Design approaches for creating person-centered, context sensitive, and sustainable assistive technology with the Global South

Chavarria Varon, Mario; Schönenberger, Klaus; Mugeere, A.; Hurst, Samia; Rivas Velarde, Minerva

How to cite

CHAVARRIA VARON, Mario et al. Design approaches for creating person-centered, context sensitive, and sustainable assistive technology with the Global South. In: Accessible technology and the developing world. Michael Ashley Stein & Jonathan Lazar (Ed.). United Kingdom : Oxford University Press, 2021. doi: 10.1093/oso/9780198846413.003.0013

This publication URL: https://archive-ouverte.unige.ch/unige:152217

Publication DOI: 10.1093/oso/9780198846413.003.0013

12

Design Approaches for Creating Person-Centered, Context Sensitive, and Sustainable Assistive Technology with the Global South

M. A. Chavarria and K. Schönenberger
EssentialTech Centre, EPFL, Lausanne, Switzerland

A. Mugeere
Department of Sociology and Anthropology, Makerere University, Kampala-Uganda

S. Hurst and M. Rivas Velarde
IEH2, Université de Genève, Switzerland

12.1 Introduction

Approximately one billion people around the world live with disabilities, 80% of whom are in low- and middle-income countries (World Health Organization, 2011). Yet only 5–15% of those requiring assistive devices and technologies have access to them (World Health Organization, 2019). The World Health Organization, in its effort to close the assistive technology gap, created the Global Cooperation on Assistive Technology, whose main purpose is to maintain or improve a disabled person's functioning and to enhance their overall wellbeing (World Health Organization, 2019). In this chapter, of the various types of assistive technology, we are specifically focusing on assistive technology to improve personal travel and mobility. The Global Cooperation on Assistive Technology initiative at World Health Organization focuses on five interlinked areas (5Ps): (1) *People*: user involvement; (2) *Policy*: development of tools to support countries in developing national policy; (3) *Products*: encouraging countries to develop a list of national priority products; (4) *Provision*: integration of assistive product service provision into the health system; and (5) *Personnel*: building the capacity of their community-level workforce (World Health Organization, 2019). However, involving users is not enough if devices continue to be based on a "bodily deficit," focusing purely on addressing impairment, which reflects an outdated understanding of disability reflected in the medical model of disability. Design of assistive technology would be better served by adopting a more comprehensive view on the experience of disability, such as the capabilities approach (Sen, 2008). This will enable assistive technology (AT) to focus on a person's wellbeing and provide tools that offer users the freedom to live lives they have a reason to value.

Our work is dedicated to developing a critical understanding of the underlying assumptions, motivations, and values that inform disability and technology research design. The chapter is divided into two parts: In the first, we outline relevant legal frameworks, then we review the methodological shortcomings of well-intentioned technology "solutions" that fail when they are implemented among the intended population due to the lack of a proper understanding of the final user and their local context. In the second part, we present lessons learned from the design and implementation of assistive devices that have overcome common barriers such as high cost and maintenance needs, dependence on access to electricity or internet, and inaccessible features. We also argue that it is necessary to gain a better understanding of disability to enhance context-sensitive and person-centered technology design. We hope to contribute to shifting the focus on the development of assistive devices to a new design approach that is person centered and context sensitive, and renders the product sustainable.

12.2 International Frameworks for AT for Mobility and Independence

It has been at least 15 years since the Convention on the Rights of Persons with Disabilities was enacted. Article 20 set the obligation for signatory countries to ensure personal mobility with the greatest possible independence for persons with disabilities, and required states to facilitate access to assistive devices. More recently, the Dubai Declaration (2018) was adopted by the International Telecommunication Union, which promotes the adoption of user-centered technology as a means to ensure equitable, affordable, inclusive, and sustainable development of telecommunication and information and communications technology networks, applications, and services. The synergies between these two frameworks, as well as regional and domestic legislation, show positive progress, but there is still much to be done. It is important that those who produce the technology take into account all aspects of accessibility, mobility, and wellbeing for persons with disabilities. Furthermore, we believe that domestic governments and the international community are moving toward a deeper reflection of the underlying philosophy of terms such as inclusive design, usability, and accessibility (Persson et al, 2015). Engineering design can produce social transformation for people with disabilities (Williams, 2019), and approaches such as human systems engineering and user-centered design based on community needs can help make progress toward the goals of the Convention on the Rights of Persons with Disabilities and Dubai Declaration.

In Uganda, for instance, the government enacted the National Policy on Disability (2006) which—among other things—established a rehabilitation and resettlement scheme that includes vocational rehabilitation services and sheltered workshops that focus on employable skills training and orthopedic workshops for the provision of AT devices such as calipers, wheelchairs, and white canes to facilitate the mobility and independence of persons living with physical impairments (MOGLSD, 2006). Other African countries such as Burkina Faso and Niger have also provided a legal framework that promotes the mobility and independence of persons living with disabilities by focusing on access to public buildings and transport, such as the provision of tax breaks designed to encourage accessibility measures (Handicap International, 2010). Other aspects of the same legislative framework in Uganda include the Urban Code or Building Code, which takes into account persons living with disabilities in the construction of new buildings, while holders of the disability card are also entitled to a reduction in travel expenses on public transport.

12.3 Available Assistive Technology and Innovation for Personal Mobility

Over the last decade, we have seen enormous technological progress on assistive devices for navigation and mobility. While the legal framework is encouraging and comprehensive, the design of such devices often overlooks the experience of disability and the everyday needs and constraints of disabled people from the Global South. To elaborate on this issue, let us take as an example a recent technology development for blind persons. We will present an overview of, first, available hardware-based navigation systems and, second, software-based navigation systems; lastly, we will discuss the shortcomings of existing solutions with regard to the needs of low- and middle-income countries.

12.4 Hardware-Based Navigation Systems for the Visually Impaired

The visually impaired population encompasses those with moderate or severe vision impairment or blindness, which refers to persons with visual acuity worse than 3/60 (we acknowledge that terminology and identity labels differ from country to country). Usually, people with visual impairment depend on a probing cane to help them move around a city safely. This method has been used for decades and it is the most common and affordable solution for the visually impaired. However, the use of a cane has major limitations, such as people only being able to detect trials and obstacles right in front of them by swinging the cane, while trying to feel what the tip of the cane is touching on the ground. This leaves the users with no information about their surroundings, outside what is at ground level and right in front of them. This poses an additional threat to the user as well as to the "mobility ecosystem" of the city. Over the last few years, we have seen the launch of highly innovative technologies that aim to overcome the abovementioned barriers. These technologies, mainly electronic travel aid systems, will be now described and discussed:

12.4.1 Electronic Travel Aid Systems

These systems aim to increase the mobility of users and provide additional information about their surroundings. These systems use different types of sensors to acquire data from the surroundings of the user and processing algorithms to convert these into audio or tactile signals. The most basic, and affordable, versions of the electronic travel aid systems are the ultrasound canes/glasses. These systems use ultrasound sensors to detect obstacles and warn the user by a sound signal. More complex electronic travel aid systems provide the user with more detailed information about their surroundings; for example, one of the earliest and most known models of electronic travel aid (ETA) is the vOICe. The vOICe navigation system uses a camera (mounted on a pair of glasses) to monitor the wearer's surroundings and an algorithm to process the acquired data and convert it into a time-multiplexed auditory representation (Milotta et al., 2015). Not all the ETA systems use audio signals; other devices use tactile interfaces, such as the forehead display of the AuxDeco system (www.eyeplus2.com), or electronic signals, such as the vision-tongue display of the BrainPort Vision Pro (www.wicab.com).

12.5 Software-Based Navigation Systems for the Visually Impaired (VI)

Alongside ETA systems, there are various software applications for visual users. With the proliferation in the use of smartphones among the VI population, the navigation apps (e.g., RightHear [https://right-hear.com/], Lazarillo [https://lazarillo.cl/en/], etc.) have become popular, affordable solutions for VI users navigating urban environments. However, these apps only provide map- or global positioning system-based information and cannot provide real-time information about the surroundings such as collision warnings, changes in the path, etc. In general, the software-based solutions can be divided into two main groups: the ones based on artificial intelligence and the ones requiring the assistance of sighted employees/volunteers. The former type requires high processing power and, therefore, expensive hardware components. An example of this kind of app is *Seeing* from Microsoft (https://www.microsoft.com/en-us/ai/seeing-ai). The *Seeing* app, running on a smartphone with camera and internet access, can help the user to read communication and correspondence on paper, identify bank notes and colors, and describe objects in the vicinity of the user. The second type of app is based on video-call communication between the user and a sighted assistant such as *Be my eyes* (https://www.bemyeyes.com/), a free app that connects blind and low-vision people with sighted volunteers and company representatives for visual assistance. The mobile apps that include visual recognition of the environment, both artificial intelligence and video-call-based, require high-speed and high-quality internet connection.

12.6 Mismatch Between Existing Solutions and the Needs of Low- and Middle-Income Countries

The tools we have mentioned are excellent, technologically speaking, and can be very useful. However, they fail to reach the large majority of the VI population due to major design flaws. Their key features may be focused on the needs and contexts of high-income countries, or perhaps they are made for a very selective pool of users that ultimately exclude the average user from the Global South. For potential users in most low- and middle-income countries (LMICs), the first barrier to accessing these solutions is the cost (WHO, 2018). Most ETA systems are expensive, with prices in the thousands or even tens of thousands of U.S. dollars, which is several times higher than the average monthly (or even annual) salary of a worker in a low- or middle-income country. In the African context, this can be illustrated by considering the cost of hearing aid technologies. In Northern Nigeria, for instance, the least expensive hearing aid costs almost a month's average salary (McPherson & Clark, 2017). Market research in Kenya also found that the main reason people with disabilities did not use splints was the cost (Cassit Orthopedics Limited, 2016). These costs are aggravated by high import duties and informal charges levied on medical appliances such as hearing aids in some developing countries, e.g., Ghana, where a 15% tax is imposed on imported hearing aids (McPherson & Clark, 2017; Borgl, 2015). In Sub-Saharan African countries and other LMICs, there are minimal to non-existent accurate statistical estimates on the availability of AT (e.g., wheelchairs, white canes, prostheses, and hearing aids) for persons with disabilities (PWDs; Mji, 2019). The poor access to such technologies is largely a result of a lack of knowledge, resources, services, and products (Visagie, 2019). Research among 400–500 households in South Africa, Namibia, Malawi, and Sudan found that the most common sources of AT were government health services (37.8%), "other" (international humanitarian aid, development charities, and religious organizations [29.8%]), and private health services (22.9%; Visagie, 2016).

Shifting AT design would require full and meaningful participation of the variety of voices and realities existing among PWDs. International and domestic disabled peoples' organizations have a crucial role in using international standards as emancipatory tools. The articles of Convention on the Rights of Persons with Disabilities (CRPD) and other international standards related to disability need to be reconstructed to make sense of the priorities, needs, and struggles of PWDs in LMICs.

Persons with disabilities are overrepresented among those living in poverty, and acquiring a smartphone or sustaining the cost associated with high-quality internet is often unattainable (Hanass-Hancock et al., 2017; WHO, 2011). There are significant knowledge gaps regarding the level of penetration of access to the internet, mobile phones, and information and communications technologies in LMICs. The Digital Accessibility Rights Evaluation Index (Global Initiative for Inclusive Information and Communication Technologies, 2020) shows that, despite worldwide progress, LMICs are still lagging behind in achieving equitable access to information and communications technology (ICT) for PWDs. Trends of poverty and lack of progress on accessibility overall call into question the relevance of apps and other technology that relies on maximum internet speed and smartphones with high-performance processing needs.

In addition to the lack of affordability and risk of increasing vulnerability, other factors that prevent the adoption of the mentioned technologies (Golledge et al., 2004; Elli et al., 2014; Tapu et al., 2018) are:

Complexity: Common ETA systems and their interfaces are difficult to use and require special training to be understood and used properly. In addition, they can interfere with other senses; for example, audio interfaces can obstruct the users' hearing, hindering their ability to receive auditory feedback from the surroundings (this can be avoided by delivering auditory stimuli via bone conduction without obstructing the external ear; MacDonald et al., 2006).

Discomfort: All wearable components should be small, unobtrusive, and light so that the devices can be carried for long periods. However, the assistive hardware components are usually heavy and voluminous, such as the tactile interface of the AuxDeco, which puts a big weight on the user's forehead, or the vision-tongue display, which has to be carried inside the mouth.

Aesthetics: Users of wearable assistive aids often consider visual appeal and acceptability as more important than the technology's potential benefit (Golledge et al., 2004; Elli et al., 2014); that is, anything that makes them look different, stand out, and attract unwanted attention, such as big electronic devices on their faces, will be rejected.

Information saturation: The amount of information provided by the assistive device must be evaluated carefully to avoid sensory and cognitive saturation of the user. This is a common case among lower-cost devices such as ultrasound canes, which do not have the processing capabilities to discern between useful and unnecessary information (Saha et al., 2019). These devices might perform well in laboratory settings, but they are useless in complex urban environments (Elli et al., 2014; Collins, 1985).

Socioeconomic context: Failing to take into account the local context can render an excellent technology useless. For example, users in countries with high levels of criminality will not use any aid system that requires carrying high-tech devices in visible places. Examples include ETA systems or navigation apps requiring them to take out their smartphones in public, which could put them in danger of being mugged. This issue is not uncommon: persons with disabilities in LMICs are particularly vulnerable to abuse, violence, and crime (Murray et al., 2013; Vilalta, 2016).

Disability is both a cause and consequence of poverty. Historically oppressed social groups such as indigenous persons, ethnic minorities, refugees, and migrants tend to have higher rates of disability than non-minority groups (Anderson, 2016; Rivas Velarde, 2018). Disability scholars from the Global South have heavily criticized disability theory and the disability rights movement, as most of the writing in dominant discourse about disability came from the Northern Hemisphere (Rivas Velarde, 2018; Hickey, 2018; Meekosha, 2011). Trends in AT suggest that historical neglect is coming to the fore once again, as the voices of those from the Global South are absent. Current trends are enforcing double layers of discrimination, where neither the needs nor realities or constrains face by disabled people in the Global South are considered. Technology and innovation serve only a privileged few. Disabled peoples' organizations from the Global South have a crucial role in addressing these patterns of neglect end ensuring meaningful representation of all voices, particularly of those facing double layers of discrimination.

12.7 Shifting the Focus on the Development of Assistive Devices

In order to deepen our understanding regarding the priorities and needs of PWDs in the Global South, we undertook a preliminary consultation that aimed to inform the development of our research questions and set up a research project partnership between research institutions in Switzerland and Colombia. This exploratory work took place between October and November 2019. We set up informal meetings and talks with disabled peoples' organizations (DPOs), academic institutions, rehabilitation centers, and government officials to learn more about the everyday priorities of organizations of persons who are blind or have low vision regarding assistive devices, as well as mapping the available technology in the market.

We learned that there is a significant mismatch between the needs of the users and the available technology in the Colombian market; there, innovative navigation systems such as AuxDeco systems that were donated to DPOs tend to be in disuse. We enquired as to why people were not interested in using them and were provided with a range of reasons, including that they attract unwanted attention and are uncomfortable to wear. Equally important was that the systems were of no use to them since, for instance, they did not allow them to move around safely in the streets of Cali, Colombia. A key reason for this was that the artificial intelligence (AI) features did not perform efficiently enough in average middle-income settings; their navigation technologies are based mostly on street maps which, in the city that we investigated, do not contain enough information for safe navigation. As an example, sometimes the streets are not perfectly perpendicular or do not have a uniform width, i.e., opposite corners are not aligned; such small details are not present in standard maps, making it difficult for the VI user to find the next walking path when crossing streets and leaving them dangerously wandering in the middle of the street.

We also observed, as shown in Figure 12.1, other barriers to using the infrastructure, such as a damaged sidewalk, obstacles in the path such as tree branches, holes, electric cables, and the absence of a pedestrian crosswalk; these were constant through their daily navigation even in the more privileged parts of town. This not only confirmed the previously discussed literature (Hanass-Hancock et al., 2017; WHO, 2011; Murray et al., 2013; Vilalta, 2016) but also raises serious concerns that go beyond the performance of a specific tool or app. It also shows that perhaps new AT may be reinforcing the exclusion of PWDs in the Global South. Assistive technology design should examine the fact that the large majority of PWDs cannot even afford basic assistive tools, such as the walking cane.

During this exploratory phase, we listened to the research priorities and concerns of DPOs and collected some examples of assistive devices that have focused on the priorities, needs, and concerns of PWDs in LMICs, but we also looked at relevant examples of low-cost technologies in high-income countries that will now be discussed individually. For instance, the Perception and Intelligent Systems (PSI) group (UNIVALLE-Colombia) developed a wearable navigation system for the blind adapted to the urban environment in Latin America, based on AI algorithms (Díaz et al., 2020). The developed system is capable of detecting

Figure 12.1 Illustrations of the Barriers Faced by A Blind Person and His Guide in Cali, Colombia

Left: Absence of aid infrastructure to navigate through the city. **Center:** Obstacles and damages on the few available aid infrastructure. **Right:** Obstacles in the path, such as tree branches, holes, electric cables, etc.

walkable spaces, obstacles, and objects of interest, such as doors, chairs, staircases, and computers, among others, and planning a path that allows the users to reach their target locations in a safe way (purposeful navigation). The navigation system was successfully tested with blind users in Cali, Colombia, who gave positive comments about its portability, navigation in indoor and outdoor environments, and its ability to run locally (not in the cloud/external servers), which allowed it to work in places without high-quality internet access or GPS-denied environments. This system reflects that co-design with users from the Global South with local scientists seems to be more likely to be accepted; however, further testing and formal evaluation are required. In this preliminary research, we learned more about the link between innovation and public policies. The Colombian government has implemented different public policy initiatives to close the technology access gap in relation to the population with disabilities, such as:

ConVerTic (www.convertic.gov.co): Provides licenses (free of charge) of different aid software for the VI.

Cine para Todos (https://cineparatodos.gov.co): Ensures access to people with sensory or physical disabilities to cinema (free of charge) by incorporating accessible elements into the films.

Centro de Relevo (https://centroderelevo.gov.co): A public platform for the communication between hearing and non-hearing persons based on video calls with sign language interpreters.

These policies were developed in collaboration with DPOs, and are examples of good practices in the use of ICT to enable accessibility and social inclusion.

12.8 Design Methods for Creating AT That Is Person Centered, Context Sensitive, and Sustainable

Context-sensitive, sustainable, and person-centered AT design requires gaining an understanding of how the assistive devices enhance each person's capabilities. The previously mentioned examples show higher involvement of users, which leads to devices and software that will likely match with what individuals value in their lives. Current dominant definitions of functioning and disability, such as the one contained in the International Classification of Functioning (WHO, 2001), are heavily focused on bodily deficit, which tends to be the view present in design approaches. However, personal agency, social determinants of health, and variations on the lived experience of disability are less present in many existing design approaches (Mitra, 2003, 2014, 2017). We suggest implementing the capabilities approach to address the shortcoming of the International Classification of Functioning (Mitra, 2003, 2014, 2017; Bickenbach, 2013).

The capabilities approach has been predominately used in the disability literature, as presented by Sen (1993, 2008) as a theoretical framework which focuses on the significance of individuals' capability to live the kind of lives they value. The capabilities approach stands upon two normative claims that the primary importance that individuals shall enjoy the freedom to achieve wellbeing as a core moral imperative, and that this freedom shall be understood in terms of a person's capabilities to do and be what they have reason to value (Sen 1993, 2008). This means focusing on peoples' real opportunities to do what they value in their terms and in their context. The capabilities approach (CA) is a useful approach to understanding the social participation, agency, and culture in the experience of impairments and disability which are not sufficiently present in the ICF (Mitra, 2003, 2014, 2017; Bickenbach, 2013). The CA offers a promising framework to improve AT design, as it provides a framework to study and understand the interfaces between agency, environment, bodily impairment, and AT. People may live with the same or similar impairments; however, the experience of disability is highly dependent on the context. Persons with different impairments face different barriers and, as such, would benefit from different interventions and technology features. The CA would allow AT design to incorporate social constraints, such as susceptibility to violence; economic hindrance, such as the inability to buy a smartphone and pay for reliable broadband on an ongoing basis; as well as culture and users' views regarding what is important for them and the capabilities they would value the most and how AT can enable them. CA shifts the focus of AT from its outdated approach of overcoming impairment by using technology to equalize or mimic the functioning of non-impaired persons, to instead focus on enhancing freedom and wellbeing. Some of the examples outlined in this chapter, including the work of Perception and Intelligent Systems group UNIVALLE and the upcoming example of AGILIS from EPFL, borrow some elements from the CA: they are seen to be driven by user priorities and a sound understanding of the users' contextual enablers and constraints, but there is as yet no evidence of the impact of these tools on wellbeing.

12.8.1 Understanding the Users

To create AT that is person centered and context sensitive, starting from a deeper understanding of functioning as described above, one has to take into account several factors.

The existing literature (Hanass-Hancock et al., 2017; WHO, 2011; ICT, 2020; Murray et al., 2013; Vilalta, 2016) and preliminary conclusions from our exploratory research indicate that it is very important to ensure high involvement of a significant variation of potential users during the concept design phase—primarily people with disabilities but also, when appropriate, their care givers, clinicians, therapists, and educators. Early and frequent prototyping can help with this, to ensure that what is being built will provide a measurable impact on the user's quality of life. Testing involving daily routines in a user's life is especially important to understand both positive and negative impacts. Also, the documentation and interfaces should be designed so the intended users can not only use it easily, but also *learn* to use it in an easy way, without having to rely on other people. In the future, more needs to be done to examine the scalability and the long-term impact that the revised tool assistive might have on the quality of life and wellbeing of its users. Interdisciplinary cooperation will be essential in putting in place appropriate methodologies to document and evaluate the outcomes of these initiatives and pave the way for the development of efficient assistant technology, ultimately closing the gaps in access. Furthermore, what is learned in design may also benefit other populations (e.g., ETA systems may also benefit people without disabilities in other contexts, such as navigating in poor light conditions or autonomous driving).

12.8.2 Designing Hardware Devices

All devices should take into account international standards in order to guarantee their safety and effectiveness. One example of a standard that should be considered is the ISO/DIS 21856 standard focusing on assistive products (ISO, 2020). This standard refers to general requirements and test methods, providing guidance and specifications for the general design of assistive products and technologies. Depending on the application and intended impact of the solution under design, there are different specialized standards that should be consulted; for example, the ISO 9241 series covers both the hardware and software ergonomics aspects of human–system interactions:

> Ergonomics is the scientific discipline and systematic study concerned with the understanding of the interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. (ISO, 2010)

The ISO 9241 series is divided into several "Parts" addressing different sub-topics. Some of the most relevant for the subject of this chapter are (see also Table 12.1):

Part 100 (ISO/TR 9241-100:2010): Introduces the designer to—and provides the designer with—standards related to software ergonomics, with a special focus on understanding and specifying user requirements as well as designing and evaluating user interfaces. This is a crucial point in order to develop universally accessible technology that provides appropriate software ergonomics considering bodily diversity.

Part 171 (ISO 9241-171:2008): Promotes increasing the usability of systems for a wider range of users by providing ergonomics guidance and specifications for the design of accessible software. Additionally, it addresses issues associated with designing accessible software for people with diverse physical, sensory, and cognitive abilities, including those who are temporarily disabled, and the elderly.

Part 210 (ISO 9241-210:2010): Provides requirements and recommendations for human-centered design principles and activities for both hardware and software components of interactive systems.

Part 910 (ISO 9241-910:2011): Provides a structure for the analysis and understanding of different features of the tactile/haptic interaction.

Table 12.1 Summary of the Discussed ISO Standards

ISO standard/code	Topic
ISO/DIS 21856	Assistive products—General requirements and test methods
ISO 9241 Series	Ergonomics of human–system interaction *Part 100: Introduction to standards related to software ergonomics* *Part 171: Guidance on software accessibility* *Part 210: Human-centered design for interactive systems* *Part 910: Framework for tactile and haptic interaction* *Part 920: Guidance on tactile and haptic interactions*
ISO 23599:2019	Assistive products for blind and vision-impaired persons—Tactile walking surface indicators
ISO 14971:2019	Medical devices—Application of risk management to medical devices
ISO 9999:2016	Assistive products for persons with disability—Classification and terminology

Part 920 (ISO 9241-920:2009): Provides guidance on the design and evaluation of tactile and haptic hardware and software (and combinations of hardware and software) interactions, including: the design/use of tactile/haptic inputs, outputs, and/or combinations of inputs and outputs, the tactile/haptic encoding of information (text, graphical data, and controls), the layout of tactile/haptic space, etc.

The ISO standards also provide guidelines for large infrastructure developments, such as the ISO 23599:2019, which provides product specifications for tactile walking surface indicators and recommendations for their installation in order to assist in the safe and independent mobility of VI persons.

When designing assistive and medical devices, it is crucial to identify the hazards associated with the device, to estimate and evaluate the associated risks, to control these risks, and to monitor the effectiveness of the controls. The ISO 14971:2019 provides guidelines for the application of risk management to medical devices (including software) and specifies the terminology, principles, and processes for risk management. This standard is applicable to all phases of the device's life cycle. It also applies to risks associated with a medical device, such as bio-compatibility, data and systems security, electricity, moving parts, radiation, usability, etc.

In technology development, providing precise and reliable documentation is essential. Technical documents can be very complex; therefore, it is important to use the appropriate, clearly defined terminology to improve the understanding of the document; for example, in the case of AT, the ISO 9999:2016 establishes a classification and terminology of assistive products for PWDs.

12.8.3 Ethical and Social Considerations

It is important to address ethical and social considerations; for example, is the device reliable enough for the user to depend on it in unknown locations? Will the characteristics of the device put the user at risk if used in neighborhoods where crime is high? Do the benefits of the device justify its cost? Is the device financially accessible to most patients with visual or hearing impairments? Is the information captured by the device managed in a way that does not violate anyone's privacy? Is the look and feel of the device such that the user does not feel embarrassed or uncomfortable to wear it?

12.8.4 Social Entrepreneurship

It is crucial to ensure that the developed technology remains sustainably available. This means the creation of a complete value chain in parallel to the technology development and a business model which will allow the creation of a social business to industrialize the technology or the transfer of the intellectual property to an existing company interested in deploying and scaling up the technology (Makohliso et al., 2020). These models often promote cooperation between the North and South, enabling collaboration between communities and worldwide experts. Social entrepreneurship is often overlooked in research and literature regarding innovation and AT in the Global South. It is important to address this knowledge gap and generate evidence of how a good idea goes beyond a prototype or an academic paper to become a sustainable long-term solution.

12.8.5 Cooperation Between the North and South

It is important to address that in AT there are points where the needs in the South and North will coincide, points where it will half match, and points where it will not match at all; for example, making low-cost systems is useful in both hemispheres, since there are also poor communities in high-income countries. An example of a half-matched requirement is concealed devices; in low-income countries it is necessary for security reasons and aesthetics, while in high-income countries (with a safer environment) it is only necessary for aesthetics. Finally, something that does not match at all is the barrier in the use of navigation apps in low-income countries for security reasons (this does not exist in safer countries). In sum, directly transferring technology from one context to another (South to North or North to South) without re-contextualization, can be problematic and render it useless.

The AGILIS project from the International Committee of the Red Cross, Switzerland, is a successful example of context-sensitive, person-centered AT development that has taken measures to ensure sustainability by creating a social business: AGILIS (https://essentialtech.center/project/agilis/) developed a prosthetic foot, considering the context of LMIC in order to create a solution that can be universally accessible. After development of the technology, the International Committee of the Red Cross decided to launch the Rehab'Impulse initiative (www.rehabimpulse.org) to deploy the developed devices among PWDs in all regions of the world. The products are provided at affordable prices, meeting the needs of both service users and providers in LMICs, enabling the first step toward social inclusion. AGILIS was first developed and deployed in Vietnam; today it has been deployed to a variety of humanitarian settings where the International Committee of the Red Cross is present (Figure 12.2).

12.8.6 Broader Impact

The development of innovative new technologies for people with disabilities can generate positive publicity, raising awareness about their current conditions such

Figure 12.2 Low-Cost, Innovative Prosthetic Foot Developed by the AGILIS Project (©M.Janier/EPFL)

as their needs and the barriers they face in their daily lives. This might lead to the creation or improvement of technology procurement, as well as social programs and policies focused on aiding people with disabilities. For local governments, the implementation of high-tech solutions, especially to help poor constituents in the country, can generate reputational benefits and pride. This effect is quite notably visible, for example, in Rwanda, where the government has gone out of its way to be seen as at the edge of research on "drones for good" and other high-tech solutions (www.africandroneforum.org/). Our experience is that technology (via the media, who are eager to report on innovation) can raise awareness about the problems faced by vulnerable people in a positive way. In turn, this can inspire aid programs and/or legislation changes to improve it further (Thackeray & Hunter, 2010).

12.9 Conclusion

This chapter is a call to action for DPOs, engineers, disability scholars, rehabilitation practitioners, policymakers to shift the way in which technology is designed, tested, deployed, and sustained. It aims to set up the groundwork to be further developed and tested. Our recommendations are not exhaustive and intend to stimulate discussion and analysis regarding the underlying values in the design of AT.

Our preliminary research suggests upcoming cutting-edge technology is often designed for high-income countries and is expected to work in LMICs. This common and erroneous assumption has led to products that do not work properly, nor do they have the intended impact. Poor or superficial understanding of the lived experience of disability and everyday constraints faced by potential users in the Global South, as well as limited knowledge about infrastructure and impact of high maintenance costs reinforce the exclusion of persons with disabilities in LMICs. This hinders the development of sustainable AT solutions that could allow persons with disabilities in LMICs to achieve the kinds of lives they have reason to value.

In Africa, research has so far demonstrated that lack of policy and poor policy implementation, lack of AT awareness, supply chain challenges, lack of trained service providers, and lack of money greatly hamper access to these technologies (Visagie, 2019). There is therefore need for more support for governments and non-governmental organizations to prioritize meeting the unmet demand and expand the range of these technologies, especially in the rural areas (Matter & Eide, 2018; Marino et al., 2015). Uganda, Rwanda, and Ethiopia are some of the African countries that promoted the use of AT devices through policy and program interventions, but there is little to suggest that PWDs are fully reaping their benefits. For Ethiopia, local governments have been mandated to provide continuous training of professionals and staff working in rehabilitation services on the use of AT devices for persons living with disabilities (Ministry of Labour and Social Affairs, 2012). Under this intervention, the decentralization system has been used as a basis for setting up orthopedic centers to provide prosthetic appliances such as crutches, artificial limbs, wheelchairs, and other technical aids and devices to PWDs. In Rwanda, the Rwanda Revenue Authority and the Rwanda Utilities Regulatory Authority exempt taxes on all AT devices to promote the mobility and independence of persons living with disabilities (Rwanda Government, 2015). These exemplify some concrete actions and steps that governments and DPOs can follow to close the AT gap.

Academics, including bio-engineers, disability scholars, anthropologists, and economists, among others, shall work alongside PWDs toward developing rigorous methodologies to gain a better understanding of how AT could enable PWDs to live the lives they would like to live. Design of AT shall be focusing on enhancing the user's agency, bodily integrity, and capabilities, and not trying to "fix disabled bodies." To address the AT gaps, it is necessary to design technology with and for its potential users. The potential users and their community (local healthcare personnel, volunteers, family, employers, etc.) are aware of the issues, needs, and available resources of the area in which they live, and so their contribution shall be at the heart of AT design (Norman, 2019).

It is also crucial to ensure adaptability to the global context. Adding customizing tools or features to the developed technologies empowers the user to configure the device to change depending on their needs or environment, without the need of specialized personnel. This can only happen by putting in place a synergic multi-disciplinary approach. The design must focus upon the entire issue under consideration, engaging all the involved disciplines as a whole and not as isolated components. In other words, all the project stakeholders (technology experts, designers, bio-ethicists, social scientists, potential users, healthcare personnel, industry and policymakers) should work together as a big team, rather than smaller sub-sections, encouraging constant interaction and communication. Additionally, no activity should be developed in isolation but as a synergic part of a complex sociotechnical system.

To ensure that a prototype reaches the market, it is necessary to incorporate a viable business model. In order to assure that the technology will remain sustainably available, it is vital that developers include, in parallel to the technology development, the development of a complete value chain and business model. By the end of the development project, the technology and business plan can be used to create a new social start-up that will industrialize the technology, or be transferred to an existing company which is interested in deploying and scaling the technology. Entrepreneurship is at the heart of the strategy to create a long-lasting impact on the shortage of efficient AT.

Designing with and for those in LMICs will not exclude the fact that the developed technology can also be useful for those in high-income countries. This is because, firstly, PWDs are also at higher risk of poverty in high-income countries; therefore, affordable assistive devices adapted to low-resource environments will enhance access for this part of the population. Secondly, the advantages of usability and processing capacity are perhaps appreciated and beneficial to those well-off consumers. It is crucial to achieve a better understanding of how AT can enable PWDs to live the lives that they have a reason to value. Disability is very diverse, and there is a lack of evidence as to what type of technology works for different people in different contexts. Consequently, we need to gain insight into bodily integrity, and how functioning is perceived by persons living with impairments, in order to develop better technologies that can be a tool for self-determination.

References

Anderson, I., Robson, B., Connolly, M., Al-Yaman, F., Bjertness, E., King, A., ... & Yap, L. (2016). Indigenous and tribal peoples' health (The Lancet–Lowitja Institute Global Collaboration): A population study. *The Lancet*, *388*(10040), 131–157.

Bickenbach, J. (2013). The international classification of functioning, disability and health and its relationship to disability studies. In N. Watson, A. Roulstone, C. Thomas (Eds.), *Routledge handbook of disability studies* (pp. 65–80). Routledge.

Borg, J. & Östergren, P-O. (2015). Users' perspectives on the provision of assistive technologies in Bangladesh: awareness, providers, costs and barriers. *Disability and Rehabilitation: Assistive Technology*, *10*(4), 301–308. http://dx.doi.org/10.3109/17483107.2014.974221

Cassit Orthopedics Ltd. (2016). *Medical personnel questionnaire*. Cassit Orthopedics Ltd.

Caycho, R. (2020). The flag of imagination: Peru's new reform on legal capacity for persons with intellectual and psychosocial disabilities and the need for new understandings in private law. *The Age of Human Rights Journal*, *14*, 155–180.

Collins, C. C. (1985). On mobility aids for the blind. In D. Warren and E. Strelow (Eds.), *Electronic spatial sensing for the blind* (pp. 35–64). Springer.

Díaz Toro, A., Campaña Bastidas, S., & Caicedo Bravo, E. (2020). Methodology to build a wearable system for assisting blind people in purposeful navigation. *3rd International Conference on Information and Computer Technologies (ICICT)*, San Jose, CA, pp. 205–212. 10.1109/ICICT50521.2020.00039

Elli, G., Benetti, S., & Collignon, O. (2014). Is there a future for sensory substitution outside academic laboratories? *Multisensory Research, 27*(5–6): 271–291

Frediani, G., Busfield, J., & Carpi, F. (2018). Enabling portable multiple-line refreshable Braille displays with electroactive elastomers. *Medical Engineering and Physics*, *60*, 86–93

Global Initiative for Inclusive Information and Communication Technologies. Retrieved May 2020 from https://g3ict.org/digital-accessibility-rights-evaluation-index/country_classification

Golledge, R., Marston, J., and Loomis, J. (2004). Stated preference for components of a personal guidance system for nonvisual navigation. *Journal of Visual Impairment and Blindness*, *98*(3), 135–147.

Hanass-Hancock, J., Nene, S., Deghaye, N., & Pillay, S. (2017). "These are not luxuries, it is essential for access to life": Disability related out-of-pocket costs as a driver of economic vulnerability in South Africa. *African Journal of Disability*, *6*, 1–10.

Handicap International. (2010). *Legal framework governing disability rights: Burkina Faso, Mali, Niger, Senegal, Sierra Leone and Togo, West Africa*. Report May 2020 retrieved from https://afri-can.org/wp-ontent/uploads/2019/08/legal_frame_ork_summary_gb1.pdf

Hickey, H., & Wilson, D. L. (2017). Whānau hauā: Reframing disability from an Indigenous perspective. *Mai Journal*, *6*(1), 82–94.

International Organization for Standardization (ISO). (2010). *Ergonomics of human-system interaction—Part 100: Introduction to standards related to software ergonomics*. Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:tr:9241:-100:ed-1:v1:en

International Organization for Standardization (ISO). (2020). Retrieved from www.iso.org

Leo, F., Ferrari, E., Baccelliere, C., Zarate, J., Shea, H., Cocchi, E., Waszkielewicz, A., & Brayda, L. (2019). Enhancing general spatial skills of young visually impaired people with a programmable distance discrimination training: a case control study. *Journal of NeuroEngineering and Rehabilitation*, *16*, 108.

MacDonald, J., Henry, P., & Letowski, T. (2006). Spatial audio through a bone conduction interface: audición espacial a través de una interfase de conducción ósea. *International Journal of Audiology*, *45*(10), 595–599.

Marino, M., Pattni, S., Greenberg, M., Miller, A., Hocker, E., Ritter, S., & Mehta, K. (2015). *Access to prosthetic devices in developing countries: Pathways and challenges*. IEEE 2015 Global Humanitarian Technology Conference. Retrieved from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7343953

Makohliso, S., Klaiber, B., Sahli, R., Tapouh, J. R. M., Amvene, S. N., Stoll, B., & Schönenberger, K. (2020, July 4). Medical technology innovation for a sustainable impact in low- and middle-income countries: A holistic approach. https://doi.org/10.31224/osf.io/2dytg

Matter, R., & Eide, A. (2018). Access to assistive technology in two southern African countries. *BMC Health Services Research*, *18*, 792–802.

McPherson, B., & Clark, J. (2017). *Preferred profile for hearing-aid technology suitable for low- and middle-income countries*. WHO. http://apps.who.int/iris/bitstream/10665/258721/1/9789241512961-eng.pdf

Meekosha, H. (2011). Decolonizing disability: Thinking and acting globally. *Disability & Society*, *26*(6), 667–682.

Meekosha, H. & Shuttleworth, R. (2009). What's so "critical" about critical disability studies? *Australian Journal of Human Rights*, *15*(1), 47–75.

Milotta, F. L. M., Allegra, D., Stanco, F., & Farinella, G. M. (2015). An electronic travel aid to assist blind and visually impaired people to avoid obstacles. In G. Azzopardi & N. Petkov (Eds.) *Computer Analysis of Images and Patterns*. CAIP 2015. Lecture Notes in Computer Science, vol 9257. Springer.

Ministry of Labour and Social Affairs. (2012–2021). *Ethiopia national plan of action (ENPA) of persons living with disabilities*. Addis Ababa.

Mitra, S. (2003, September 8–10). *The capabilities approach of disability* [Paper presentation]. Third Conference on the Capabilities Approach From Sustainable Development To Sustainable Freedom, University of Pavia, Italy.

Mitra, S. (2014). Reconciling the capability approach and the ICF: A response. *ALTER: European Journal of Disability Research, Forthcoming*, Available at SSRN: https://ssrn.com/abstract=2377333

Mitra, S. (2017). *Disability, health and human development*. Springer Nature.

Ministry of Gender, Labour and Social Development (MOGLSD, 2006). National Policy on Disability in Uganda, Kampala.

Mji, G. & Edusei, A. (2019). An introduction to a special issue on the role of assistive technology in social inclusion of persons with disabilities in Africa: Outcome of the fifth African Network for Evidence-to-Action in Disability conference. *African Journal of Disability*, *8*(0), a681. https://doi.org/10.4102/ajod.v8i0.681

Murray, J., de Castro Cerqueira, D. R., & Kahn, T. (2013). Crime and violence in Brazil: Systematic review of time trends, prevalence rates and risk factors. *Aggression and Violent Behavior*, *18*(5), 471–483.

Norman, D. & Spencer, E. (1 January 2019). *Community-based, human-centered design*. Retrieved from https://jnd.org/community-based-human-centered-design/

Persson, H., Ahman, H., Yngling, A. A., & Gulliksen, J. (2015). Universal design, inclusive design, accessible design, design for all: different concepts: one goal? On the concept of accessibility: historical, methodological and philosophical aspects. *Universal Access in the Information Society*, *14*(4), 505–526.

Rivas Velarde, M. (2018a). The Convention on the Rights of Persons with Disabilities and its implications for the health and wellbeing of indigenous peoples with disabilities: A comparison across Australia, Mexico and New Zealand. *Disability and the Global South*, *5*(2), 1430–1449.

Rivas Velarde, M. (2018b) Indigenous perspectives of disability. *Disability Studies Quarterly*, *38*(4). http://dx.doi.org/10.18061/dsq.v38i4.6114

Rwanda Government (2015). *ICT and Disabilities in Rwanda*. Kigali.

Saha, M., Saugstad, M., Maddali, H. T., Zeng, A., Holland, R., Bower, S., Dash, A., Chen, S., Li., A, Hara, K, & Froehlich, J. (2019, May). Project sidewalk: A web-based crowdsourcing tool for collecting sidewalk accessibility data at scale. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1–14).

Sen, A. (1993). Capability and well-being. In M. Nussbaum & A. Sen (Eds.), *The quality of life*. Clarendon Press. 10.1093/0198287976.001.0001

Sen, A. (2008). The idea of justice. *Journal of Human Development*, *9*(3), 331–342.

Sonar, H. Gerratt, A., Lacour, S. P., & Paik, J.(2020). Closed-loop haptic feedback control using a self-sensing soft pneumatic actuator skin. *Soft Robotics*, *7*(1): 22–29.

Tapu, R., Mocanu, B., & Zaharia, T. (2018). Wearable assistive devices for visually impaired: A state of the art survey. *Pattern Recognition Letters*. https://doi.org/10.1016/j.patrec.2018.10.031

Thackeray, R. & Hunter, M. (2010). Empowering youth: Use of technology in advocacy to affect social change. *Journal of Computer-Mediated Communication*, 15, 575–591.

Varao Sousa, T., Carriere, J., & Smilek, D. (2013). The way we encounter reading material influences how frequently we mind wander. *Frontiers in Psychology*, *4*, 892.

Vilalta Perdomo, C., Castillo, J., Torres, J. (2016). *Violent crime in Latin American cities*. *IDB-DP-474*. Institutions for Development Sector. Inter-American Development Bank.

Visagie, S., Eide, A. H., Mannan, H., Schneider, M., Swartz, L., Mji, G., Munthali, A., Khogali, M., van Rooy, G., Hem, K.-G., & MacLachlan, M. (2016). A description of assistive technology sources, services and outcomes of use in a number of African settings. *Disability and Rehabilitation: Assistive Technology*, *12*, 705–712. http://dx.doi.org/10.1080/17483107.2016.1244293

Visagie, S., Matter, R., Kayange, G., Chiwaula, M., Harniss, M., & Kahonde, C. (2019). Perspectives on a mobile application that maps assistive technology resources in Africa. *African Journal of Disability*, *8*(0), a567. https://doi.org/10.4102/ajod.v8i0.567

Williams, R. M. & Gilbert, J. E. (2019). "Nothing about us without us": Transforming participatory research and ethics in human systems engineering. In R. D. Roscoe,

E. K. Chiou, & A. R. Wooldridge (Eds.), *Advancing Diversity, Inclusion, and Social Justice Through Human Systems Engineering* (pp. 113–134).

World Health Organization (WHO). (2001). *International classification of functioning, disability and health*. World Health Organization.

World Health Organization (WHO). (2011). *World report on disability 2011*. World Health Organization.

World Health Organization (WHO). (2018). Assistive technology. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/assistive-technology

World Health Organization (WHO). (2019, August 22–23). *Global perspectives on assistive technology: proceedings of the GReAT Consultation 2019, Volume 1*. World Health Organization.