaboration and iterations. Furthermore, according to the interviewees, these principles are shared with fields of science relevant for ICT4D, for example social sciences. If that is the case, teaching Agile (or rather, the principles behind Agile) to team members without an ICT background may not be a problem. After the training is done, Agile project management processes and Agile software engineering techniques need to be applied. One possible difficulty that can arise here is the interference of donors. According to the interviewees, the commitment of the team is stronger to the donors (who are the customers) than to the local community (who are the users). In the experience of the interviewees, managers of donor companies prefer contracts, clear roadmaps, and traditional software development.

Team capability (Agile-CSF2) requires two further considerations to be made. First, the team members need to possess domain knowledge, or gain domain knowledge through interaction with the local community. The latter method will require cooperation. Second, in satisfying the CSFs demand-driven (ICT4D-CSF2), local ownership (ICT4D-CSF5), and local partnerships (ICT4D-CSF7), motivation of the local community for the project is built. Both domain knowledge and motivation are important aspects of team capability.

In summary, several CSFs for ICT4D projects have to be considered before Agile can be used in ICT4D projects. First, the ICT4D project needs to be demand driven (ICT4D-CSF1). Second, Agile practices need to be taught to the local community members involved as well as to team members without an ICT background (ICT4D-CSF3). Third, a cultural understanding must be developed (ICT4D-CSF12). According to the interviewees, an ICT4D project should start out by looking at what the local community has, and by letting the local community explain what they do. Field research is important in this initial step, and the goal is to determine in what ways ICT could be used. In this initial step a cultural understanding can be developed, thus allowing Agile to be used once development initiates. Fourth, trust must be built (ICT4D-CSF13). Similarly to developing a cultural understanding, trust can be built in that initial step. However, trust cannot be fully built, because it is in iterative and dynamic process [37], which is also echoed by the interviewees. If a demand-driven approach does not build enough motivation within the local community, local ownership (ICT4D-CSF5) and building local partnerships (ICT4D-CSF7) also becomes a prerequisite for using Agile. Building local partnerships may also help building a cultural understanding (ICT4D-CSF7). According to the interviewees, local partnerships may also help building trust. Finally, one incompatibility between Agile and ICT4D exists. Agile may be incompatible for ICT4D projects because it is not always possible to work on location.

5.2 How Agile software development can improve ICT4D projects

The effects of Agile on ICT4D projects are determined by analyzing which advantages or characteristics of Agile can influence which CSFs for ICT4D projects.

Monitor and evaluate project progress regularly (ICT4D-CSF1). The improved control over projects (Agile-ADV9) suggests that Agile can contribute. In particular, the good internal communication of teams can be of benefit here (Agile-ADV5). The frequent meetings can (and should) be used to discuss the current progress of the ICT4D project. Furthermore, the frequent delivery of project deliverables (Agile-CSF6) and the feedback from users (Agile-ADV2) can help with regular evaluation.

An ICT4D project must be demand-driver (ICT4D-CSF2). Agile has several advantages that can contribute to ensuring an ITC4D project is demand-driven. First, user collaboration is one of the key pillars of Agile, and as a result Agile has good communication with the user (Agile-ADV2). Elicitation of requirements is done iteratively and frequently, ensuring that the ICT fits the demand of the users. Second, should requirements change, which occurs more than normally for ICT4D projects [17], then Agile has the advantage of being robust to change (Agile-ADV1). According to the interviewees, demos, prototypes, workshops and movies make the local community familiar with ICT and helps them understand how ICT could help them in their lives.

Relevant skills must be built and trained (ICT4D-CSF3). One result from section 5.1 is that skills pertaining to Agile have to be built and taught as well, thus making this CSF more time consuming to achieve. However, Agile might also help building and training Agile related skills and other ICT skills, because Agile methods foster organizational learning (Agile-ADV10). For example, pair programming helps build programming skills. The net effect of Agile upon building and training relevant skills is thus unknown.

Efforts must be made to retain staff (ICT4D-CSF4). Two benefits of Agile that can help are the increased job satisfaction of employees (Agile-ADV6) and increased organizational learning (Agile-ADV10). One research found that job satisfaction is negatively correlated to turnover intention, which is to say that increasing job satisfaction will reduce the intention to leave the firm (or the project) [52]. Furthermore, that same research found that an organizational learning culture is strongly, positively correlated with job satisfaction. Finally, the correlation between learning culture and turnover intention was not significant. However, organizational learning culture is still a good construct to increase employee retention, because organizational learning culture is indirectly linked to turnover intention through job satisfaction [52].

Project ownership must be given to local parties (ICT4D-CSF5). An important antecedent for user participation is the user's perceived support by the organization [53]. This can be achieved by, for example, listening to the problems of the users and solving these problems [54]. Agile can indirectly increase participation of the local community due to the positive effect of Agile for ensuring an ICT4D project is demand-driven. Furthermore, the good communication with users (Agile-ADV2) can help with facilitating participation.

A cultural understanding of the local community must be developed (ICT4D-CSF12). A strong presence within the local community helps develop a cultural understanding [12], which Agile contributes to by focusing on user collaboration and by improving user communication (Agile-ADV2). Furthermore, the good, internal communication (Agile-ADV5) and the improved organizational learning (Agile-ADV10) of Agile can help disseminate the cultural understanding throughout the organization.

Trust between the local community and outside parties must be built (ICT4D-CSF13). To summarize how trust is built, there are two important concepts: the trustor's propensity to trust and the trustee's perceived trustworthiness [37]. Agile cannot influence the trustor's propensity to trust, because there is no reason to believe Agile can influence factors such as personality or culture. Agile also cannot initially influence the trustee's perceived trustworthiness, because there is no reason to believe Agile can influence the ability of the trustee (although skills and expertise, such as domain knowledge, are required to make Agile work successfully, Agile-CSF1), the benevolence of the trustee, or the integrity of the trustee. However, the perceived trustworthiness of the trustee is dynamic and affected by the results of trust-taking behaviour of the trustor. In the context of ICT4D projects, trust-taking behaviour of the trustor can be considered as letting an organization into the local community or allowing them to develop ICT that will impact their lives. The iterative nature of Agile and the frequent delivery of working software (Agile-CSF6) will allow for more frequent outcomes of trust-taking behaviour. And the increased user satisfaction when using Agile methods (Agile-ADV4) suggests that these outcomes will be more frequently positive.

Agile might have some small effects on the following CSFs for ICT4D projects. By contributing to other CSFs for ICT4D projects, Agile helps ensure the continued use of and therefore the demand for the ICT. Sustainable demand is one of the pillars of an economically self-sustainable ICT4D project (ICT4D-CSF6). Additionally, by focusing on working software and by frequently delivering software (Agile-CSF6), local content (ICT4D-CSF8) can be created earlier on in the ICT4D project. Finally, because Agile contributes to ensuring a demand-driven ICT4D project, an improved understanding of the local community's needs is gained. This will allow the right technology to be chosen with greater accuracy (ICT4D-CSF11).

Agile was not believed to have any significant impact on three CSFs for ICT4D. The collaborative nature of Agile (see the Introduction) might improve the communication with and satisfaction of partners (ICT4D-CSF7) and project champions (ICT4D-CSF10), similar as to how it improves the communication with and satisfaction of users (Agile-ADV2, Agile-ADV4). However, it cannot help with seeking partners and building partnerships, or with finding project champions. Finally, Agile was not believed to be able to analyse and consider the political context (ICT4D-CSF9). However, the adaptive nature of Agile (see the Introduction) and the subsequent robustness to changing requirements (Agile-ADV1) allows an ICT4D project to respond to changes in the political context.

Additionally, in terms of frequency, the most important advantages and characteristics of Agile can be identified. Improved communication with the user (Agile-ADV2) has a positive effect on four CSFs for ICT4D, improved organizational learning (Agile-ADV10) on three, and good communication within the team on two. Furthermore, while not defined as an advantage, the focus on frequent delivery (Agile-CSF6) has a positive effect on three CSFs.

6 DISCUSSION

ICT4D projects have high rates of failure [3, 4] and the Agile methodology was found to increase the success rate of ICT projects [5]. However, Agile methods successful in western countries cannot carelessly be applied in ICT projects for developing countries [8]. Examples of why are the worse or lack of ICT and management skills [10] and cultural barriers [11, 12]. Furthermore, current research on why to apply Agile methods is mainly limited to the benefit of improved user collaboration [14–16].

The main value of this research lies in the insight it gives into how Agile can improve ICT4D projects and in what ways. This is important both for Agile frameworks as (for example [19, 21]) and for frameworks using Agile elements (for example [18, 20]), because there might be additional aspects of Agile that could further improve the frameworks discussed in the related works section or form the theoretical basis of new ICT4D frameworks. Existing literature mainly focuses on user collaboration as a reason for why Agile methods can improve ICT4D projects [14–16], whereas this paper found other aspects of Agile as well that can improve ICT4D projects. Most notable are organizational learning, team communication, and frequent delivery.

However, several limitations to this research must be addressed. First, a limitation regarding the ICT4D literature. In the interview that was held, the interviewees raised a potential problem in ICT4D literature. On one end there are case studies. While interesting, the question is what their findings mean for ICT4D as a whole. On the other end there is desk research. Such research attempts to create policy for ICT4D as a whole, but lacks a link to real ICT4D projects. The interviewees' opinion thus suggests that the ICT4D literature used in this paper is inadequate to provide a conclusive answer to the research question. Furthermore, literature for the CSFs for ICT4D and Agile and for the advantages of Agile was not collected in a systematic way, thus providing no guarantee that the CSFs of ICT4D and Agile and the advantages of Agile are exhaustive. A final limitation is that the findings of this research have not been validated in practice or through rigorous expert interviews.

7 CONCLUSION

The relationship between Agile and ICT4D was explored largely due to the focus of Agile on user collaboration. Theory postulated that there are additional variables to consider in an ICT4D project, and as such an answer to the following research question was sought: 'To what degree can Agile software development improve ICT4D projects?'. This paper arrived at an answer to the research question by answering two sub-questions, the answers of which are summarized below. Collectively, these answers provide an answer to the main research question.

SQ1: *Can Agile methods successfully work in an ICT4D project?*

Four critical success factors for ICT4D need to be satisfied before an Agile method can work: the projects needs to be demand-driven, skills pertaining to Agile need to be taught to the stakeholders actively involved in the development, a cultural understanding must be developed, and trust must be built. Though not necessarily prerequisites, local ownership and building local partnerships can also play an important role in ensuring that Agile can work correctly by increasing the motivation of the local community. Local partnerships can also contribute to developing a cultural understanding and building trust. The advice for parties who seek to set up a demand-driven ICT4D project is to select an Agile method for ICT4D projects that allows for a substantial pre-development phase, in which relevant skills can be taught and developed, a cultural understanding can be developed, and trust can be built. However, the parties must also consider that all those three critical success factors are iterative processes. Therefore, the Agile method must also allow for efforts to be made towards satisfying those three critical success factors in later stages of the project.

SQ2: *How can ICT4D projects benefit from an Agile approach?*

Agile can positively contribute towards satisfying all but four critical success factors for ICT4D: monitor and evaluate the project regularly, ensure a demand-driven ICT4D project, make efforts to retain staff, give local owernship to the local community, ensure economic self-sustainability, create local content, choose the right technology, develop a cultural understanding, and build trust. For three critical success the effect is insignificant: build local partnerships, understand the political context, and ensure a project champion. For the remaining critical success factor, building and training skills, there is both a positive and negative effect, thus resulting in an uncertain net effect. The most important advantages or characteristics of Agile, in terms of frequency, are the improved communication with the user, improved organizational learning, good communication within the team, and the focus on frequent delivery.

As addressed in the discussion, the results of this research have not been validated in practice. Case studies are thus necessary in which Agile methods are used, so that the proposed benefits can be assessed. Furthermore, as ICT4D is a multi-disciplinary field, it might prove worthwhile to investigate the effects of other software engineering techniques or approaches from other sciences, which can then be used to design an ICT4D framework.

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Knowledge Management Practices for Development - Lessons from Post-Earthquake Nepal.

A case-study on using technology to facilitate inclusive data gathering

Aske Robenhagen
Vrije Universiteit Amsterdam
Department of Artificial Intelligence
Faculty of Sciences

Marije Visscher
Vrije Universiteit Amsterdam
Department of Organization Sciences
Faculty of Social Sciences

Dr Victor de Boer
Vrije Universiteit Amsterdam
Department of Computer Science
Faculty of Sciences

Dr Julie E. Ferguson
Vrije Universiteit Amsterdam
Department of Organization Sciences
Faculty of Social Sciences

ABSTRACT

Responding effectively and appropriately to large scale natural disaster requires information-driven coordinated action between many different stakeholders. Evidence from one NGO engaged in reconstruction work after the 2015 Nepal earthquake sets out some of the knowledge management practice issues faced by an organization performing this work in a challenging geographical environment with low-connectivity. Key issues are identified and a data gathering tool that encourages data-driven bottom-up development practices is presented.

Keywords

ICT4D, Knowledge Representation, Emergency Response, Inclusive Development

1. INTRODUCTION

Responding to widespread destruction wrought by natural disasters requires the coordinated long-term efforts between many different actors spanning from the local community level to large international NGOs and state actors [10]. Responding effectively requires precise and continuous input of information which can be turned into appropriate action. In recent years technology has increasingly been used to facilitate development data gathering processes[1]. Given the changing complex environments and resource limitations, different development efforts have to prioritized based on the collected data. Within the domain of inclusive development and empowerment of peoples, affected citizens have a legitimate part in choosing these priorities[3]. Based on a field-study within a Nepalse NGO, the particular knowledge management issues facing an organization engaged in reconstruction and development work after the 2015 Nepal earthquake were identified. One of the key findings was that the information gathering processes and technological tools used, can lead to affected citizens having a reduced say in the relative prioritization and choice of development goals. Instead objectives set by donors and higher management are favoured, even if organizational goals include inclusive development. Development is a complex, multi-aspect endeavor and having an organizational focus is important, however it can lead to priority-biases. In this paper, the CitizenHelper data gathering tool is presented as a solution to highlight these organizational priorities as part of the data gathering process, whilst simultaneously aiding their information gathering processes.

2. CASE STUDY - ACCOUNTABILITY LAB

At 11:56 Nepal Standard time 2015, a 7.8Mw earthquake struck Nepal with its epicenter in the Gorkha district approximately 80km from Kathmandu. The earthquake left nearly 9000 people dead, injuring 22000, and caused widespread destruction of buildings and infrastructure[2]. Nepal is poor landlocked mountainous country ranking 144th on the UN Human Development Index[1] and responding effectively to a disaster of this magnitude is a challenge for any country. In the aftermath of the shock and subsequent aftershocks, many local organizations and self-organizing groups started to organize to deliver aid and coordinate response efforts affected areas outside of Kathmandu not yet reached by government and NGO workers. One of these organizations is the Citizen Helpdesk project[2], at the time known as the Quake Helpdesk. This organization established a network of volunteers to visit remote rural villages either not connected in the first place or disconnected from the mobile phone networks due to quake damage, in order to asses the damage and needs of affected citizens. This information could then be brought to NGOs to help ensure a more accurate picture of the needs across Nepal and help to organize the response effort accordingly. As the emergency response efforts progressed from immediate needs for medical treatment, shelter, and food towards the long-term development goal of reconstruction - the nature of the work changed. The

[1] `http://hdr.undp.org/en/countries/profiles/NPL#` Accessed 03/03/2018
[2] `http://citizenhelpdesk.org` Accessed 02/04/2018

needs of affected citizen, some of them among the most vulnerable in the world, remains significant. More than two years after the earthquake more than 600000 families were still living in temporary shelters and less than 10% of homes had been rebuilt with many more suffering from damaged property, farmland, and irrigation systems. Money has been earmarked for reconstruction effort, but many of the most vulnerable people are still suffering the consequences of the quake. Helping these people requires an understanding of their needs and data gathering to find out where the issues of accessing and utilizing the earmarked resources fail. Citizen Helpdesk does this through a team of Community Frontline Associates (CFAs) who each cover a geographic area and their communities, conducting surveys, interviews, and organizing community meetings in response to the specific needs of their communities. The organization does not provide aid itself, but seeks to use data to break down barriers and bring the information to relevant stakeholders who can take action and be held accountable. In many the cases access to local government is geographically hard to reach, otherwise inaccessible[3] or unknown to citizens in the communities.

2.1 Knowledge Management Practices

For this case study, a living labs[11] field study was conducted during 6 weeks in April and May 2017. The study was conducted through a mixture of participant observation, semi-structured interviews, and subsequently an agile development process whereby technology was used to ameliorate some of the identified knowledge management issues identified. The identified issues were:

1. Communication issues between main office staff and CFAs.
2. Existing data collection tools not suited to the Citizen Help Desk work practices.
3. Limited knowledge sharing between CFAs.
4. Differing information requirements at the different levels of the organization not being met by existing tools.
5. Evidence of organizational focus biases not visible to stakeholders.

Communication issues between the staff in the headquarter in Kathmandu and the community front line workers caused by many different modalities of communication (some used CFAs primarily used Facebook messenger, others email, text, or phone calls). This paired with the differences in access to internet and phone connectivity mean that organizing and disseminating information in both directions suffered. The organization had gone through a number of different data gathering practices, but reported that the **existing tools** all were too rigid and schematic for the open forum format used by the CFAs for their community meetings where the citizens often were the driver behind the choice of topics. **Knowledge sharing** between CFAs was limited due to the different ways of communicating and infrequent in-person meetings due to long travel costs and distances caused by the topography of Nepal. **The information Requirements** at the different levels of the organization varied and were sometimes in conflict. Three main levels of information requirements were identified, one for the CFAs who favoured personal stories and localized information to bring local organizations and stakeholders to help with issues in their communities and administrative wards. The staff in the main office on the other hand primarily dealt with larger organizations at the governmental and UN level, where the need for stricter data formats and standardized practices were demanded. Finally the donor organizations were interested in statistics and impact assessments in the form of reports. **Organizational focus** was found to be primarily driven by the donor organizations. During the course of the 6 weeks field study, a new donor organization began to fund the project and with that the project changed focus from reconstruction to issues surrounding labour migration. The issues of reconstruction, development, and migration are deeply interlinked and all are important aspects of the overall development efforts. Labour migration is the largest export of Nepal and it has large consequences, good and bad, for those leaving and for those staying behind (See [13], [8], [7], and [6] for an overview of some of the effects of large-scale migration). However, one issue that appeared in many communities and community meetings was water issues including drought and water uncertainty. Little of this extra information made it to the higher levels of the organization because the data gathering tools rigidly imposed a particular format for reports. This is important as Nepal, despite its large water resources in some parts, lacks significant planning in water management with many of those most adversely affected living in remote mountain areas.

[3]Nepal suffered through a long and protracted civil war[12] which mean that local elections where not held for more than a decade. During the field study the first local elections since the new 2015 constitution where held.

3. THE CITIZENHELPER TOOL

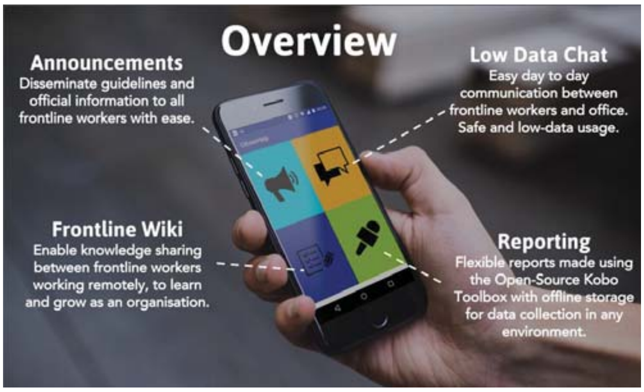

Figure 1: CitizenHelper App Overview

The CitizenHelper tool was developed in Nepal with the office staff of the Citizen Helpdesk and their community front line workers during focus groups and testing in Kathmandu and in the field. The CitizenHelper tool combines an app built around four modules, which together aims to solve the problems identified in the previous section of this paper. Together the intention is to create a synergy that amplifies the reach and effectiveness of the Citizen Helpdesk project's work. The app combines a simple low-data use **chat module** which stores messages locally and sends and receive them when the phone is connected for easy field communication between CFAs and office staff. The apps **reporting module** is built around a Kobo Toolbox[5] backend, but uses Enketo webforms to display freeform reports which allows flexibility in the reporting instead of the strict progression enforced by other data collection tools. Kobo was selected in accordance with the criteria set out in [1] for mobile data gathering tools, but with the extra criteria of easy maintenance, higher emphasis on low-cost, and the extra criteria of external acceptance and data integration (The open-source Kobo Toolbox is supported by the United Nations with free hosting and allows sharing and queries across different data sources). An **Announcement Module** allows dissemination of guides and training to CFAs from the main office, whilst a **Wiki Module** allows CFAs to share their knowledge and experiences. Finally the application auto-generates additional meta-questions about the structure of each report with the aim of providing a mechanism where extra information in meetings can be gathered and priority mismatch can be identified. This final feature means that, in conjunction with organizational practices that encourages it, the opportunity for inspection and adaptation of the work increases.

Figure 2: Smartphone Use during Community Meeting[14]

4. EVALUATION

The CitizenHelper system, like all technological interventions, is a tool intended to facilitate the process of development and not an end in and of itself[4]. A tool has to be evaluated to answer the question of what, if any, change it has effected in the community where the tool was deployed. Extensive evaluation over time should be considered an integral part of the development process and for ICT4D interventions should draw on multiple fields of research [9]. The present research employs the evaluation framework of Mthoko et al.[9] where evaluation is carried out in line with the guiding themes of Strategic Value, Most Significant Change, Empowerment, Livelihoods, and Sustainability. Each of the themes are related and interdependent. Mthoko et al. make the distinction between outcome assessment and impact assessment, where the former is the direct effects observed and the latter is the contribution those impacts (long-term effects) make towards development goals (which can be negative)[9]. Strategic value asks for the immediate effects and reactions to the intervention with the other themes requiring progressively larger spheres of consideration to evaluate (community level, long-term sustainability of the livelihoods using the technology, amongst others). Providing mobile phones with free calls might have the outcome that people make more phone calls, which could have an impact on empowerment if that leads to citizens using phones to organize and putting pressure on elected officials. The evaluation of the current project is an ongoing process that evolves with the project and in the present focuses on the observed effect, with the long-term impacts being evaluated in upcoming work. During focus groups with the Community Frontline workers the immediate outcomes were a great desire to use the technology in their day to day work, the unexpected outcome that they expected to save money on paper by relying on the phone for their documentation, and appreciation that they felt that having a tool made for them was a sign of the organization investing in them.

5. FUTURE WORK

The informational needs and knowledge practice issues identified in the particular organizational setting discussed in this paper have a universality that could make the Citizen Helper applicable to situations where organizations are geographically dispersed in a low-connectivity context and engaged in information-driven development work. However, to ascertain its usefulness in other context more research is needed. Technology does not exist alone and consistent practices and long-term uptake determine their success, so long term evaluation of the impact is needed as well.

6. CONCLUSIONS

This paper has argued that effective disaster response requires long-term coordination between diverse stakeholders and that providing an effective response requires high-quality data gathering over time to monitor interventions. This data gathering can be facilitated by technology. It has been argued that organizational biases in choosing development priorities can be exacerbated by the use of data gathering technology without the flexibility and possibility for affected citizens to have an input into the prioritization process. To help alleviate this issue, the CitizenHelper data gathering tool was presented which auto-generates meta-surveys on deployed report formats to help show if there is a discontinuity in prioritization between the providers and recipients of development interventions.

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Kasadaka: A Voice Service Development Platform to Bridge the Web's Digital Divide

André Baart
Amsterdam Business School, Universiteit van Amsterdam
Amsterdam, The Netherlands
a.h.j.baart@uva.nl

Anna Bon
Network Institute, Vrije Universiteit Amsterdam
Amsterdam, The Netherlands
a.bon@vu.nl

Victor de Boer
Computer Science Department, Vrije Universiteit Amsterdam
Amsterdam, The Netherlands
v.de.boer@vu.nl

Wendelien Tuyp
Centre for International Cooperation, Vrije Universiteit Amsterdam
Amsterdam, The Netherlands
w.tuijp@vu.nl

Hans Akkermans
Network Institute, Vrije Universiteit Amsterdam
Amsterdam, The Netherlands
hans.akkermans@akmc.nl

ABSTRACT

The World Wide Web is a crucial open public space for knowledge sharing, content creation and application service provisioning for billions on this planet. Although it has a global reach, still more than three billion people do not have access to the Web, the majority of whom live in the Global South, often in rural regions, under low-resource conditions and with poor infrastructure. However, the need for knowledge sharing, content creation and application service provisioning is no less on the other side of this Digital Divide. In this paper we describe the *Kasadaka* platform that supports easy creation of local-content and voice-based information services, targeted at currently 'unconnected' populations and matching the associated resource and infrastructural requirements. The Kasadaka platform and especially its Voice Service Development Kit supports the formation of an ecosystem of decentralized voice-based information services that serve local populations and communities. This is, in fact, very much analogous to the services and functionalities offered by the Web, but in regions where Internet and Web are absent and will continue to be for the foreseeable future.

KEYWORDS

digital divide, low literacy, sub-Saharan Africa, voice-based services, low-resource hardware, services development software kit

1 INTRODUCTION

The World Wide Web is a unique public space for knowledge sharing, content creation and application service provisioning for billions on this planet. Although it has a global reach, still more than three billion people do not have access to the Web: the 'Digital Divide' [2]. The majority lives in the Global South, often in remote rural regions, under low-resource conditions and with poor or even absent infrastructures.

However, needs for knowledge sharing, locally relevant content and application service provisioning are certainly no less beyond the current borders of the Web.

To overcome the Digital Divide, various policies are promoted to improve global access to Internet, Web and its vast arsenal of resources. A prominent one, for which quite large funds have been made available by donors such as the World Bank, is the attempt to roll out forms of "affordable internet" to currently unconnected regions.[1] Basically, the underlying idea is a form of relatively straightforward technology transfer from advanced countries to developing and emerging regions [1, 3, 4].

Our research focuses on information exchange and knowledge sharing support for smallholder and family farmers in the African Sahel (including e.g. Mali, Burkina Faso, northern Ghana). In a country such as Mali, around 80% of the population depend for their livelihood on work in small susbsistence agriculture in remote rural regions where there is no Internet, very limited electricity, and high levels of low-literacy (around 50% on average, for women even significantly higher). Under these conditions it is highly unlikely that a technology transfer policy of internet roll-out to bridge the Digital Divide will come to fruition in some foreseeable future.

This does not imply that nothing can be done. The contribution of this paper is that one can, and that it is possible to develop and deliver web-reminescent services for information and knowledge exchange, but not in a one-size-fits-all technology transfer approach. It requires a thorough investigation *in the field* of conditions, requirements and local specificities. This leads to insights and technical directions that cannot be derived from advanced but far-away technology considerations alone.

2 KASADAKA TECHNICAL IMPLEMENTATION AND EVALUATION

The Kasadaka platform and especially its Voice Service Development Kit aims to facilitate the formation of an ecosystem of many

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[1] See: https://webfoundation.org/our-work/projects/alliance-for-affordable-internet/

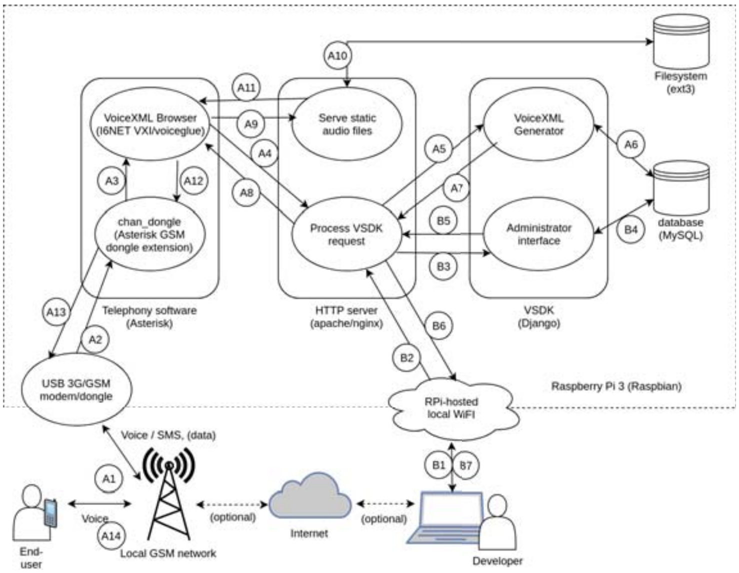

Figure 1: Overview of the Kasadaka system architecture

decentralized voice-based information services that serve local populations and communities. This is, in fact, very much analogous to the services and functionalities offered by the Web, but in regions where Internet and Web are and will continue to be absent for the foreseeable future.

The platform that we propose is called *Kasadaka* (*talking box* in a number of northern Ghanaian languages). The platform consists of a combination of hardware and accompanying software. The hardware forming the foundation of the KasaDaka platform is the Raspberry Pi, which is a low-resource computer based on an ARM processor (like found in many smartphones). The Raspberry Pi runs Raspbian, a Debian based Linux distribution. To provide the Raspberry Pi with connectivity to the local mobile phone network, a USB 3G modem is used. The total costs of the hardware is around EUR 60. The main software component that enables the development of voice services is called the *Voice Service Development Kit*, or VSDK in short. The VSDK allows for the development of voice service (prototypes) in a web-based development environment, by users without programming skills. The VSDK also generates the VoiceXML files that describe the interactions in a voice service. To serve these interactions in a phone call, the Kasadaka runs a stack of (mostly open-source) applications that provide the different functions that are required for voice-based interactions. Asterisk, an open-source telephony exchange application is used in conjunction with chan_dongle and VXI, to provide the voice-based interactions through the local GSM network.

The evaluation of the VSDK and the Kasadaka platform in general was structured in two phases: the first was an evaluation in the Netherlands with inexperienced users, that have developed voice services for several use cases from the west-African context. The second validation was a case study in Mali with a local radio station, that developed a citizen journalism application in the local language Bambara.

Both evaluations showed that the Kasadaka platform is suitable for the development of simple voice services, by users with minimal programming skills. For more complex voice services, the VSDK does not (yet) provide sufficient functionalities out-of-the box, and needs to be extended with data models and interactions that are specific to the use case. Despite this limitation, the platform clearly shows potential for the development of (financially) sustainable voice services in the development context.

3 CONCLUSION

The wider aim of the presented Kasadaka platform and its Voice Service Development Kit is to allow the populations on the other side of the Digital Divide to share knowledge and create content, analogous to the advantages that the Web provides. The platform is lightweight and is tailored to the harsh circumstances that are found in the Global South and takes into account the information needs of the local population. By enabling local voice service development and making custom voice services affordable for the world's rural poor, Kasadaka enables the formation of a network of decentralized voice services. Such a network has the potential to provide the benefits of the internet to the rural poor, reducing the gap of the Digital Divide and helping to improve the quality of life and well-being in the developing world.

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Tech4Good: Collectively scaling up social transformation

Sanjay Podder
Accenture Labs India
Bangalore, India
sanjay.podder@accenture.com

Shalabh Kumar Singh
Accenture Research India
Bangalore, India
shalabh.kumar.singh@accenture.com

Praveen Tanguturi
Accenture Research
Bangalore, India
praveen.tanguturi@accenture.com

Pradeep Roy
Accenture Research
Bangalore, India
p.roy@accenture.com

Christophe Gueret
Accenture Labs Ireland
Dublin, Ireland
christophe.gueret@accenture.com

Neville Dubash
Accenture Labs India
Bangalore, India
neville.dubash@accenture.com

ABSTRACT

The fourth Industrial Revolution is opening unprecedented opportunities to solve some of the hardest social problems and, in the process, make significant business gains, However, scaling up these new solutions is not easy. Leading businesses will need to reinvent the way they do business to capture these opportunities, including addressing the risks and challenges posed by new technologies. The essential components of scaling up the new business model include being good at orchestrating an innovation ecosystem, defining the guiding principles to harness the collective intelligence of all the ecosystem players, and devising a methodology for successful execution from development and design to sustainable operations. This paper summarizes the position of Accenture on "Tech4Good" and provides actionable insights and guidance for businesses to scale up Tech4Good solutions.

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1 INTRODUCTION

We're entering a fourth Industrial Revolution, rooted in digitalization, that is enabling society and industry to build and consume smart products and services. Thanks to the combinatorial power of AI, blockchain, genomics and other exponential technologies, there are unprecedented opportunities to solve some of the hardest problems we face-including providing access to education and healthcare and promoting gender equality. While the power of digital technology is profound, no single player-government, business, civil society, academia or individuals-could possibly harness it alone. We believe that only a synergistic architecture of these societal players and their 'collective intelligence' can steer the combinatorial forces of technology toward the desired digital impact. The ability of multiple partners to pool significant resources, skills and knowledge is key to advancing the sustainable development agenda.

In this emerging world, big businesses need to think and act differently. The ecosystem play will either help create markets for them where none exist today, or address cracks in the market that prevent them from managing profitable growth. And it is the combination of new market forces, digital technologies and new ecosystems that will, in turn, solve complex social issues and drive impact at scale. Businesses also need to address the new risks emerging from exponential technologies. Some of these are visible. Digital impacts are challenging democracy with fake news, threatening individual freedoms with cyber-bullying, exploiting humans through data privacy breaches and, above all, raising the fear of artificial intelligence (AI) algorithms dehumanizing society at unprecedented speed and scale. Digital technology must therefore be steered to ensure a positive impact on society and the environment. Corporations can be part of this process by joining collaborative ecosystems and leveraging emerging technologies to solve real-world problems while, at the same time, making significant business gains. This is a key component of the "Tech4Good" (Technology for Good) agenda-managing growth, responsibly.

This paper outlines the position of Accenture on Tech4Good. Section 2 describes the ecosystem at play for doing Tech4Good. The basic principles of work are then described in Section 3. This is followed by suggestions for scaling up Tech4Good in Section 4 and Section 5 before concluding in Section 6.

2 TECH4GOOD INNOVATION

We frame Tech4Good around three elements: societal challenges, an ecosystem of partners to tackle these challenges and a framework defining the collaboration between the ecosystem players.

2.1 The Tech4Good Challenges

In January 2016 the United Nations Development Program outlined a set of 17 goals as a call to action to "end poverty, protect the planet and ensure that all people enjoy peace and prosperity." [8]. Those goals can be used to focus the work and the attention of the ecosystem players, especially businesses. Innovating to address these challenges will help business capture part of a US$12 trillion market opportunity by 2030.[5]

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Figure 1: Sustainable Development Goals [8]

2.2 The Tech4Good Ecosystem

Businesses looking for the next big growth opportunity are unlikely to do so alone. Instead of seeking to develop new technologies themselves, they're more likely to adopt and adapt solutions developed by academia and startups, before building them out at industrial scale. They also face challenges in creating innovations where market mechanisms fail to function well. This means they need help from civil society and government. For instance, the poor may not have the capacity and capability to absorb innovations that big businesses create because of constraints in purchasing power, education and infrastructure. By contrast, governments can incentivize change through policy and subsidies. Civil society, especially social entrepreneurs, can create markets where none exist today. All of this means that businesses need to orchestrate a synergistic innovation ecosystem as depicted on Figure 2.

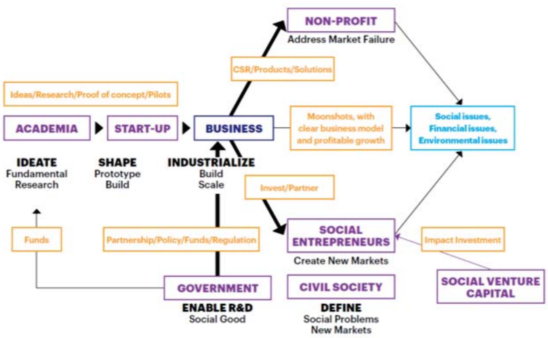

Figure 2: Tech4Good Innovation Ecosystem

2.3 The Tech4Good Innovation Framework

Academia and research institutions conduct fundamental research, develop relevant technologies and shape future progress. All this converts into a growth in startups that build prototypes and innovative business models around these new ideas. The role of big business is to use its vast operational and financial prowess to capture these innovations and industrialize them at scale. Businesses can also create partnerships with academia and government to launch new experiments.

Innovating for people who lack disposable income (those at the bottom of the pyramid) has to overcome the two fundamental issues of relevancy (solving the specific problems faced by people with very low levels of income) and adoption (people's limited capacity and capability to absorb the social innovation).

Because they can live with lower or no returns, nonprofits can address these gaps and help innovation to be absorbed by society. An interesting case here is Akshaya Patra, the world's largest non-profit supplier of cooked meals for schoolchildren. Through a collaboration with Accenture [4], the organization has taken an important step toward ensuring sustainable growth by implementing a blockchain pilot in combination with AI and the Internet of Things. The results suggest that implementing the solution in 15 kitchens will likely result in operational savings of Rs 30 million. By continuously reducing the cost of each meal it supplies, Akshaya Patra can do more with the resources it has, making it easier to reach its goal of feeding 5 million children by 2020 (from around 1.6 million children today). Government, businesses, foundations and non-profit organizations like Akshaya Patra, which provide last-mile connectivity, all have a critical role to play in solving these problems at scale.

Social projects like Akshaya Patra play a big role in developing and scaling Technology for Good. But the ecosystem also requires one more set of players to be effective in promoting innovations. This is a vibrant social venture capital community ready to provide impact investment.

Businesses need to bind all the players in the ecosystem together in a Tech4Good Innovation Framework. This will harness the 'collective intelligence' currently distributed across the system into a synergistic whole. The result? Innovative solutions that solve complex social problems, scaling up successful models and addressing market gaps through alternative options. Each player in the ecosystem can then contribute based on core competencies like research from academia, funds from government, products and goal orientation from businesses, and reach and focus from civil society (See Figure 3).

3 THE 5ES OF TECH4GOOD

Motivations for participating in the Tech4Good Innovation Ecosystem will be different for each of the players. Academia will likely be driven by ideas, requiring funds for breakthrough research. Governments may favor transformational change-driven by broader economic, social and political goals. Businesses must remain true to creating shareholder value through proper returns on investment. The social impact they create justifies the existence of civil society. Stitching these players into a Tech4Good Innovation Framework to achieve common goals is by no means easy. That's why it's essential to define the guiding principles that will glue them together. To harness the power of innovation for scaling positive digital impact, businesses need a strategic framework that incorporates the 5Es of scaling Tech4Good (see Figure 4):

(1) Build a strong foundation of digital Ethics
(2) Engineer solution for the next billion
(3) Embed social good in business models and offerings
(4) Enable civil society with digital capabilities to address market cracks, and

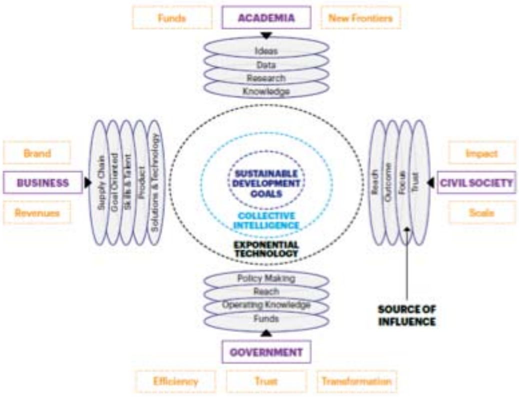

Figure 3: Tech4Good Innovation Framework harnesses "collective intelligence". Each entity stands to benefit from the others, who fill key gaps in their own ability to deliver on social development goals.

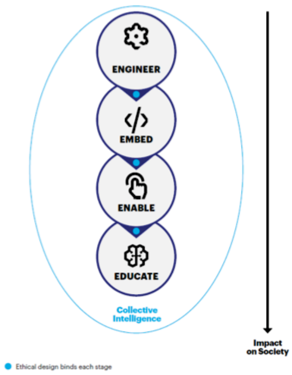

Figure 4: The 5Es framework for scaling Tech4Good: Ethics, Engineer, Embed, Enable, Educate

(5) Educate to build capacity to absorb innovation for the masses

3.1 Build a Foundation of Digital Ethics

The Tech4Good goal is to ensure inclusiveness with the help of digital technologies. Opportunities in an inclusive world would ideally be available to all. Businesses would focus not only on profitability but also on societal and environmental returns to stakeholders-the triple-bottom line. At present, the impact on society and the environment, along with the need to make benefits more widely accessible to society, are largely ignored. Dissonance results.

The synergistic Tech4Good Innovation Ecosystem must be supported by a foundation of digital ethics. At a granular level, this foundation would manifest itself in data protection and privacy practices, and ethical AI algorithms. Ethical AI algorithms would ensure that humans are not exploited for greater profitability and are free from the effect of bias. With this ethical foundation in place, businesses can explore different go-to-market strategies and achieve maximum inclusiveness while ensuring profitability-a potential win-win for all. Market cracks can be reduced or eliminated by re-imagining business models and market offerings with the help of digital technologies.

3.2 Engineer For The Next Billion

Engineering solutions for an inclusive world represents a potential USD$12 trillion opportunity by 2030 that will create 377 million new jobs. But it calls for different design thinking: engineering for the next billion customers may require co-creation with the target population.

3.3 Embed 'Tech4Good' in Current Offerings

Businesses need to examine whether 'Tech4Good' is embedded in their offerings. Are accessibility requirements designed into systems? Are adequate data protection and privacy measures in place? Are algorithms audited to ensure against biases and unethical practices?

3.4 Enable Social Enterprise and Nonprofits to Address Unserved Markets

Even when solutions are engineered for the billions, there will always be populations that fall through market cracks, deprived of opportunities in jobs, education and health-care, among others. While these cracks are typically addressed by nonprofits and social enterprise, businesses can enhance the ability of these organizations to address the needs of the bottom of the pyramid.

One of the major challenges faced by nonprofits and social enterprises serving the market cracks is their ability to manage digital technology. They often lack the skills in-house-the expertise to select and operate the right digital technologies to serve the next billion. Accenture's Tech4Good program [3] also enables nonprofits and social entrepreneurs, helping them effectively use technology innovation for various causes like extending accessibility solutions,[2] improving financial inclusion, and ensuring more children get midday meals[4] and do not leave formal education.[1]

3.5 Educate to Build Capacity for Absorption

The final element of the Tech4Good Innovation Framework is the need to educate-to build capacity and capability at the bottom of the pyramid to absorb innovations. Accenture Labs, for example, has been working with Maya Healthcare to create a Tech4Good solution that educates rural Indian youth to focus on the wellness element of healthcare and prevent non-communicable diseases.[7]

4 SCALING UP TECH4GOOD

All innovators are challenged by the question of scale. Without scale, appropriate returns on investment are extremely unlikely. Businesses are not only good at scaling up new innovations-given their financial, technical and operational competencies. But it is also essential for them to justify the investment and generate shareholder value. There is, however, no ready recipe for scaling Tech4Good innovations. Challenges range from a lack of understanding of end-customers and insufficient information to make strategic decisions, to an inability to adapt to a changing business and social environment, made more acute by inflexible business models. Many projects fail to scale beyond the pilot stage due to a failure to understand the underlying social and economic context.

It is essential to study cases of both success and failure to understand the key principles for scaling up Tech4Good innovations. The lessons from case-studies of global organizations are clear:

- Scaling Tech4Good solutions requires new skills and capabilities (both business and technical). Large businesses should not force their existing organizational approaches to scale Tech4Good solutions;
- Strategic investors and partners are critical for long-term success, and to lend their expertise in new markets;
- Flexible solutions and a flexible business model are needed to reach end-customers. Don't address all market needs with a predefined solution;
- Influencing the system or key stakeholders and actors in the system should be the focus, rather than trying to completely overhaul the system;
- Advocacy is needed for influencing or collaborating with ecosystem partners and decision-makers to adapt and adopt new solutions;
- Along with advocacy, new communications approaches will be required-such as enrolling NGOs to promote solutions and benefits and working with local communities to design and propagate solutions.
- Finally, the fact that template-driven approaches will likely not work should be embraced-adaptability is key to scaling up.

These lessons, derived from case-study analysis and expert interviews, can be further summarized as a four-step methodology for scaling Tech4Good projects.

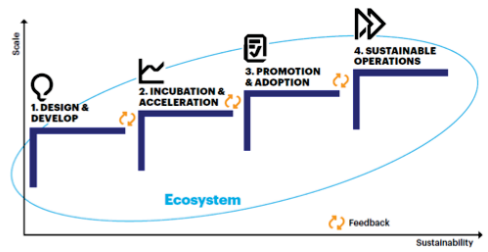

Figure 5: The four-step methodology for scaling Tech4Good solutions

Step 1: DESIGN & DEVELOP is the stage where businesses define customers' unmet needs, as well as identifying challenges that need to be overcome. This is followed by gathering data and evidence, and creating a feedback mechanism for testing, measuring, refining, and proving if the prototype should be taken to the next stage (Incubation & Acceleration). At this point, design is limited to a smaller scale, and may or may not involve ecosystem partners.

Step 2: INCUBATION & ACCELERATION programs are run alongside corporate venture programs or through independent accelerators. These programs focus on providing mentorship, developing the business plan, finding co-creation opportunities, and seeking financial assistance. Innovators can seek financial subsidy in the form of grants, government aid and philanthropy. Financial subsidies are not only common, they are also very helpful in mitigating the high risks of starting a business in volatile, low-margin markets. They do not seem to discourage organizations from becoming self-sustaining.

Step 3: PROMOTION & ADOPTION includes using evidence from the Incubation & Acceleration stage to start securing collaboration agreements with civil society, NGOs and government entities to promote the product or service and adopt and absorb innovation. This is the most time-consuming phase, as promotion and adoption rely on relationships, advocacy and policy development. Every case study we examined involved partnering with a national/local government or an NGO, from pilot stage to finally scaling up operations. Governments, as partners, enable social innovators to achieve large-scale systemic change.

Step 4: SUSTAINABLE OPERATIONS require companies and entrepreneurs to understand the cultural context and develop a structure that can work in any indigenous system. It requires companies to dedicate necessary financial and non-financial resources and invest time to explore ways of operating (as no single organization will be able to mobilize resources alone). It is important to create shared value at the intersection of financial performance and society to solve big problems. To unlock value, companies will need to forge multi-stakeholder collaboration models and incentive mechanisms.

For a sustainable operation, social innovators will need to address market needs by adopting a combination of business models that are either adaptive or disruptive in nature.

5 STRATEGIC GUIDANCE FOR STAKEHOLDERS

All five elements of the Tech4Good Innovation Framework need synergistic coordination between government, academia, business and nonprofits (see Figure 6). The question remains whether digital technology can help us build the collective intelligence that's so important for Tech4Good projects. Evidence suggests that this can be achieved.

Inspired by systems like Wikipedia and Linux, Climate CoLab [6] is a project run by Professor Malone as an open problem-solving platform where a growing community of over 100,000 people-including hundreds of the world's leading experts on climate change and related fields-work on and evaluate plans to reach global climate change goals.

The other big question is how do we prevent tech for bad? Technology is neither good nor bad in itself. But it can be put to good or bad uses. There are a number of areas where the use of technology needs to be regulated to prevent harm. The priority? Governments, policymakers, leaders from technology, civil society, and people in

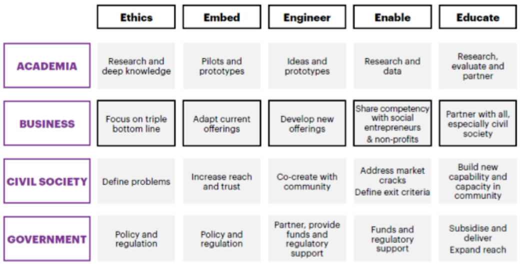

Figure 6: The 5Es require synergistic coordination and collective intelligence for success

general must work together to draft equitable and fair standards. These standards should be focused on three areas:

- **HUMAN AT THE CENTER**: Offering a range of services that enable technologies like AI that are compatible with the wellness of human stakeholders (employees, customers, etc.);
- **ETHICAL DESIGN**: Architecting and implementing solutions that comply with ethical design standards and provide transparency to the process;
- **COMPLIANCE**: Influencing and evolving with government regulations and public sentiment on responsible technology guidelines.

The pace of technological change must be accompanied by ever faster and smarter regulatory changes. We need policies and regulations that address new challenges, risks and threats, including privacy and security. Businesses, along with other ecosystem partners, have an important role to play in helping governments develop appropriate regulations that can steer the impact of digital technologies.

6 CONCLUSION

Businesses can amplify their mission and profitability by leveraging the collective intelligence of an Tech4Good Innovation Ecosystem comprised of regulators, academia, innovators and civil society-rather than doing it alone.

By structuring these interactions in line with our recommendations, it will be possible for businesses to address the needs of society with differentiated go-to market strategies powered by digital technologies and collaborative partnerships.

In doing so, businesses will discover new revenue growth models and develop a differentiated brand. They'll also be contributing to building an inclusive world that is just, fair and prosperous.

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Measuring surface water quality using a low-cost sensor kit within the context of rural Africa

Allard Oelen
Vrije Universiteit Amsterdam
Netherlands
a.b.oelen@vu.nl

Chris van Aart
2CoolMonkeys BV
Netherlands
chrisvanaart@2coolmonkeys.nl

Victor de Boer
Vrije Universiteit Amsterdam
Netherlands
v.de.boer@vu.nl

ABSTRACT

Monitoring water quality is done for a variety of reasons, including to determine whether water is suitable for drinking or agricultural purposes. In rural areas of Africa the traditional way of measuring water quality can be costly and time consuming. In this research, we have developed a low-cost water quality measuring device that designed to operate in the context of rural Africa. Firstly we select appropriate water quality sensors. Secondly we developed a water quality monitoring device that takes the contextual requirements and constraints of rural Africa into account. Lastly the device is evaluated and tested using water samples that were collected in rural Africa.

KEYWORDS

ICT4D, water quality monitoring, low-cost sensor kit

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1 INTRODUCTION

Measuring surface water quality has been done for decades for a variety of reasons. Among those reasons are to find out whether water is drinkable or if it can be used for agricultural purposes [2]. Traditional methods to determine water quality can be time consuming and expensive [9]. Water samples are sent to a laboratory and those samples are analyzed there. Using this method of water analysis it is not possible to determine water quality ad hoc. For example in the context of rural Africa, a farmer wants to know if the water from the river can be used to water his or her crops. If the farmer has to wait a few weeks to find out whether the water at that moment is suitable for watering crops, the results are not relevant anymore when they arrive. The water composition could have been changed since the samples were taken. A more suitable method of determining the water quality would be a solution that provides information about the water quality instantly. This device should be affordable from a financial perspective. Using such a device has multiple advantages over traditional water quality measuring approach: water quality can be measured instantly, measurements can be taken continuously and measuring can be done by stakeholders itself instead of being dependent on a laboratory. A disadvantage of using a low-cost sensor kit is that fewer water parameters can be measures and these measures are potentially less accurate.

In this research, we will develop a low-cost water quality measuring device. This device (or sensor kit) is designed to function within the context of rural Africa. This means that there will be various requirements and constraints that are related to this context. To be able to develop the water quality measuring device, the following research questions will be answered:

1. *What is an effective design of a low-cost water quality measuring kit within the context of rural Africa?*
1.1 *What are the requirements and constraints of the system design with respect to the context of rural Africa?*
1.2 *What are appropriate sensors to measure water quality for the measuring kit?*

The meaning of the word effective in the first research question, is explained in more detail in the two subquestions. For the purpose of our research, we define effectiveness as how well the system conforms to the requirements and constraints. For example, if there is no internet connection a available, alternative methods for connectivity should be included in the system design. Additionally, there is a trade-off between the building costs and measuring quality. This also involves the selection of appropriate sensors. Sensors are considered appropriated for this context, if they are low-cost and still provide correct information about water quality parameters.

2 RELATED LITERATURE

2.1 ICT4D context

In this research, we focus on implementing an ICT solution within rural Africa. This results in multiple requirements and constraints that are specifically related to this context. ICT research for development is called Information and Communication Technologies For Development (ICT4D or ICTD). More specifically, ICT4D is defined by Gyan as the use of ICT in socio-economic and international development. This includes disadvantaged population all over the world, but more often ICT4D is related to developing countries [5]. Ali et al. mentions three benchmarks that are important for successful ICT4D projects: context, community participation and sustainability. However, sustainability seems to be conflicting with ICT in general, which is changing often. Therefore Ali et al. qualifies sustainability of ICT4D projects as an unrealistic concept and that pursuing sustainability leads to project failures [1].

Implementing an ICT system within developing countries raises multiple challenges that are not obvious or present in first-world

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countries. Users of ICT systems often have limited education, are underemployed and have low incomes [11]. On the other hand, stakeholders of such systems are from different countries and have different sociocultural backgrounds [12], which can complicate determining the goals of a project. Pitula et al. described other challenges of the complicated context in which ICT4D projects operate, related to infrastructures, power supplies, connectivity and extreme operating conditions. Additionally three main components of ICT4D projects are described: 1) infrastructure development, 2) create ICT capacity and 3) providing the digital service. The first component relates to the required infrastructure to operate the system. The second component relates to the capacity to use and maintain the system. Finally, the third component relates to the value of the service itself [12]. Because network connection are extremely unreliable or not available at all in rural areas of developing countries, other techniques are used to make the web accessible. Research of Valkering et al. focuses on transmitting data via SMS in rural areas [18]. Most of the challenges listed above, are also relevant for our research. Solutions to overcome power and connectivity issues should be investigated in order to design a usable water quality measuring device for rural Africa.

According to Tongia et al. many ICT4D project fail either partially or completely. This is caused by a incomplete problem definition or by the metrics used for evaluation [16]. Other research confirms that most ICT systems for development do indeed fail [6, 12]. Among the reasons for failure is a gap between the design of the system and the reality. The findings of the previously mentioned researches are relevant for our research. It indicates that the ICT4D context should be taken into account in both the system design phase and other phases (like the evaluation phase) in order to succeed in this context.

2.2 Water quality measurement

Water quality can be determined using the physical, chemical and biological properties of water [17]. The Environmental Protection Agency of Ireland described 101 parameters to determine water quality. Below a selection of those parameters are listed and categorized by the previously mentioned quality property categories. Firstly, physical parameters include: electrical conductivity, pH, temperature, transparency and turbidity. Secondly, chemical parameters include: dissolved oxygen and other measures of how much of a certain substance are present in water. Lastly, biological properties include measures of bacteria and viruses (e.g. salmonella) [15]. The listed properties are relevant for this research because they can be measured using low-cost sensors. A study of Rao et al. describes a low-costs water monitoring system that is measuring some of the parameters that were described earlier. This includes temperature, pH, electrical conductivity and dissolved oxygen [13]. The findings of Rao et al. are relevant for this research since they also involve building a low-cost water quality measuring system. Our research is different because it focuses on the context of rural Africa where the system should operate.

3 METHODOLOGY

3.1 Water quality parameter selection

In order to design the water quality measuring kit, water quality parameters are selected together with the appropriate sensors to measure these parameters. The parameters are selected based on their relevance in rural Africa. This means that parameters that are hard to measure (because of a high sensor price or a complicated procedure) are not included in this research. The parameters do provide information about the quality of surface water. The selection of the parameters has been done using a literature review. The final result of selecting water quality parameters is a table that contains information about each individual parameter.

3.2 Measuring kit design and development

Based on the table of water quality parameters, the appropriate sensors have been selected. The measurement device is using an Arduino micro controller unit (MCU) to control the sensors. We have chosen for Arduino because it is an inexpensive and open source I/O board that is often used for prototyping [3]. Additionally, the availability of analog I/O pins is convenient for reading analog values from various (water) sensors.

The development of the kit includes research into the most appropriate power source, housing and communication method with respect to the context of rural Africa. As has been described in the related literature section, multiple challenging factors should be taken into account during the system development. To be able to find out how these constraints affect the design of the kit, the constraints are listed together with possible design options. A list of design options is shown below. This list is based on challenges found by Pitula et al. [12].

- **Power supply**: power net, battery, solar panels, smartphone battery
- **Connectivity**: using smartphone app, GPRS, LoRa, SMS, save on SD card
- **Communication**: using smartphone app, LCD screen, web interface
- **Operating conditions**: waterproof housing, industrial sensor, lab sensors

In the following sections, two different types of usage scenarios are being described. The system requirements and constraints are determined based on these scenarios.

3.2.1 Water quality measurement on demand. The water quality kit is designed to be used on demand. This means that when someone wants to know certain water quality parameters, he or she takes a sample of the water and puts in inside a cup. Afterwards the sensors of the measuring kit are also placed in the cup to measure the water quality. Using the measuring kit using this method has implications for the system design. Firstly, powering the kit becomes less of an issue since the kit could be powered by the user (e.g. via a smartphone or a power bank). Secondly, connectivity and communication can also be handled via the smartphone. Lastly, more (expensive) sensors could be connected to the kit because it will not be left unattended. In contrast to the continuous measuring scenario (that will be discussed in the next section) fewer sensors kits have to be created to be effective and that is another reason why sensor pricing is less of an issue. A disadvantage of this method, is that most water quality parameters are only relevant if measured for a longer period of time (like temperature, dissolved oxygen and oxidation reduction potential). This means that their value itself (without the ability to measure changes) is not very helpful in determining water quality. A continuous water quality measuring approach would overcome this problem.

3.2.2 Continuous autonomous water quality measurement. In contrast to measuring on demand, it is possible to do continues measurements. Multiple sensor kits will be placed at different locations and they will constantly collect information about water quality. This is done using an Internet of Things (IoT) approach, which will connect the sensors to the internet. This has implications on the system design, including questions regarding: how to power the system, how to communicate the data to the stakeholders and how to handle connectivity? Possible answers to these questions are: using solar power, communicate data via a web Graphical User Interface (GUI), connectivity via GPRS. Additionally, the pricing of the sensor kit becomes more important since the kits can be stolen or damaged and because multiple sensor kits have to be created.

3.3 Testing and evaluation

The device is built in multiple iterations. The first prototype has been shipped to rural Africa. The testing phase is focusing on multiple factors. Firstly, the sensors are tested to find out whether they provide accurate information about water quality. This testing is done using water samples collected from Ghana and Burkina Faso. Testing in a real life setting is done in The Netherlands. The sensor kit is placed at several rivers, lakes and canals. This is done both for testing the sensors and to test and evaluate overall system design.

In the end, the evaluation of the system focuses on answering the research questions that were stated in section one. This includes an answer to the first research question: *What is an effective design of a low-cost water quality measuring kit within the context of rural Africa?*. An answer is provided by the description of an effective design. This is done by evaluating the requirements and by testing different design option available to fulfill these requirements. An effective system should be able to correctly measure water quality parameters and make some conclusion about the actual water quality. In the evaluation the trade-off between building costs and measuring quality is explained. An optimal solution is determined for a system that is low-cost, but still provides relevant information about water quality. Depending on the usage scenario of the system, some design options could be in favor of others. The evaluation provides a clear overview of what design decisions were taken during the development of the kit, and what other design options are available. Since this research is still work in progress, the design decisions are not extensively discussed in the results. This will be done at a later stage of the research.

4 RESULTS

4.1 Water quality parameters

In Appendix A a table can be found with a list of six water quality parameters that are useful for this research. In this table the parameters are listed together with a description and a standard for drinking water. These standards come from both the United States Environmental Protection Agency (EPA) and the World Health Organization (WHO). Some of the parameters provide clear safety range for drinking water. For example, water with a pH below 6.5 should not be drunk. But a parameter like temperature does by itself not provide information about whether the water is drinkable or not. A bottle of water that has been heated by the sun can still be perfectly drinkable. However, when measured for a longer period of time, monitoring the water temperature can provide helpful insights into the water quality. The final parameter list is composed based on existing literature of research concerning water quality measurement [8, 13, 14, 17, 19]. According to Tuna et al. the following parameters are main parameters to measure water quality: electrical conductivity, dissolved oxygen, nitrate, pH, temperature, turbidity.

4.2 Development of the device

The water quality kit of the first iteration has been shipped to Mali for testing in the field. This prototype contained the following sensors: temperature, turbidity, pH and TDS. In appendix B a more detailed overview of the specific sensors and hardware of this device is listed. The housing of the device was printed using a 3D printer. The total price of the kit is around 150USD. The device can operate both as "water quality tool on demand" or as "continuous autonomous water quality monitoring tool" (the two use cases described in section 3.2). For the first use case, a LCD screen on the device displays water quality parameters in real time. For the second use case, the data is send to a server. The sensors were controlled with a Linkit One[1]. This device runs the same code as Arduino, but has multiple connectivity options built in. Among other things, GPRS and GPS are included. GPRS is used to send the sensors data, time and location to a server. GPS is used to determine the current location of the device. The device operates as follows:

(1) Set up device (connect sensors, turn on solar panel)
(2) Put the sensors in the water
(3) Water quality parameters appear on LCD screen. LCD background is green if the parameters are in a safe range, the background becomes red if values are outside the safe range
(4) Water quality parameters and location are sent to the server

The second iteration of the device is currently being constructed. This iteration focuses on adding more sensors and on improving the construction of the device itself. Among the new sensors is an ORP sensor. On the device shipped to rural Africa, some internal wires came loose. The second generation device will therefore be more robust to prevent this from happening.

4.3 Online interface

The online interface displays the data that the device has sent to server. Using the time range selector, it is possible to monitor and

[1] http://wiki.seeedstudio.com/LinkIt_ONE/

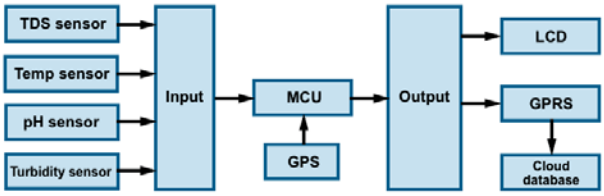

Figure 1: Block diagram of first iteration device

compare water quality parameters over time. The map shows the location of where the device was used to measure water quality. The source code of the program can be found online[2]. Figure 2 shows a screenshot of how the interface looks like.

4.4 Water quality data

The first iteration device did collect data from a well in Burkina Faso. The second iteration device has not been shipped to rural Africa, but has been tested in The Netherlands. This device is used to determine the quality of water samples that were collected at multiple locations in rural Africa. The collected data is publicly available, via: [10]. For the first iteration device that was tested in Burkina Faso, all measured values were within the safety range. However, some water samples that were tested using the second iteration device, did have a pH value that was below the EPA guideline (below pH 6.5).

5 DISCUSSION

This research is still work in progress. We expect to add more sensors in a later stage. Some hardware changes will be made to make the device more robust, and to make it better suitable for monitoring over a longer period of time. Additionally, a more detailed evaluation of the design decisions will be added.

5.1 Device usage

The first prototype has been shipped a rural Africa. The device was used by a researcher to measure the water quality at a certain location. After the researcher left, the device was given as a present to the locals. The device could have been used by them, to test the quality of different water sources. However, we did not receive any data from the device, which is an indication that the device is not used anymore. Therefore, one can question whether the water quality on demand use case, is a realistic scenario. In the end, such a device can never give a definitive result about whether the water is drinkable or not. This means that using the device on demand is less interesting to locals. The device is still useful for monitoring water quality over a longer period of time. The device in this scenario works autonomously, and therefore the previously described difficulty does not apply.

5.2 Future work

In this research, we focused on using low-cost sensors and hardware to monitor water quality in rural Africa. Low-cost sensor kits can

[2]https://github.com/aoelen/compteur-deau

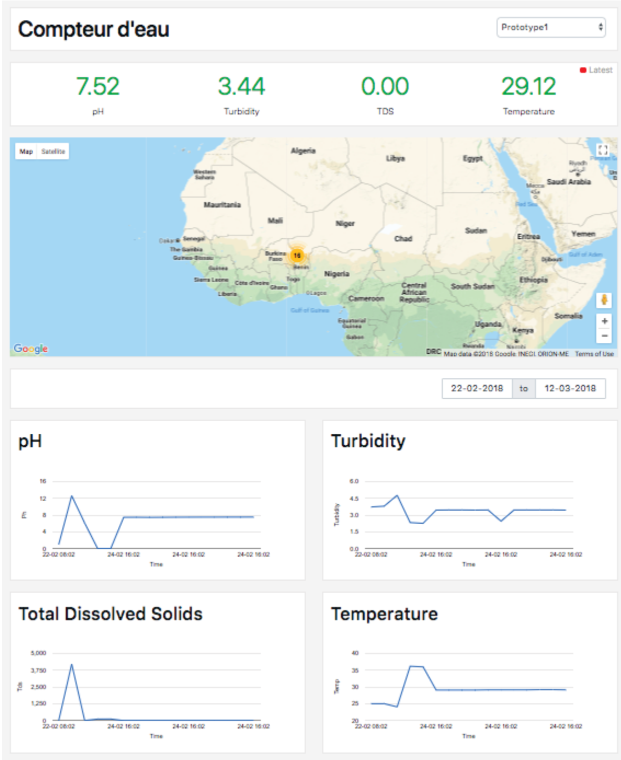

Figure 2: Online interface screenshot

be useful for other application in the ICT4D context as well. For example, it is possible to develop low-cost weather stations using a similar setup as presented in this research. The sensors would be different, but many of the requirements and design options are the same. Another interesting research topic would be reusing old computer hardware. For example, computers have multiple sensors for measuring temperature, research could focus on how to reuse such sensors in similar projects.

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A LIST OF WATER QUALITY PARAMETERS

Parameter	Description	Drinking water standard	Reference
Total Dissolved Solids (TDS)	Parameter to measure the total amount of dissolved solids. A higher TDS might be an indication of pollution in the water.	<600 mg/l	WHO [4]
Dissolved oxygen (DO)	The amount of oxygen that is dissolved in the water. Low levels of dissolved oxygen can be due to high water temperatures or can be indicative for bacteria in the water.	No guideline	EPA[3]
Oxidation Reduction Potential (ORP)	The ability of water to either accept or release electrons. Bacteria are killed by increasing the ORP level.	No guideline	NSW[4]; EPA [7]
pH	Measure to determine whether the water is acidic (pH <7) or basic (pH >7). Water with a low pH contains elevated amounts of toxic metals.	6.5<pH<8.5	EPA[5]
Temperature	High water temperatures can cause the growth of microorganisms and can effect the taste and smell of the water.	No guideline	WHO [4]
Turbidity	Measures suspended particles in the water. The more particles, the more change of microorganisms in the water (which can be attached to the particles).	<5 NTU	WHO [4]

B SPECIFICATION OF HARDWARE USED IN PROTOTYPE

Type	Description	Costs
Haoshi H-101	Industrial pH sensor	$56.95
Linkit One	Development board for sensor control	$59.00
DFRobot analog TDS sensor	TDS sensor	$12.90
DS18B20	Temperature sensor	$6.90
TSD-10	Turbidity sensor	$9.90

[3]https://www.epa.gov/national-aquatic-resource-surveys/indicators-dissolved-oxygen
[4]http://www.health.nsw.gov.au/environment/factsheets/Pages/orp.aspx
[5]https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals