A ratification of means: International law and assistive technology in the developing world

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ABSTRACT: Several nations around the world have ratified the UN Convention on the Rights of Persons with Disabilities (CRPD) since 2008. Ratifying states commit that national law will guarantee rights enumerated in the CRPD. The use of Assistive Technology (AT) in ensuring the social inclusion of people with disabilities is specifically mentioned in the convention. Although AT is increasingly seen as necessary in facilitating functional equity in social and economic participation, most AT and accessibility tools are not just expensive but are also and typically designed for use by people in industrialized nations. The practical implication of the CRPD's impact on AT for the developing world is a vast subject, in this paper we examine the cost of AT for people with vision impairments at current day costs, and find that the functional fulfillment of the CRPD for a lot of the signatory countries would be extremely difficult without significant technological innovation and market expansion in this space.

I. INTRODUCTION

The historic opening of the UN Convention on the Rights of Persons with Disabilities (UNCRPD) was hailed by many as a unique success among international agreements within the UN system. There were more signatories to the convention on the first date of its opening than for any other comparable convention in the history of the UN system. The convention has for many countries been the first such document recognizing disability from a rights-based perspective. It committed nation-states to providing legal equity, physical, political, social and economic access, and enabling conditions to allow for full participation in society. Depending on the constitutional and legal systems of individual states, the Convention may automatically form part of national law on ratification of the Convention; in some cases, the legislature may have to adopt an act of ratification at the national level for the Convention to be incorporated into domestic law.

The signing and swift ratification of the UNCRPD by several countries, including some of the several countries from the UN's low-income economies bracket, raises the hopes of social and economic equity among millions living with disabilities around the world, but also raises a number of questions. We examine particularly those related to Assistive Technologies (AT) and (technological) accessibility. The convention if adopted to its full intent will be revolutionary, since many countries have no existing national legislation for the rights of persons with disabilities. However, even if the convention is not adopted to its full meaning by signatory countries, there is still a likelihood that there will be a constitutional recognition of rights for the disabled, and on the availability of services for people with disabilities.

II. RELATED WORK

A. Existing research on disability in the developing world

We can divide the scholarly work on disability in the developing world into two broad classifications. The first may be called a medical model approach, examining disability in terms of disease burden (Maulik and Darmstadt, 2007; Murray and Lopez, 1997; Simeonsson, 1991; Snow et al., 1999), focusing on the enumeration and prevention of disability, or examining the impacts of disability through one specific variable of analysis. The second is anthropological and philosophical work on disability, approaching it from cultural frames of social or rights-based models (Devlieger, 1995; Jackson and Mupedziswa, 1988; Rösing, 1999; Stone and Priestley, 1996). In this article, we take a somewhat mixed position, examining assistive technology through means that may be seen as a medical model of thinking, but using the UN Convention as an artifact of analysis from which to build theory. Within the work on disability in the developing world, little or no empirical work exists on assistive technology or accessibility, while there has been some work discussing the scope of the UN Convention (Kanter, 2006) and on the education of children with disabilities in relation to the convention (Hernandez, 2008).

B. Existing research on international conventions

An important goal of making the UN Convention central to the arguments set forth in this article is to examine from a historical perspective the outcomes of past international legislation on services for a specific population. In the two years following the Convention's opening, there have been a number of international conferences, as well as work by NGOs and research groups looking at the CRPD including work at G3ict and the Burton Blatt Institute.

In general, international conventions have the baggage of limited real enforceability against nation-states because of state sovereignty and a broad cultural resistance to global governance of any form (Paul, 2000). The ability of nation-states to culturally interpret international law has typically meant that the implementation of several such conventions is largely dependent on the appropriation of the nation-state in question, as has been seen in the cases of human rights (Hathaway, 2001), women's rights (Cook, 1989; Venkatraman, 1994), and torture (Miller, 2002). From an

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international law perspective – the granularity in outlining specific rights and responsibilities is very important. Greater specificity has the benefit of calling out to the importance of one of a set of rights, but also offers the risk of the blatant non-fulfillment of those mentioned provisions. The mention of AT in articles of the CRPD thus brings attention to AT worldwide, but can also potentially reduce the credibility of the convention as a whole if nation states are unable to deliver the cited promise.

C. Incremental contribution within ICTD

The past decade of work in ICTD has led to improvements in personal devices and networking technology, explicitly built for use in low-resource or low-technological skill scenarios. The 'technologist' side of ICTD has often been comprised of smart young engineers looking for interesting research and implementation issues that need solving.

The result has been a range of personal computing devices (Ali and Langendoen, 2007; Hourcade et al., 2008), networking and communications (Patra et al., 2007; Seth et al., 2006), interfaces (Kam et al., 2008; Parikh and Lazowska, 2006), and data management technology (DeRenzi et al., 2008; Sharma et al., 2008). Such work has extended the limits of computing in education, healthcare delivery, microfinance, and even primary sectors such as agriculture and fishing. Surprisingly, work on assistive technology has been an exception, in spite of a vibrant community of activists and practitioners working on disability rights issues and frequently reiterating the need for low-cost technologies.

The ICTD community, as a unique intersection of engineers, social scientists, and development scholars, is very well positioned to play a leadership role in solving some of the key problems. In Section V, we describe AT technology and argue that there are not only interesting applied engineering problems, but also new research questions that need solving in the AT space if these are to be made low-cost and widely available.

III. Approach

We use the UN Convention as our primary point of departure in making the case that there is much scope and need for social science and technology research for assistive technology and accessibility for persons with vision impairments. As a multi-disciplinary group of scholars, assistive technology users, and disability rights activists, we divide our approach into three parts.

First, from the legal standpoint, we make a detailed examination of the UNCRPD and the elements in it that pertain to assistive technologies, to make the case that significant new investments are needed in accessibility and assistive technology development and production.

Second, we describe the state of assistive technology for the vision-impaired populations and describe the key technological and cost-related challenges for the various technologies.

Finally, we do a very basic enumeration of costs to five countries, randomly selected from each continent, that have signed the Optional Protocol. The goal of doing this, while recognizing that the costs of many technologies would fall should they be manufactured at scale, is to get a rough idea of the ability of countries to fund AT and accessibility for constituent populations that need these.

Our choice of technologies for vision impaired users is solely based on our familiarity with these technologies.

IV. Convention

The Convention has its roots in the UN from three decades ago when the General Assembly (GA) adopted the World Programme of Action concerning Disabled Persons, which promoted the full participation of persons with disabilities in social life in all countries regardless of their level of development. The use of 'promotes' meant that there were no binding actions, but the specific mention of 'all countries regardless of their level of development' was an important step ahead that did not demote rights for the disabled as secondary to national goals of economic development. This is noteworthy given the history of General Assembly voting and the discourse of several nations of posturing of national economic development as trumping other areas of concern such as human rights, environment, etc.

The decade immediately following --from 1983 to 1992-- was declared the UN Decade of Disabled Persons. At the end of this, in 1993, the GA adopted the 'Standard Rules on the Equalization of Opportunity for Persons with Disabilities,' which required states to remove obstacles to equal participation. A Special Rapporteur was appointed as a monitor for the implementation at national levels, but this was not legally binding.

The most frequently-raised objection against a separate convention for the rights of persons with disabilities was that the existence of a Universal Declaration of Human Rights technically extends to all people, despite not explicitly mentioning disability. The movement for a separate classification was supported by a number of factors. First, a number of states legislated these disability rights, in spite of having general citizen rights constituted, thus highlighting the recognition for a separate discussion on disability. Second, the Decade of Disabled Persons had not led to much quantifiable progress. Finally, the UN's recognition of a distinction beyond the general 'human rights' definition in its creation of a Convention on the Rights of the Child (which also explicitly mentioned disability), strengthened the case for a separate convention. The ad-hoc committee meetings for the Convention began in 2002, and culminated in a General Assembly adoption of the final Convention in 2006, which was opened to signing by nation-states on 30 March 2007.

The convention makes certain duties explicit for signatories. Among these are requirements to remove discriminatory laws, stop torture and cruel treatment of people with disabilities, especially in mental health institutions (Perlin, 2009), and to create mechanisms for the reporting, investigation, and resolution of discrimination allegations. Some elements of the general principles and obligations of the convention are related to anti-discrimination. They require legislative changes rather than any immediate infrastructure, technology, or social spending. Other elements that involve the actual facilitation of equity are far more complex, and their broad definition makes it harder to define the extent of the state's responsibility.

A. Technology and the UN Convention

"Individuals who cannot access the Internet are denied a certain degree of involvement in society."

Chapter 6, UN Enable

A discussion of technology in relation to the UNCRPD can be tricky because there are both explicit and implicit roles for assistive tools in implementing the convention to its intended spirit. The explicit form here refers to specific mentions of Assistive Technology and Accessibility, which are clearly stated in certain contexts such as research and development. The implicit, and more complex cases, are those where a right is defined, such as for instance the right to education, which may be extremely difficult to achieve for persons with certain disabilities without the intervening use of some form of assistive technology either at the individual device level or at a broader infrastructural level. As an example, in several countries where governance and the economy are increasingly technology-heavy, the right to work or the right to political and public life--both defined in the Convention--may not be actionable without adequate access to computing resources. In addition, there is much evidence that assistive technology significantly raises educational and workplace opportunities for people with disabilities (Beijen et al., 2007; Parette and Petersen-Karlan, 2007). Thus, the inclusion of widespread access to assistive technology is increasingly central to any discussion on equitable participation by all.

There are several articles in the convention that specifically refer to assistive technology or accessibility in some form. We describe these in some detail to emphasize the importance of new research in assistive technology, towards their large scale development and availability for populations in signatory nations. These include:

- Article 4 (General Obligations), Sections 1(g) and (h): Section 1(g) refers to states' commitment to undertake or promote research and development of new technology and give priority to technologies at affordable costs. Section 1(h) commits states to providing accessible information about assistive technologies.
- Article 9 (Accessibility), Section 2(g) and (h) commit states to promoting the design, development, production, and distribution of accessible ICTs at an early stage, such that these technologies become accessible at a minimal cost.
- Article 20 (Personal Mobility), Section (b) commits states to facilitating access to quality mobility aids and assistive technologies for persons with disability. Section (c) commits states to encouraging entities that provide assistive technologies to conduct needs assessments of people with disabilities.
- Article 21 (Freedom of expression and opinion, and access to information), Section (b) commits states to facilitate augmentative and alternative communication (AAC). Section (c) commits states to urging private entities with an internet presence to providing information in accessible and usable formats. Section (d) commits states to urge the same to mass media.
- Article 26 (Habilitation and rehabilitation), Section 3 requires that states promote assistive technologies for rehabilitation. Article 29 (Participation in political and public life) Section (iii) requires that states facilitate assistive technologies for the voting process.
- Article 28 (Work and employment), Section 1(d) commits states to enabling persons with disabilities to have effective access to technical and vocational guidance. Section 1(h) calls for the potential promotion of affirmative action programs. Most significantly, Section 1(i) commits states to ensuring reasonable accommodation is provided to persons with disabilities in the workplace. Technology is central to this particular item, especially in the case of vision-impaired persons in the labor market who require accessible computing tools.

In addition to all of these, there is also Article 8 (Awareness Raising), Section 2.a.iii. This specifically requires states to promote the recognition of skills, merits and abilities of persons with disabilities in the workplace and labor market, which in turn is relevant to the integration of people with disabilities into the workforce, with the accompanying technological tools that enable this participation.

The Optional Protocol delineates a process whereby a central Committee may receive communications and conduct investigative proceedings regarding potential violations of the Convention by signatory parties to the Protocol.[1] Thus, overall, the number of specific requirements is fairly comprehensive. Although most of the statements are worded with ambiguity on the actual level of commitment required, the fact that states need to provide periodic reports on their progress with providing these services suggests that the signing of the convention is well beyond lip service.

B. Country-wise examination

To contextualize our study in tangible terms, we chose to conduct a country-wise examination of what it would cost to implement the aforementioned articles through the provision of assistive technologies. The objectives of this examination are to get a sense of the real gap among various nations in what it would cost to get assistive technologies to everyone who needs them, and to identify the likely areas of critical need within technology research.

We selected five countries from among the signatories to

[1] Although certain language in the Protocol requiring exhaustion of domestic remedies (Article 2) and limiting Committee action to making recommendations for redress (Article 6)

the Optional Protocol of the UNCRPD, one from each continent in no particular order. At this point, we are solely interested in these countries from the perspective of their per capita income, to isolate what it would cost for each of them to provide assistive technologies at current market prices at either an individual or a shared model of use. As a shared model, for most technologies we assume a 1/100 ratio of product purchase.

We selected five countries that have ratified the Optional Protocol, as a means of picking from those nations that have outlined the highest level of commitment. Of the countries selected, two are high-income nations (Australia and United Kingdom), one upper-middle income (Brazil), one lower-middle income (Mongolia), and one low-income (Niger).

V. Technology

A. *Definitions: Assistive Technology and Accessibility*

"Accessibility" is the degree to which a product, device, service, or environment is accessible by as many people as possible. "Assistive technology" (AT) is defined as any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities (US Public Law 100-819).

B. *Scholarly directions in accessibility and assistive technology in vision impairment*

The computer science research community has been very active in publishing its ideas on improving accessibility in conferences, such as the ACM Conference on Computers and Accessibility (ASSETS) and the more industry-dominated CSUN Conference.[2] However, there is a general lack of coordination between the research community, which is driven by the novelty of work, and the industry, which is more concerned with monetization due to being in an extremely small market with high pressures (Vernardakis et al., 1995). Some recent research has hinted at the need for greater involvement of AT domain experts in academic work in accessibility, which tends to be dominated by HCI experts. (Allen et al., 2008).

We identify three areas in which we find much engineering interest at present. The first is web accessibility, which for reasons of compliance is of significance to industry and research alike. One of the important new directions in web accessibility is that of social accessibility through collaboration (Takagi et al., 2009). There is also research that works on improving blind users' ability to rank link usefulness by increasing the information scent that can be a guide to whether the link leads to a useful webpage (Vigo et al., 2009). Such work on folksonomies and collaboration in general is likely to be an important area of accessibility research in the future, as there is greater convergence between personal technology with an increasing population of blind users online.

[2] Both of these are typically North American conferences

A second area of AT focus deals with the better description of sight-intensive screen information such as maps, charts, and equations. There is much interest currently in tactile graphics, including technologies that convert images and their accompanying text using commercial embossers to create tactile maps or tablet-front sound-based maps (Wang et al., 2009). A related area of work is in making maps and charts accessible on office applications (Doush et al., 2009). There is also significant interest in the disambiguation of mathematical expressions into speech (Gellenbeck and Stefik, 2009).

A third area of recent research is that of mobility. There is work on the use of sensing technology mounted on canes (Ju et al., 2009), and on the use of haptic devices in wayfinding (Amemiya and Sugiyama, 2009). Such work is an important direction moving ahead, since it is also tied to the use of cellular telephones in wayfinding. With phones getting both cheaper and holding greater possibility of geographical tagging using GPS, this is an area of research likely to continue to grow very significantly.

One of our purposes of discussing the major directions in technology research is to underline some of the mismatch between what academia in accessibility and assistive technology is currently interested in, and what is likely to be needed for the developing world in the future, given the UNCRPD. Sadly, there is little mainstream interest in subjects such as language localization of screen readers, development of low-cost alternatives to existing screen readers, or mobility tools on low-cost cell phones. These areas are of immediate importance to the developing world.

C. *Visual Impairment and Technology*

1) *Definition*

The medical definition of visual impairment (or vision impairment) is vision loss (of a person) to such a degree as to qualify as an additional support need through a significant limitation of visual capability resulting from either disease, trauma, or congenital or degenerative conditions that cannot be corrected by conventional means like refractive correction, medication, or surgery. Choice of appropriate assistive and accessible technology (visual, auditory or tactile) will depend on the user's level of functional vision.

2) *Assistive Technologies and the cost of providing them widely*

In this section, we discuss the key assistive technologies, and consider their cost as well as the current state of research in each to discuss the work needed ahead to make them reliably available.

Table1: Types of Vision impairments and technology commonly used

Low vision	**Blind & Legally Blind**	**Deaf Blind**
Hi resolution screen	Braille Display	Braille Displays
Oversize monitors	Braille Translators	Braille printers
Glare guard	Braille Printers	Braille translators
CCTV	Screen readers	Screen readers

Screen magnifiers Devices for audio output	OCR Systems Devices for audio output	OCR Systems Deaf blind communicator

For the sake of calculating an ideal case scenario, we assume each assistive technology will be provided to every person who theoretically needs it (this is of course rarely true even in the developed world), just to get a ballpark figure of what it would cost in real GDP dollars as well as in terms of cost per capita to the entire country. It also offers the cost of a shared model where one device is provided per 100 persons. We also proceed initially with the hypothetical case that the entire blind population in each country knows Braille and can use Braille devices.

Table 2: Countries, blind population and GDP per capita

Country	Date of Ratification	Blind Population	Real GDP PCI in US$
Australia	08/2009	80531	41,982
Brazil	08/2008	744526	7,737
Mongolia	05/2009	11126	1,564
Niger	06/2008	45,943	375
United Kingdom	09/2009	243741	35,728

We briefly list the key assistive technologies, the range of cost of current off-the-shelf options, and additional needed

Table 3: Assistive Technologies, Requirements, Cost range and additional needs.

Technology	H/W & S/W requirement	Cost (Range)	Addl. Needs
Braille Translators	CD-ROM Drive IBM Compatible PC, 150MB or higher memory	$200 - $1000	Printer, Paper
Optical Character Recognition Systems	CD-ROM Drive IBM Compatible PC,500MB memory Sound Card Scanner	$1000 - $4000	Speech synthesizer, Braille display
Screen Readers	IBM Compatible PC, 20MB-125MB and 256MB RAM Sound Card	$0 - $1500	Speech synthesizer
Speech Synthesizers	IBM Compatible PC, 20MB-125MB and 256MB RAM Sound Card, screen reader	$150 - $1000	Screen Reader
Screen Magnification Systems	CD-ROM Drive IBM Compatible PC RAM 256MB Sound Card	$300 - $600	Speech synthesizer and screen readers if speech output needed
Braille Displays	IBM Compatible PC	$3,500 - $15,000	Screen reader
Braille Printers	IBM Compatible PC	$1,800 - $80,000	Screen Reader, Paper
CCTVs/Video Magnifiers	NA	$1400 - $2700	CCTV-compatible Computer

D. Summary of key technologies

a) Braille Display (Cost: $3500-$15000)

Learning Braille is critical for persons with vision impairments. Although a number of audio-based technologies allow communication, knowledge of Braille is literacy. Braille displays provide access to information on a computer screen by electronically raising and lowering different combinations of (usually nylon) pins in Braille cells. The advantage of Braille displays over synthetic speech is that they provide direct access to information. Most current Braille display devices rely on piezoelectric materials for pin actuation. Because of the complexity of producing a reliable display using these materials that will cope with daily wear and tear, these displays are expensive and out of reach for many potential consumers. The cost of the Braille display also depends on the number of characters it displays at a given point in time.

The rotating-wheel Braille display is a system in which Braille dots are placed on the edge of a spinning wheel. This allows the user to read text continuously using a stationary finger as the wheel spins round at a selected speed. As the Braille dots are set in a simple scanning style and the Braille characters are set by an actuator, the cost and complexity of manufacturing a unit is reduced greatly as compared to traditional displays.

Table 4: One-time cost of providing Braille Display to population (in individual and shared models)

Country	Blind Popn.	Cost Range in US$ Mil.	Cost /GDP Range (%)	Shared Model Cost in $US Million
Australia	80531	281.9 - 1208	0.03 - 0.14	2.81- 12.08
Brazil	744526	2606 - 11168	0.18 - 0.78	26.06 - 111.68
Mongolia	11126	38.9 - 166.9	0.9 - 3.87	0.38 - 1.66
Niger	45943	160.8 - 689.1	3.8 - 16.17	1.6 - 6.89
United Kingdom	243741	853 - 3656	0.03 - 0.16	8.53 - 36.56

Typically, Braille displays are the most expensive form of assistive technology. We see here that even for countries like Australia and UK, the cost of providing a high-end Braille display to every individual who needs one would be in the range of 0.15% of the entire GDP, or almost 5% of the entire GDP in Niger. An additional issue with a Braille display concerns the need for additional computing infrastructure as well as a screen reader. The shared model cost here is quite useful in estimating what it would take to kick-start a ‘Braille display’ project; we see here that for US $1.6 Million, a shared model of a few Braille displays--possibly at a public library--could be provided to serve the entire population.

Braille displays are among those technologies for which there is unlikely to be any cost reduction without a significant technological breakthrough of the complex nature of the design. One interesting direction ahead consists of low-cost hydraulic Braille displays using bendable actuators made with electro-active polymers. In general however, the Braille display is likely to stay out of reach for most blind people, even in the industrialized world.

b) Braille Printers (Cost: $180-$80000)

Braille printers receive data from computer devices and emboss that information in Braille onto paper by using solenoids that control embossing pins.

Table 5: Cost of Braille printers

Country	Blind Popn.	Cost Range in US$ Mil.	Cost /GDP Range (%)	Shared Model Cost in $US Million
Australia	80531	145 – 6442	0.0 - 0.77	6.4
Brazil	744526	1340 - 59562	0.09 - 4.18	59.5
Mongolia	11126	20 - 890	0.46 -20.7	0. 9
Niger	45943	82 – 3675	0.19 - 86.3	3. 7
United Kingdom	243741	4387 – 19499	0.02 - 0.9	19.5

Access to a small $200 home Braille printer can be an alternative to a Braille display, though the smaller Braille printers are typically used to print small signs rather than full documents and are generally expensive to print on.

There is a vast range of single and double-sided printers. Depending on whether the print is intended to be preserved, the material used may differ. Each of these has cost consequences. Thermoform embossers use a vacuum and heat to create raised areas on special plastic paper; such plastic paper typically lasts longer. A Braille printer is also something that one may typically expect to see at a library. Thus, a large industrial strength Braille printer would probably suffice for a fairly large population assuming the printing needs are not of a daily nature.

For industrial strength Braille printers, we use a calculation above at the assumption of 1 printer servicing 10,000 blind users. Still, we see that the cost at current market prices remains exceptionally high; even a wealthy country like the U.K. would probably have concerns allocating the equivalent of US $20 million for just the Braille printers.

c) Braille Translators (Cost: $200-$1000)

A Braille translator takes a document and converts it into a Braille file. The Braille file can then be sent to a Braille printer or read on a Braille display or a personal digital assistant. The language support it provides for translation is much less. Therefore, it would be an engineering challenge to provide support for as many languages as possible since multiple-language support makes the display costlier.

Table 6: Cost of Braille translators

Country	Blind Popn.	Cost Range in US$ Mil.	Cost /GDP Range (%)	Shared Model Cost in $US Million
Australia	80531	16.1- 80.5	0.001- 0.009	0.16 - 0.80
Brazil	744526	148.9 - 744.5	0.01- 0.05	1.48 - 7.44
Mongolia	11126	2.2 – 11.1	0.05- 0.25	0.02 - 0.11
Niger	45943	9.2- 46	0.21- 1.07	0.09 - 0.46
United Kingdom	243741	48.7- 243.7	0.002 -0.01	0.48 - 2.43

Even though there are expensive Braille translators, this is an area where low-cost software may soon win the battle. The existence of cloud options means that governments can make Braille translation software or possibly Braille transcription services (involving a human mediator) readily available.

d) Optical character recognition system (Cost: $300-$1200)

Optical character recognition (OCR) systems provide persons with the capacity to scan printed text and then have it spoken in synthetic speech or saved to a computer file.

Table 7: Cost of Braille printers

Country	Blind Popn.	Cost Range in US$ Mil.	Cost /GDP Range (%)	Shared Model Cost in $US Million
Australia	80531	24.2 - 96.5	0.002- 0.01	0.24 - 0.96
Brazil	744526	223.4 – 893.4	0.01- 0.06	2.23 - 8.93
Mongolia	11126	3.3- 13.4	0.07- 0.31	0.03 - 0.13
Niger	45943	13.8- 55.1	0.32-1.29	0.13 - 0.55
United Kingdom	243741	73.1- 292.5	0.003- 0.01	0.73 - 2.92

e) Screen Readers (Cost: $0-$1200)

Screen readers are software programs that allow users to read the text that is displayed on the computer screen with a speech synthesizer. A screen reader is the interface among the computer's operating system, its applications, and the user. The customer base for screen readers is much smaller, and people are not aware of the alternatives. It is a marketing challenge to make people aware of the need-based alternatives.

Table 8: Cost of screen readers

Country	Blind Popn.	Cost Range in US$ Mil.	Cost /GDP Range (%)	Shared Model Cost in $US Million
Australia	80531	0- 96.6	0 - 0.01	0 – 0.96
Brazil	744526	0 - 893.4	0 - 0.06	0 – 8.93
Mongolia	11126	0 - 13.4	0 - 0.31	0 – 0.13
Niger	45943	0 - 55.1	0 - 1.29	0 – 0.55
United Kingdom	243741	0 - 292.5	0 - 0.01	0 – 2.92

We argue that there can be no negotiation on the public provision of screen readers, since blind users essentially have no way of using computers without them. In the shared model of cost described in Table 8 above, we use the crude calculation of 1 licensed screen reader per 100 blind users, assuming this were available in public libraries.

Two screen readers--JAWS and Window-Eyes--together control over 90% of the screen reader market. The two products rank highest in functionality, and support the range number of applications. A number of free and open source alternatives exist, most significantly NVDA, but research shows that there is still much work to do before these options become stable and reliable enough to replace the functionalities of the market leaders (Hahn, 2009). In addition, online tools exist for blind users unable to afford another screen reader and for web developers targeting accessible design (Bigham et al., 2008). The work to be done in making screen readers inexpensive revolves mainly around building interfaces and compatibilities between the reader and applications designed for the sighted. This not only requires applied work, but also holds scope for thinking of new ways of to approach the technical challenges of translating screen information to audio.

f) Speech synthesizer (Cost: $50-$800)

A speech synthesizer is a text-to-speech system used with computers. It can be a card inserted into the computer, a box attached to the computer by a cable, or software that works with the computer's sound card**.** Naturalness and intelligibility (i.e. spoken clarity, explicitness, lucidity, comprehensibility and precision) are required to improve the quality of available speech synthesizers.

Table 9: Cost of speech synthesizers in individual and shared models

Country	Blind Popn.	Cost Range in US$ Mil.	Cost /GDP Range (%)	Shared Model Cost in $US Million
Australia	80531	12.1 - 80.5	0.001 - 0.009	0.12 - 0.80
Brazil	744526	111.7 - 744.5	0.007 - 0.05	1.11 - 7.44
Mongolia	11126	1.6 - 11.1	0.03 - 0.25	0.01 - 0.11
Niger	45943	2.2 - 36.8	0.05 - 0.86	0.02 - 0.36
United Kingdom	243741	36.5 - 243.7	0.001 - 0.01	0.36 - 2.43

Speech synthesis systems use two basic approaches. The first, “text-to-phoneme conversion,” involves a large dictionary containing all the words of a language and their correct pronunciations being stored by the program and matched to the spelling. In the other approach, “rule-based conversion,” pronunciation rules are applied to words to determine pronunciation based on their spelling.

From the perspective of developing regions, the first approach is quick and accurate, but fails if it is given a word not contained in its dictionary. As a result, a challenge for new languages involves getting a large enough corpus of words in place. The text-to-phoneme conversion method is more convenient for phonetic scripts like Indic languages than for writing systems that use morphosyllabic characters (as are common in East Asia). Greater accessibility to speech synthesis in the developing world thus poses both challenges of new technology and of corpus development.

g) Assistive Technologies for low-vision users

We briefly discuss the important magnification technologies that are typically used by low-vision users (as distinguished from visually-impaired users). We do not make estimations to the cost of providing these since they pertain to the low-vision population. In the interest of space, and due to lack of accurate statistics on low-vision--especially ageing populations in the developing world--we are unable to provide a rigorous analysis of this segment of AT products.

(1) CCTVs and Video magnifiers (Cost: $1400-$2700)

A video magnifier, or closed-circuit television (CCTV) system, uses a stand-mounted or handheld video camera to project a magnified image onto a video monitor, a television (TV) screen, or a computer monitor. There is research on low-cost devices fabricated like optical mice, with small inbuilt cameras to be placed over books to be read, and relayed to televisions. Those ICTD folks familiar with the Parikh study—which used cell-phones mounted on small handmade wooden cradles to capture images for microfinance transactions (Parikh et al., 2006)--can imagine the same principles applied to low-cost video magnifiers.

(2) Screen magnification systems (Cost: $300-$600)

A screen magnification system enlarges text and graphics on a computer screen. It is loaded into the computer’s memory and functions similarly to a magnifying glass moving over a page, following the cursor, and magnifying the area around it. A few free and low-cost screen magnification systems are readily available.

E. Cell Phone Accessibility

Cell phones are constantly evolving with new features and capabilities. Each additional feature can add another level of inaccessibility. There are very few phones available with significant speech output functionality, and most displays are not designed to be viewable by the majority of individuals with low vision. Though accessible tactile keypads are now common,[3] the expansion of touch-based dialing interfaces has brought a new set of accessibility problems. Problems with the lack of a significant ‘market’ for accessible commodity cell-phones deterred industry action in this space, but accessibility legislation has been helpful in getting more phones for the disabled. For this reason, the CRPD holds important promise on cell phone accessibility.

Here, we evaluate five “accessible” cell phone models, examining the capacity to identify and use the keypad tactilely, determining the ease of navigating menus through auditory and vibratory feedback, and assessing the readability of the visual display.

[3] Done by raising the “5” key on the keypad

Table 10: Cell phone models, features and their accessibility[4]

Phone[5] / Feature	Motorola i580 (US$ 170)	LG VX 8350 (US$ 300)	iPhone (US$ 500)	Nokia 3650	Toshiba VM 4050
Menu options	Y	Y	Y	Y	N
Battery level	Y	Y	Y	Y	Y
Signal strength	Y	Y	Y	Y	Y
Call status	Y	N	Y		Y
Access to text messages	N	N	N	Y	Y
Power on/off alert	Y	Y	Y	Y	Y
Tactile numeric & function keys	Y	Y	N	Y	Y
Adjustable contrast	N	N	Y	Y	N
Adjustable Font & character size	N	N	Y	N	N
Brightness	N	N	Y	N	N
Magnifiers	N	N	Y	N	N
Product manuals in accessible formats	N	Y	Y	N	N
Phone book	Y	Y	Y	Y	N
GPS feature	N		Y	N	
Ringer volume/vibrator control & indicator	N	N	Y	Y	Y
Speed dialing	Y	N	Y	N	N
Audio Caller identification	Y	Y	Y	Y	Y
Keypad lock mode	Y	N/A	Y	Y	N/A
Roaming indicator	N	N	Y	N	Y

As we see from this chart, the range of accessibility features in smart phones is rapidly expanding. Although the cost of these phones remains high, both the second-hand markets and the gradual dropping of prices are making accessible phones more available to those who need them. Research thus far has looked at cell-phones only from the perspective of accessibility, but in the years ahead, the cell-phone itself as an assistive technology device is likely to gain far more attention. As noted in Section V (B), cell-phones are likely to become an important tool for mobility, especially as street infrastructure improves and GPS-based navigation becomes cheaper and more viable. In fact, our entire attention to AT will change over the next decades as cell-phones themselves get more powerful and closer to replacing personal computers. For several high end cell-phones, most of these factors are already in place.

VI. Summary of Data Trends

Clearly, the cost-as-percentage-of-GDP figures among the various available vision-impaired assistive technologies indicate both their high overall cost and their potentially prohibitive price for developing nations such as Niger. Supplying items such as a Braille display (Table 4) would cost up to a 16.2 per cent of Niger's entire GDP.[6] Based on their relatively high cost, these same items would represent a significant expense for all of the countries sampled regardless of economic status. Even the less-expensive technologies hold a cost-as-percentage-of-GDP figure hovering around a full percent for the developing country in our sample, Niger. Although the shared-model analysis of such technologies addresses to some extent a strategy for making these technologies available to as wide a range of disabled persons as possible, such a model does not fully address the particular problem of cost within (or even without) developing countries. The data as a whole indicates that for certain AT, cost remains a significant impediment to facilitating the inclusion of the vision-impaired population in essential professional and social functions. However, this also means that there is a significant business case to be made on the potential for industrial research in AT, to bring down the prevalent market prices in light of new institutional and individual customers in the developing world. The increase of accessibility features on cellular phones is clearly a nod in this direction.

VII. Discussion

An analysis of the data on the cost of assistive technologies across the five countries reveals, as would be expected, significant disparity in the cost of such technologies as a percentage of GDP between the higher-income nations (Australia, United Kingdom) and the mid- to low-income nations (Brazil, Mongolia, Niger). The wide range of available assistive technologies for vision-impairments discussed here have are theoretically potential to bring about equity, but there needs to be in place a range of supporting infrastructure both material – such as power, infrastructure, computers, and ability-related – such as technology training, basic literacy, social awareness etc.

Nonetheless, the discussion on assistive technology is of immediate consequence precisely because of the growing ubiquity of technology use in the labor force participation of able bodied persons. For disabled persons in developing countries, inclusion in the functions of workplace and society necessitates the availability of these assistive technologies.

[4] We of course recognize that the rapid evolution of the cellphone market means these models and features will soon give way to newer ones.

[5] All prices assuming unlocked cell. Nokia 3650 and Toshiba 4050 no longer sold without special order

[6] The Braille printer example shows 86%, but it is only a technical possibility since every blind computer user in the country would not need a commercial grade Braille printer

Our goal in highlighting these costs and technologies is both to call for action from technologists in this space and to identify a set of concerns for signatory countries. Within two years of ratification, countries are expected to provide the Committee with an update of what has been done in their respective countries in the spirit of the Convention. We find in our assessment of the costs that the case for R&D in assistive technologies is clear: without such research, most countries in the developing world would almost certainly rely on external aid to provide reasonable access to just these technologies outlined (and we have not even begun yet the discussion on architectural and transportation improvements). This point also keeps with the spirit of Art 9.2(G,H) “commit[ting] states to promoting the design, development, production, and distribution of accessible ICTs at an early stage, such that these technologies become accessible at a minimum cost.” To understand this in comparative terms, the US budget for research on AT for 2009 was US$ 292 million, of which $43 million of stimulus funding was a one-time allocation. To put this in perspective, the same amount would give licensed copies of JAWS to only one in three people who need it in Brazil. Indeed, this is an apples and oranges comparison, but helpful in understanding the scale of the problem.

At present, almost all AT research work is centered in institutions in the US, Japan, Western Europe, and South Korea. One notable exception consists of work in Thailand (Punyabukkana et al., 2009). At most international events, AT research in the developing world is typically represented by groups like Daisy Consortia. This needs to change.

The fact of AT being prohibitively expensive at present adds the spectre of continuing non-participation of the disabled citizenry in the workplace and social forum. This not only limits the contribution of a section of society to the economic growth of these countries, but also raises another important question – can a country that does not adequately address social inclusion be considered truly developed?

Collaboration--both among the signatory nations themselves and between the public and private sectors--is essential to lowering the overall cost of AT. The commitment to provide AT means state parties have a natural interest in lowering the cost of AT by increasing university or national laboratory based AT research. Likewise, for industry, there is a case for investment in this space. At the most immediate level, there is an economies of scale argument in the expansion in the consumer base for AT by virtue of the state’s commitment to providing it. Two potential examples consist of government subsidies (to both industry and educational institutions) for such research, and the awarding of telecommunications licenses/contracts by governments to private companies based on those companies’ making basic AT functions available for disabled citizens in items such as phones. Developing countries which still have enormous untapped bases of potential telecommunications customers, offer significant opportunities for governments to grant licenses based on adherence to basic AT standards

VIII. CRPD and Geopolitical meaning

People in policy and disability rights circles are justified in being concerned about middle and low-income country signatories that have signed and ratified in good intent but lack the ability to actually provide AT, even shared, to populations that need it.

Indeed, that the Convention and Optional Protocol have established a system for review, and moving forward, a more transparent, globalized public forum for examining an individual signatory nation’s treatment of its disabled citizens can only be seen as a positive step. However, the potential inability of certain, particularly developing nations, to implement the strategy of the Convention should be seen as a potential problem not only for these individual nations but also for the global community, and for the legitimacy of international agreements. That the Optional Protocol deals with violations of the Convention not through punitive measures, but with review proceedings and detailed recommendations, is testament to the spirit of the Convention as a means for the signatory nations to collaboratively find ways to enable all disabled citizens of the world to participate fully in both the professional and social spheres. Each signatory nation to the Convention, developing or developed, has made a commitment to that fundamental purpose of the Convention. It only follows that the problematic scenarios of nations being unable to implement the guidelines of the Convention should be resolved through collaborative effort. In examining the state and cost of technology for vision impairment, we find a solid case for global efforts to expand AT research. Given that much AT needs to be commercialized, this work cannot be done without significant industry involvement in the expansion of research centers.

Ultimately, comparing the articles of the Convention with the existing technologies (and costs of such) available for assisting disabled persons evinces a contrast that is particularly troubling for disabled persons in developing countries. Technologies *are* available that will improve disabled persons’ access to the internet, sight-intensive screen information, and cell phones, but the cost of such technologies remains a likely impediment for disabled persons in all but the wealthiest countries. As our country-wise analysis details, signatories to both the Convention and Optional Protocol have committed themselves to comprehensive guidelines for facilitating disabled persons’ access, despite these countries having disparate abilities to actually enact such guidelines. The Protocol’s articulation of a centralized review-and-recommendation process for violations of the Convention should therefore be seen not as a punitive step, but as a means of providing guidance and transparency in the evolving world of accessibility.

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