

Opportunities for digital assistive technology innovations in Africa and Asia

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Opportunities for digital assistive technology innovations in Africa and Asia

Definitions

Assistive technologies	An umbrella term covering the systems and services related to the delivery of assistive products and services that maintain or improve an individual's functioning and independence, thereby promoting their well-being.[1]
Digital assistive technologies	Frontier technologies and applications of ICTs that support persons with disabilities to live independently and fully participate in society. These include digital technologies that do not require a mobile phone as well as those that rely on mobile.
Non-mobile digital assistive technologies	Digital solutions that are reliant on hardware but do not require a mobile phone (e.g. virtual reality headsets).
Mobile-based assistive technologies	Mobile phone-based solutions that use an app, a connected device or built-in accessibility function to help users perform functions in everyday life. These solutions enable or enhance personal functions in real time (e.g. object identification using a phone camera and app).
Digitally enabled service	Mobile phone- or computer-based resources that make services more accessible to users with disabilities. Examples include platforms or apps for education, to learn new skills, find a job, and access or manage specialised healthcare.

Acronyms

AT	Assistive technology
DPOs	Disabled Persons' Organisations
ICT	Information and communications technology
LMICs	Low- and middle-income countries
NGOs	Non-governmental organisations
UN CRPD	United Nations Convention for the Rights of Persons with Disabilities



Summary

Today, over one billion people need at least one form of assistive technology (AT), but around 90 per cent do not have adequate access to the AT they require.[2] Digital assistive technologies, particularly mobile-based ATs, have the potential to be a valuable and cost-effective tool for persons with disabilities. To realise this opportunity there is a need for locally relevant digital ATs which meet the range of needs of persons with disabilities. This report looks at the current state of innovation in digital ATs in low- and middle-income countries (LMICs) and the experiences from innovators from Africa and Asia working in this space.

Drawing on a literature review and stakeholder interviews, this landscaping study found that across Africa and Asia there are innovative digital ATs being developed but that the numbers vary by country with many at early stages of development and, also, with no examples found in many countries. However, there is an active tech community working with disability organisations helping drive increased digital inclusion of persons with disabilities and address their need for ATs.

Eighty per cent of the digital AT solutions identified rely on the use of a mobile phone, highlighting that the growing adoption of smartphones provides a platform for the deployment of digital ATs in LMICs. From solutions that support someone's functional limitations (e.g. using the phone camera for object identification) to solutions that provide much-needed services for persons with disabilities (e.g. information about accessibility of public spaces), **innovators are finding creative ways to break existing barriers faced by many persons with disabilities**. These locally developed innovations are resolving problems that conventional solutions have not previously addressed.

Innovator experiences illustrate that **opportunities for commercially viable digital AT innovations exist**. Innovators are deploying digital ATs and seeking to ensure that they are affordable for persons with disabilities by being able to offer them at affordable prices, through freemium models, and subsidised pricing. Nonetheless, as a nascent field largely led by small start-ups and non-governmental organisations (NGOs), there is a need for funding and grants to help them absorb risks throughout the innovation process. This will allow innovators to test and evaluate their digital AT and strategies for reaching people with disabilities, assess their potential for commercial sustainability and scalability and pilot as required.

Insights from this research also show that mobile **operators can actively unlock innovations to reach customers with disabilities**. Developing inclusive solutions and supporting start-ups creating digital ATs can offer commercial opportunities for mobile operators delivering both social impact as well as providing access to services to an excluded segment of the population.

Key findings

1. Hotspots of digital AT innovations were identified in India, Kenya, Egypt, and South Africa, particularly in urban centres with active innovation ecosystems and reliable infrastructure.

2. In some countries, no innovations were found, suggesting that either digital AT innovations are not a priority—perhaps due to lack of demand or interest from innovators—or that significant barriers for innovators exist.

3. Many digital ATs remain at the early stages of development and long-term sustainability is a challenge. Financial support and investment for innovators of digital AT is limited, difficult to access, and often only available for early stages of the innovation pathway. Funding support is needed for testing and piloting new models and strategies for digital AT development and deployment.

4. Innovation hubs, accelerators and incubators have provided key resources for innovators to enable them to successfully launch and test ideas. Mentorship has been particularly helpful for the often young and digitally-driven community of innovators.

5. Contextual knowledge and understanding user needs is critical for designing relevant digital ATs. User-centred design and the inclusion of persons with disabilities in the innovation process is essential for successful digital ATs.

6. Ensuring affordability is key to uptake of the services by persons with disabilities. Innovators of digital ATs must think creatively to generate revenue from their solutions.

7. Many challenges remain for digital AT innovators in LMICs, such as a lack of financing mechanisms for implementation and growth. However, this is as a nascent field, where there are many opportunities and areas yet to be explored from which digital ATs can emerge.

Opportunities for digital assistive technology innovations in Asia and Africa

Introduction

Access to ATs in LMICs

An estimated 15 per cent of the global population live with a disability.[3] Assistive technologies (ATs) are systems and devices that support people to live independently and enable them to fully participate in society, yet only five to fifteen per cent of those who need ATs have access.[4] Over 80 per cent of persons with disabilities live in low- and middle-income countries (LMICs), where ATs are not readily available.

Meeting the needs of the majority of persons with disabilities in LMICs requires high-quality and affordable ATs. Traditional ATs—such as mobility aids, wheelchairs and magnifying glasses—are typically provided free of charge by non-governmental organisations (NGOs), small local providers and governments.[5] This, coupled with a lack of understanding of the benefits of ATs and the need for bespoke solutions (e.g. prosthetics, glasses), limits the demand for ATs and restricts economies of scale. Consequently, many solution providers do not perceive there to be a strong commercial opportunity in these markets and therefore ATs available in LMICs are limited in supply and vary in quality. To address this need, some tech players in LMICs are looking at innovative approaches to provide ATs in these markets.

Key challenges to accessing ATs

- A critical need for ATs exists, but users and providers lack awareness of products available to them that are adequate to their needs and environment.
- Many ATs are designed by organisations that fail to understand contextual needs, resulting in ATs that are often expensive and inadequate.
- The limited availability of high-quality ATs, their high costs, a lack of trained staff, poor governance and limited finance mechanisms for the provision of ATs are key access barriers.
- ATs are often distributed and provided by faith or non-profit organisations to those who cannot afford them. This supply mechanism is financially unsustainable.
- The low-income base and insufficient demand (e.g. a potentially narrow customer base for specific types of AT and lack of knowledge of ATs) can cause investors to perceive the market as unviable. This results in limited numbers of suppliers available in these markets, affecting the options and quality of AT available to persons with disabilities.

Source: Thompson S. (2018). K4D Emerging Issues Report. Brighton, UK: Institute of Development Studies; MacLachlan, M. et al. (2018). Int. J. Environ Res Public Health. 15(12): 2627.

Digital ATs

Digital ATs have the potential to overcome many of the challenges highlighted above. Mobile phones, in particular, have the reach and capabilities to benefit many people. For persons with disabilities, smartphones[6] in particular embed many ATs and are increasingly replacing more expensive assistive devices such as audio players with Digital Accessible Information System (DAISY) capabilities and communication books.[7] According to the Global Initiative for Inclusive ICTs (G3ict), mobile phones are the second ranked AT for reading and understanding digital outputs. Screen readers were ranked first,[8] and are available for smartphones, but access to smartphones is limited in many emerging markets due to cost.[9] Mobile phones, with their additional benefits, remain more affordable than specialised ATs and therefore could enable ATs to reach more people in LMICs.

Many digital ATs available globally have been developed by major tech players (e.g. Apple, Microsoft and Google). These solutions however often fail to consider contextual and cultural needs (e.g. local variants in spoken or sign language). The need for locally relevant digital ATs[10] has created opportunities for innovations and new business opportunities for digital ATs by local organisations.[11] There is little research, however, to understand their strategies, the level of their success, and gather lessons from their experiences that could inform the innovation process for digital ATs.

This report looks to better understand the landscape of digital innovations for assistive solutions in LMICs and to capture experiences from innovators in Africa and Asia working in this space. Through a literature review which looked at 60 countries in Africa, Asia and the Middle East, examples of frontier technologies and ICTs used as ATs were identified.[12] From these, 10 innovations in Asia and Africa were selected for deep dive analysis. Findings were complemented by 30 interviews with global experts in AT, accessibility, and innovation.

Hotspots of digital AT innovation

Through landscape analysis, three broad categories of digital ATs were identified:

- **Non-mobile digital ATs.** These solutions rely on hardware but do not require a mobile phone. Examples include the use of virtual-reality headsets to provide therapy, including communication for autistic children, chronic pain, and others.
- **Mobile-based ATs.** These mobile phone-based solutions use an app, a connected device or built-in accessibility function to help users to perform daily tasks. This includes, for instance, the use of a camera to explore someone's surroundings, and to identify objects and faces.
- **Digitally enabled services.** These solutions use mobile phone- or computer-based resources to make services more accessible to users with disabilities. Examples include platforms or apps for education, to learn new skills, find a job, and access or manage specialised healthcare, etc.

Across Sub-Saharan Africa, South and South East Asia, and the Middle East and North Africa, 92 digital AT solutions were identified in 67 countries (Figure 1). Almost 80 per cent of the total number of digital ATs rely on the use of a mobile phone (49 per cent are digitally enabled services, and 29 per cent are mobile-based ATs).

Spotlight: Kibo in India

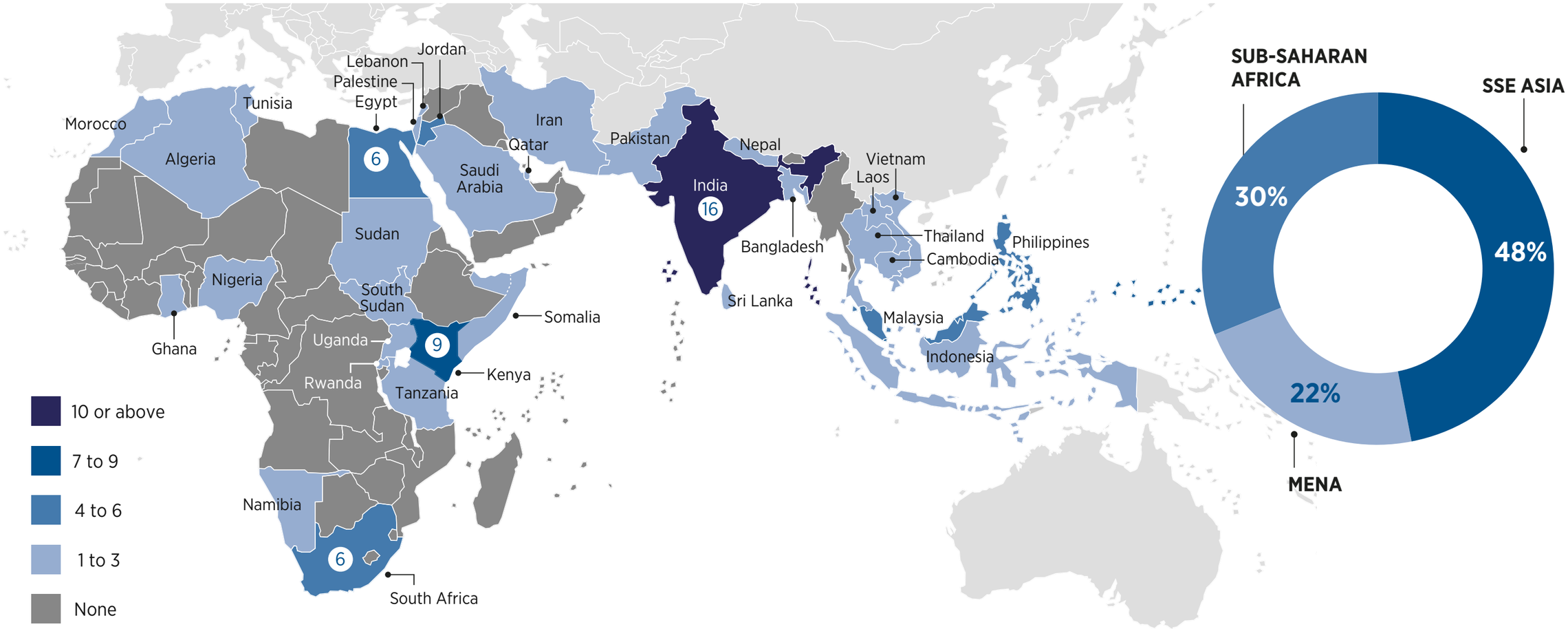
Trestle Labs in India developed a solution to help persons with visual impairment to listen to text in eBooks and scanned documents. Kibo XS uses a camera to capture printed documents and digitise text, which is then uploaded and read out loud using the Kibo website. Considering that many of their users are smartphone owners, Trestle Labs has developed Kibo app which uses the smartphone camera to capture text or scan documents, without the need of using Kibo XS. They have over 20,000 active users, and over 10 therapy centres use Kibo XS in India, Tanzania and Singapore. The Kibo app can be downloaded for free by the users.

Organisation type: *Start-up.* ***Digital AT type:*** *Mobile-enabled AT*

Opportunities for digital assistive technology innovations in Africa and Asia

Figure 1

Geographic spread of digital AT innovations in Sub-Saharan Africa, South and South East Asia and the MENA region.



There are digital AT innovations across the three major geographic regions but the numbers vary across markets. Notably, more innovations take place in urban centres that offer better infrastructure, reliable connectivity, strong supportive networks, and access to innovation hubs (e.g. Nairobi and Bangalore).[13] Hotspots of innovation for digital ATs are evident in India (16) and Kenya (nine), followed by Egypt and South Africa with six cases each. In addition, some countries with few digital ATs had solutions which were relatively advanced (see 'Spotlight: Kibo in India' and 'Spotlight: VRapeutic in Egypt').

However, 33 countries had zero instances of digital AT innovation. This suggests that either digital AT innovations are not a priority—perhaps due to lack of demand or interest from innovators—or that significant barriers remain for innovators to succeed in this area. Further research is needed to understand the enabling environments and required strategies for developing the market in these countries.

Spotlight: VRapeutic in Egypt

VRapeutic is a start-up that offers a supervised VR experience to provide therapy to children with learning disabilities and developmental or neurological disorders.[14] The solution offers a VR headset, connected to a laptop or a tablet, and software modules which are used by therapists to plan and tailor a therapy for each child's needs. The therapist can visualise and control what the child sees and evaluate performance data for every child. The solution is currently provided to therapy centres and private clinics, and the start-up is planning to develop the technology further to allow mobile-connectivity.

Organisation type: *Start-up.* ***Digital AT type:*** *Non-mobile based AT*



Digital AT innovation in Africa and Asia

Investment in the development of digital ATs for LMICs is limited and evidence of success is scarce. **Many digital ATs are at the early stages of development and long-term sustainability remains a challenge**.

Deep-dive analysis of 10 digital ATs highlights why additional resources are needed to drive the success of digital ATs in Africa and Asia (see Table 1).

Opportunities for digital assistive technology innovations in Africa and Asia

Table 1

Ten digital AT innovations in Africa and Asia

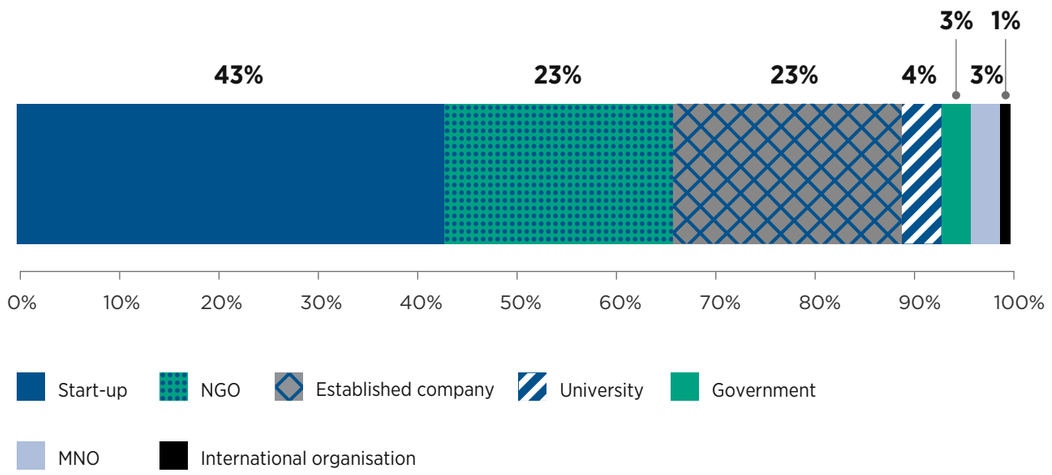
Digital AT / Organisation / Country	Service provided	Technology used
DeafTawk, *Pakistan* (Start-up)	Mobile app that bridges the communication gap between Deaf people and the hearing community. Users can initiate video calls with sign language interpreters to communicate.	Smartphone with 4G to enable video calls.
TuneMap, *Indonesia* (Start-up)	Anyone can upload information on the location of hazards in public spaces and along pedestrian routes. Persons with visual impairment can find accessibility ratings and are warned about obstacles by audio and vibration alerts.	Smartphone with 4G. GPS to enable hazard alerts.
Kibo, Trestle Labs, *India* (Start-up)	Mobile app paired with a digital reader that enables persons with visual impairment to access textual material in real time in their own languages through translation.	WIFI-enabled digital reader smartphone app. Deep-learning for language detection.
Annie, Thinkerbell Labs, *India* (Start-up)	An e-Braille reader paired with online content that aims to improve Braille literacy by rapidly and effectively imparting Braille reading, writing, and typing skills.	e-Braille reader on WIFI-enabled Raspberry Pi. Online content.
IXAM, Tech Era, *Ghana* (Start-up)	Platform that allows students with visual impairments to access and practice past exam questions.	Online platform that relies on 3G or above. Text recognition and voicing.
Senso, *South Africa* (Start-up)	Wearable bracelet paired with four sensors that allows persons with hearing impairments to be alerted to specific sounds such as a door opening, a baby crying or a car window breaking.	Sound identification. Bespoke radio frequency.
Alex Cane, TotoSci, *Kenya* (Start-up)	White cane for users with visual impairments paired with a smartphone app to help identify hazardous objects.	Image recognition that relies on 4G connection.
DMap, DRD, *Vietnam* (NGO)	App that allows anyone to view and rate the accessibility of specific locations and provision of facilities, such as public toilets.	Smartphone with 4G. GPS to enable location tagging.
M-Pesa, Safaricom, *Kenya* (MNO)	Jitambulishe–'identify yourself' voice biometric (VB) service–allows customers with visual impairments to authenticate without having to type a PIN or password.	Voice biometrics. Interactive voice response (IVR).
e3rafli Magnifier and Reader, Vodafone, *Egypt* (MNO)	App that uses a smartphone camera to view and identify objects, connected to an AI-enabled image recognition database.	Smartphone with 4G. Image recognition.

Initial funding is a major barrier to digital AT innovators and foundations

Most digital AT innovations in LMICs have been developed by start-ups (see Figure 2). Many are still extremely small in terms of turnover and staff. These start-ups typically have only a couple of employees and are in the very early stages of the innovation process (e.g. prototype, proof-of-concept). As such, initial funding has been critical to drive digital AT innovations.

Figure 2

Proportion of digital ATs developed by type of stakeholders



The start-ups described in Table 1 were all financially supported by entrepreneurship competitions, international donors, government grants, or foundations. Early stage seed funding is often difficult to find, yet this type of funding is particularly helpful for digital AT innovators. The lack of venture capital investment for digital AT development—often available for other start-ups—or funding to support further development poses huge challenges for innovators who do not have the means or resources to absorb the risk and can result in promising innovations being shelved.

Mentorship, innovation hubs, incubators and accelerators are an important source of support for innovators

Innovation hubs, incubators and accelerators provide key resources for digital AT innovators, even when located in other countries. For example, TuneMap was established in Indonesia and accepted onto an incubator in Malaysia, which facilitated global links to mentors such as the Open Data Institute in London. Also, many digital AT innovations are driven by the young and digitally driven who, besides the incubation support, benefit from the expertise of mentors.

Mobile network operators (MNOs) have also supported innovative start-ups via innovation hubs or incubators. For example, Jazz in Pakistan funds the xlr8 accelerator within Pakistan's National Incubation Centre (NIC) in Islamabad that provided DeafTawk with mentoring and support on their innovation path.

User-centred design is critical for the success of digital ATs

Local context is critical for the uptake of digital ATs. Solutions need to meet the needs of users and consider factors such as spoken language, sign language, knowledge of local accessibility constraints and linkages to local services. The inclusion of persons with disabilities in the innovation team provides essential insight for successful innovations. DeafTawk and DMap, for instance, were founded by persons with disabilities seeking to alleviate the barriers experienced by themselves and others.

When start-ups do not have persons with disabilities in the team, innovators have typically gathered insights via user-centred methods such as surveys and focus groups. In some cases, development teams have immersed themselves in the user experience, as the Thinkerbell Labs team did when designing the e-Braille reader 'Annie'.

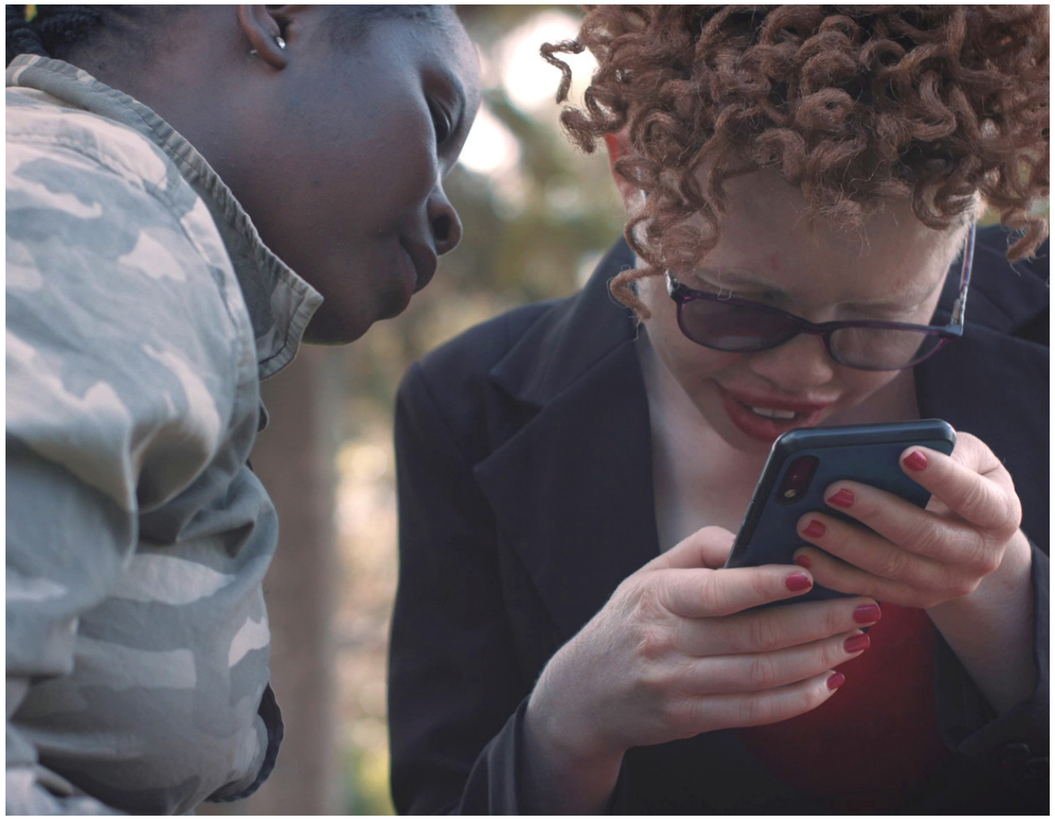
The role of disability NGOs and Disabled Persons' Organisations (DPOs) in the innovation process is also important, both as innovators themselves, leading 23 per cent of digital ATs (see Figure 2), and as a bridge between innovators and the users of the end product.

Innovations that focus on user needs and experience tend to be successful in terms of identifying the best solutions and are in turn more likely to gain traction in terms of user numbers.

Spotlight: DeafTawk in Pakistan

DeafTawk is a start-up that works closely with Jazz, Pakistan's biggest telecoms provider. They are dedicated to enabling greater participation in society for persons with hearing and speech impairments. There are very few certified sign linguists in Pakistan, a country with a population of 200 million. DeafTawk is working to provide real time online sign language interpretation services for Deaf clients or business clients, using digital platforms. This is currently achieved by linking a user with a trained sign language interpreter. However, to scale up the service and meet the large demand across Pakistan, they plan to implement a machine-learning process, feeding in thousands of hours of video call data to create an automated interpreter or chatbot. This will improve cost efficiency and reduce user tariffs while reaching a much larger proportion of the market.

Organisation type: *Start-up.* ***Digital AT type:*** *Mobile-enabled AT*



Business models for digital ATs in Africa and Asia

Offering affordable digital ATs requires innovators to think creatively about diversified revenue sources. A range of creative commercial models are emerging, where other sources of revenue are possible beyond the beneficiary of the AT (see Table 2). Affordability or being able to provide a product for free is pivotal for the business model to deliver digital ATs.

Table 2

Summary of the commercial models for the selected digital AT innovations

Type of model	Cost for person with disability using the service	Target client	Example
Full payment for service	Affordable pricing	Persons with disabilities or carer make direct purchase	**DeafTawk**
Service is free, paired with hardware that must be purchased or vice versa	Affordable pricing	Persons with disabilities or carer make direct purchase; organisations or companies purchase for persons with disabilities (e.g. school, university etc. purchase for students).	**Kibo** by Trestle Labs
Service subsidisation: revenue generated from other uses of data	Free	Government, businesses or other organisations pay for data which they use for their business	**TuneMap**
Service subsidisation: subsidised by another customer for the AT solution	Free or heavily reduced price	Other users that value the capability such as hospitals, businesses, call centres etc.	**DeafTawk**
Freemium model	Free for basic mode	Users with greater disposable income pay for more advanced features	**Kibo** by Trestle Labs
Business to Government	Free– Government procures AT for users	Governments that wish to provide better service to persons with disabilities in education or healthcare etc.	**IXAM** by Tech Era (ambition)
Business to Patron	Free– Patron such as an NGO or donor procures the AT for users	NGOs, DPOs, foundations or other individual or organisational patrons that seek social impact	**Annie** by Thinkerbell Labs

Innovative business models help bring digital ATs to market

Understanding the way in which digital AT innovations currently operate can highlight opportunities and challenges for innovators. The commercial models identified include:

- **Full payment for service by the user.** Digital ATs are purchased by the user as a one-off payment or on a subscription or payment by instalments model to make it more affordable. Innovators must consider whether their potential customers can afford the service.

- **Free digital content, with paid for hardware, or vice versa.** Digital AT users either purchase a device and receive digital content for free, or pay for the digital content (i.e. PAYG, subscriptions) and receive the device for free. Kibo, by Trestle Labs in India, is a free app that can pair with the Kibo XS digital reader to help persons with visual impairment to access digital text, including textbooks, books, and official documents.

- **Subsidisation of innovation through revenue generation from other uses of data.** Some digital ATs are available for free or at a heavily discounted price to the user by generating a service for another type of customer. For example, TuneMap in Indonesia generates data on where public spaces need to be made accessible or fixed, which is then purchased by Bandung municipal government for their planning work. This model could work for all types of data, if relevant local and international data privacy requirements are upheld.

- **Subsidisation of innovation in one market through revenue generation in another market.** Digital ATs could be free or discounted for persons with disabilities if the solution is beneficial for a wider range of customers. DeafTawk in Pakistan is a valued tool for customers, but also for hospitals or businesses looking to increase their capability to communicate with persons with hearing impairments. This model can greatly increase a customer base, helping to reduce costs for the end user.

- **Freemium model.** Paying for more advanced features can help subsidise the free basic version of a service. Through a freemium model, customers can switch adverts off in exchange for a subscription charge and access more advanced functions that users consider are worth paying for. Trestle Labs plans to implement a freemium model where people who want to access more advanced features can pay for them, allowing the companythem to provide free content to other users.

- **Business to Government (B2G).** Some digital AT providers target government as a customer. This could work when the digital AT increases the accessibility of public services, such as education or healthcare. Tech Era in Ghana are working towards deploying this model for their IXAM platform, where the government could roll out their solution across the country, enabling students with visual impairments to gain access to accessible education materials.

- **Business to Patron.** NGOs, DPOs, foundations or other individual or organisational patrons are also buyers of digital AT solutions and can distribute them for free to those who need them. For example, Thinkerbell Labs sells the Annie e-Braille learning service in India to NGOs who provide the equipment and necessary training to persons with disabilities.

Three models which have not been widely utilised but could also be considered are:

- **Advertising revenue.** Advertising is another commercial model available to innovators, enabling a free service to the user while other businesses interested in targeting a similar market segment could pay the digital AT innovator to place adverts. Ethical practices and privacy safeguards need to be considered.

- **Commission-based referrals to other suppliers.** Digital AT innovators could generate income from commissions when customers purchase products or services from the endorsed company because of the digital AT placement.

- **Business to business (B2B).** Several digital AT innovators in our wider sample were able to generate revenue via sales of the AT solution to another company, often a large employer distributing the AT to their employees for free as part of their corporate responsibility. VRapeutics, for instance, offers an annual license to therapy centres and private clinics to use a VR headset and software modules to provide tailored therapy to children. B2B models can also be attractive for innovators in markets where employers are required to make these accommodations.

Spotlight: MNOs innovating in digital ATs

MNOs have developed digital AT solutions for persons with disabilities. In Africa and Asia, some examples include:

- Safaricom in Kenya provides visually impaired customers with access to services that require authentication without having to type a PIN or password. The services use interactive voice response (IVR) and have proven to be transformational by making financial services available through M-Pesa more accessible to all.

- Vodafone in Egypt developed the E3rafli app, which uses voice control features to help persons with visual impairments to identify objects and colours, recognise and count currency, recognise and read a Vodafone top-up card, and read a taximeter. With the exception of the top-up card recognition, the app does not require an internet connection to function.

- Vodacom in South Africa offers the 112 emergency app to provide an emergency services calling system for people with visual, hearing and speech disabilities. The service allows registered customers to request help by calling the contact centre from emergency services using the app, including ambulance, fire, police and sea rescue.

Through these solutions, MNOs deliver support to their customers with disabilities, which may result in increasing their customer base and improved customer loyalty. These examples show that MNOs can play an important role in improving access to digital AT around the world.

The enabling ecosystem is critical for the success of digital ATs

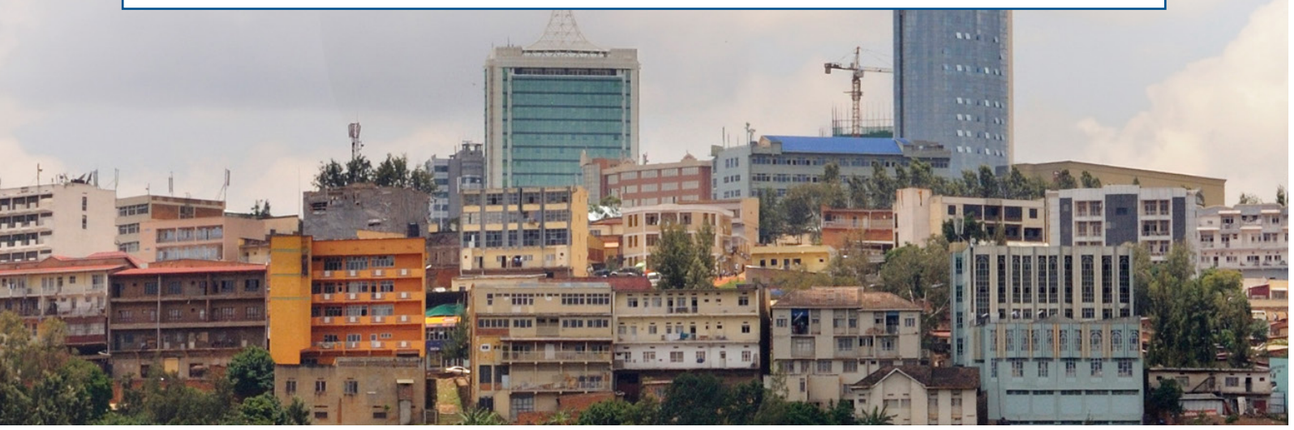
For innovators to succeed in the development and scaling up of digital ATs, some considerations are important for creating an enabling environment for digital AT innovation in LMICs. As reported by innovators, these are:

- **Internet coverage.** While some digital ATs may function offline or not rely on the internet, most mobile-enabled ATs require reliable internet connectivity. When the innovation requires more intensive processing, such as image recognition or voice calling, the need for reliable 4G connectivity is crucial. A significant challenge still remains in many rural areas as many mobile-enabled AT, including DeafTawk and TuneMap, are currently only operational where connectivity is reliable.

- **Government policy on digital inclusion.** Some LMICs have made greater efforts than others to implement the policies established by the United Nations Convention on Rights of Persons with Disabilities (UN CRPD). The implementations of the UN CRPD have spurred innovations where services were inaccessible, such as education, online learning, and remote employment.

- **Government policy, regulation, and legal frameworks to support digital innovation.** Policy on ICT innovation, data standards and intellectual property protection can also create more favourable conditions for digital AT innovation, including interoperability and integration with global standards and frameworks.

- **Local leadership on disability inclusion and digital AT innovation.** Digital AT innovation tends to benefit greatly from local leadership or a local champion, whether that comes from government or civil society. Deep dive analysis showed that NGOs, DPOs and allies of persons with disabilities play an important role in creating awareness and identifying user groups, from which digital AT solutions can grow. More importantly, local leadership can drive efforts to combat stigma and other inclusion barriers for persons with disabilities.





Looking ahead: scaling digital ATs

Photo credit: Trestle Labs

As a nascent field, evidence of the challenges and opportunities for digital AT innovations is limited but growing. This report presents insights into the digital AT innovations currently emerging from Africa and Asia, and while the digital AT innovations highlighted here are varied, shared challenges and opportunities have emerged from the research.

Addressing challenges to scalability and sustainability of digital ATs

The general lack of funding to support later innovation stages is a challenge for innovators and possibly limits the success of digital ATs. While most innovators have accessed grant funding for early stages, many reported **limited funding for implementation and service expansion**, for example to cover increasing staff costs or to invest in new technologies. Funding is needed for innovators to creatively develop and test business models to scale up.

The market and customer data required to create digital ATs is often lacking in LMICs. This is compounded by the innovators' lack of awareness of new or better technologies, or their lack of availability in the market. A supportive ecosystem, including the digitisation of government services and the proactive sharing of information and data, can help digital AT innovators to access better quality data that can lead to informed product and service designs.

The implementation of international standards to ensure a well-designed system architecture and trading agreements (i.e. intellectual property requirements) is another challenge. Many innovators are unfamiliar with these standards or do not know how to implement them locally. Failure to comply with international standards from the outset creates difficulties with user interfaces, sharing external data, or connecting with other service providers.

Finally, innovators may face competition from other providers with a more loyal local customer base, which may reduce the ability of their innovations to gain traction.

Scaling digital AT innovations: future opportunities

To scale or replicate in other markets, it is important to balance a detailed **understanding of the needs** of target users with openness to wider applications of a **versatile** AT solution. A clear example is DeafTawk which addresses needs from multiple customer segments and that, as a start-up developed in Pakistan, is now establishing itself in Singapore and plans to launch in Indonesia.

Contextual and cultural considerations may be perceived as detrimental for the scalability of digital ATs. For instance, sign language is contextual and, as such, a solution would not work if an algorithm was based on a particular sign language, limiting use to those who communicate using that sign language. This is an important consideration because most digital ATs identified a need for improved textual or verbal communication, providing much needed solutions for the digital inclusion of persons with hearing, visual or speech impairment. However, being open to wider applications of the solution also means considering the **relevance of the solutions for more than one group**. By addressing the needs of one particular group, the solution may resolve the barriers faced by other people, including people with no or low-literacy levels, and older people who may not identify themselves as someone with a disability.

Innovators should also explore a **combination of commercial models** to generate income through different streams and ensure their sustainability. For instance, Thinkerbell Labs sells the Annie e-Braille learning service in India directly to customers, while also targeting NGOs in other low-income markets.

Developing the **digital skills** of users is fundamental for the uptake and scaling up of digital ATs. Some innovators are taking a dual approach by offering training to persons with disabilities as well as creating useful digital AT solutions. Tech Era in Ghana have focused the IXAM App on secondary education students with visual impairments, who are more likely than younger students to have typing or e-Braille skills.

Finally, frontier technologies are increasingly used in innovations in LMICs and, with that, some digital ATs have emerged (for instance, see 'Spotlight: VRapeutic in Egypt'). While most applications are in early development, the results are promising ways to increase the inclusion of persons with disabilities in an ever more digital society.

Endnotes

1. World Health Organization (2018). *Assistive technology*.
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4. *Ibid*.
5. MacLachlan, M. et al. (2018). *Intersections Between Systems Thinking and Market Shaping for Assistive Technology: The SMART (Systems-Market for Assistive and Related Technologies) Thinking Matrix*. Int. J. Environ Res Public Health. 15(12): 2627.
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10. Samant Raja, D. (2016) *Bridging the Disability Divide through Digital Technologies*.
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12. Examples from high-income countries were taken into account where they are actively used in developing countries and where there is high potential for new technologies to enable rapidly evolving solutions in developing countries.
13. GSMA (2016). *A few things we learned about tech hubs in Africa and Asia*.
14. Tracxn (2020). *Artificial intelligence start ups in Egypt*.

Notes

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