UK Government

Rapid Review of Assistive Technologies for Persons with Disability in India

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ACRONYMS

DFID	Department for International Development
AAC	Augmentative and Alternative Communication
AADI	Action for Ability Development and Inclusion
ADIP	Assistance to Disabled Persons for Purchase/ Fitting of Aids and Appliances
ALIMCO	Artificial Limbs Manufacturing Corporation of India
BIRAC	Biotechnology Industry Research Assistance Council
CATI	The Centre for Assistive Technology and Innovation
DEPwD	Department of Empowerment of Persons with Disabilities
EOG	Electrooculography
GRID	Grants-Research-Industry-Dissemination
HAAT	Human-Activity Assistive Technology
HCI	Human Computer Interface
IIT	Indian Institute of Technology
ISO	International Organization for Standardization
NCPEDP	National Centre for Promotion of Employment for Disabled People
NISH	National Institute of Speech and Hearing
R2D2	The Rehabilitation Research and Device Development
UNCRPD	United Nations Convention on the Rights of Persons with Disabilities
WHO	World Health Organisation

EXECUTIVE SUMMARY

1. Disability is a precipitously evolving public health problem. It is estimated to affect over a billion persons in the world today, with extrapolations suggesting a doubling over the next 10 years. Its major causes include congenital causes, injury due to conflict or accident, ageing and chronic non communicable diseases among others. The last three causes are growing rapidly, thus making the response to disability an immediate concern. Over 80% of those with disability live in the developing world. Between 10 - 20% of persons with a disability face considerable difficulties in carrying out activities in their daily life.

2. Assistive technology refers to any devices to maintain or improve an individual's functioning and independence to facilitate participation and to enhance overall wellbeing. Access to assistive technology serves as the gateway to access to education, employment, social inclusion and other opportunities to participate in civic life. Assistive technology devices range from simple as in a walking stick, to complex as in speech aids. Of the many solutions that are available in the world, several are available in India, but few of high quality or easily affordable by the masses.

3. Research on assistive technology in India is remarkably inadequate, albeit not entirely absent. To locate sufficient research for this rapid review on assistive technology in India, it was necessary to reach out as far back as 1987. In all, 115 studies were reviewed and 15 experts interviewed for their insights to the sector and suggestions for grey literature. Much of the research is small in scale referring to studies with a small number of participants or descriptions of the development process of a certain technology. Many studies are 'non-originating' research having been carried out by researchers in countries other than India, or as collaborations between foreign and Indian researchers.

4. The Human Activity Assistive Technology or HAAT framework was found to be useful as a way to classify studies for the review, providing insights into the extent and nature of evidence base needed to develop assistive technologies.

5. The context in which persons with disability live and operate was rarely researched for its own sake. Typically, studies that discuss the context in which people live have been carried out as an adjunct study to the development of a particular aid or device rather than to develop its own understanding. Studies also do not discuss engineering considerations for design of assistive technology devices other than as a description linked to the presentation of a particular device. As a result, a holistic picture of the field is not available and few generalisations or signposts are available to the researcher or manufacturer seeking to identify areas in which more work is required.

6. Most of the studies accessed related to work done in the space of mobility and visual impairment, many relating to modification of mobility devices for the elderly. Research attention was largely on assistive devices that aid in education or employment with little attention to other aspects of a person's life such as everyday living, leisure and recreation,

participation in social life, etc. Present day dropout rates from assistive technology that has been adopted, is reportedly as high as 80% – studies are required to understand why this is so and what can be done to correct the situation.There are several aspects which make a structured response to disability in India difficult. To begin with, the extent and contours of the problem have not been fully understood. Studies that capture the prevalence of disability, while being very extensive, have yielded numbers that many contest. Further, the two largest datasets describing disability in the country are not consonant and hence robust comparisons cannot be drawn or lessons taken away. Extrapolations as to the likely size of the problem in the foreseeable future have not been carried out. All of this means that an appropriate response cannot be mounted. Add to this the underlying context of India – a country with low per capita income and where demand for health services outstrips its delivery. It is clear that better information is required and policies put in place that strongly encourage market players to participate in this sector.

7. India has been an early signatory of the UNCRPD. It has had a law relating to disability in place since 1995 which was recently revised and replaced in 2016. Several other Acts of Parliament also have helped to develop systems to respond to the needs of those with disability. There is a network of national institutes, digitization of disability certification has taken place, the National Innovation Fund has recognised and awarded innovators in the space etc. Many schemes are available to those with disability – several are of many years' standing and argument may be made about whether or not the support that they provide is sufficient or needs to be updated.

8. Robust research on the demand for rehabilitative and palliative services involving assistive technology has not been undertaken. Global generalisations indicate that over 90% of demand may remain unmet – with the expected increase in numbers due to increasing longevity and non communicable diseases, this may expand further.

9. ALIMCO is a government sector entity that is easily the largest producer of assistive technology solutions in India, producing over 350 different kinds of aids and appliances. But questions are raised about the suitability and sturdiness of its aids and appliances. There are few developers or producers in the private sector except in niche areas such as spectacles, wheelchairs, walking canes etc.

10. Several challenges remain to be addressed. In order to make assistive technology accessible, there needs to be greater awareness among persons with disability and their caregivers. Information regarding aids and their utility, source of availability, cost, operating cost, support services etc. must be pushed. For this, a better understanding must be developed regarding the size and nature of the problem.

11. In order to help researchers and manufacturers better respond to the need, the context in which the assistive technology must operate, the activities for which it is required and the skills and abilities of its users should be the subject of studies, along with studies on accessibility, affordability and inclusivity of devices. With the context in India being as diverse as it is, this is no mean task – devices are needed for both the 'new India' as well as the old, if market penetration is a desirable goal. The role of government as an enabler of solutions rather than purveyor must be fully explored. A key debate that has important

implications in the India context is the appliance *vs* tool debate given its present situation and expected rapidly increasing need. Does India need tools that are built-from-scratch, custom-designed and require significant training for the user to be able to use it effectively? Or should the focus be on producing appliances that are built on existing technological platforms, easy to adopt and require minimal or no training for use? Should India adopt an either-or policy or assign some expectation of distribution of research and development on either side of this debate?

12. Disjunctures such as the fact that assistive technology falls within the purview of the Department for Empowerment of Persons with Disabilities, Ministry of Social Justice and Empowerment rather than Ministry of Health and Family Welfare must find resolution. In order for the assistive technology market to function, and function efficiently, all parts of it – basic and applied research, knowledge translation, manufacturing and marketing must be well connected through a common platform. The present lack of linkage between key actors in the space has to be addressed so that efficiencies can be achieved.

13. Several recommendations can be drawn from the study:

    1.   More and better data is required on disability prevalence and unmet need for assistive technology. The distribution of need is of particular importance, requiring data on type, geographical and income distribution.
    2.   Data is also required to develop the aids and appliances required for populations affected by disability. The HAAT framework provides a useful way in which to approach the problem; the most urgent data needs may need to be prioritised.
    3.   While Indian law does cover disability, policy requires further expansion in order to more comprehensively address modern day assistive technology devices that need to be put in place. In particular, experts point to the absence of an assistive technology Act and standards for assistive technology.
    4.   Laboratory to market connections remain weak, despite the emergence of green shoots with respect to assistive technology in India. Platforms for discussion and networking are sorely needed, vexed legal issues with respect to software use need to be explored, and financial solutions to support the industry must be considered.
    5.   There is need for many more studies to support a strong and considered disability response, both to develop and manufacture assistive technology devices as well as to put suitable policies in place.

14. In sum, it may be said that a strong push to develop India's work on assistive technology is urgently required to ensure that the needs of a growing complement of persons with disability are met and productivity of India's work force is continued. With a large number of engineering institutions, a vibrant research community, innovative manufacturing capabilities and a government committed to improvements, India has the wherewithal to make this happen.

C h a p t e r   I
B A C K G R O U N D

Disability has become part of the mainstream. Once perceived as an object of pity, those with disability have fought a pitched battle to secure their dignity. They have demanded devices that can help them do what other people can do, be it in daily living, education, employment, arts or sports. Today, mechanisms such as the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) entitle persons with disability as a matter of right, to assistive technology that ensure their full and equal enjoyment of all human rights and fundamental freedoms.[1]

Several initiatives have been taken up in support of disability and inclusion at an international level. In July 2014, WHO established a global initiative, the Global Cooperation on Assistive Technology or

> Disability is not objectively defined. Different scholars and organizations define disability in different ways. Similarly, the definition of assistive technology is very broad covering selection, acquisition and use of a device and service.

GATE, to improve access to high-quality affordable assistive products. More recently, the Global Disability Summit held in London in July 2018 under the leadership of the Government of the UK, saw several international commitments being made to disability.[2] In 2011, the World Report on Disability noted that disability prevalence is high and growing. Of the 1 billion persons estimated to be living with disability in the world, about 110 - 190 million face significant difficulties in functioning. Apart from congenital causes, a growing number of persons are experiencing disability as a result of old age, chronic health conditions, conflict as well as injury, diet and substance abuse. Disability is also known to be more prevalent among the most vulnerable – women, older people and the poor. About 80% of all disability is estimated to occur in developing countries.[3]

The term disability is not objectively defined. Different scholars and organizations define disability in different ways.[4] The Economic and Social Commission for Asia and the Pacific notes that, "disability prevalence in the Asia-Pacific region varies dramatically. These figures are heavily shaped by the contrasting ways that governments define disability and collect data.…".[5]

International Classification of Functioning, Disability and Health

The WHO's International Classification of Functioning, Disability and Health defines disability in terms of challenges that a person faces as a result of the interaction between the state of their bodily functions and structures, activities and participation in society, and their personal and external environment.[6] It describes functioning as the (positive) interaction between a person's abilities and the environmental context, while viewing disability as the (negative) interaction between a person's impairments, activity limitations and participation restrictions and the environmental context. Thus, the International Classification of Functioning, Disability and Health underscores that assistive technology must take into account, not only a person's impairment of

functions and structures of body, but also the activities that the person would like to carry out and the nature of her/ his preferred modes of participation in society at large.[7]

Figure 1: Interaction between the Components of ICF
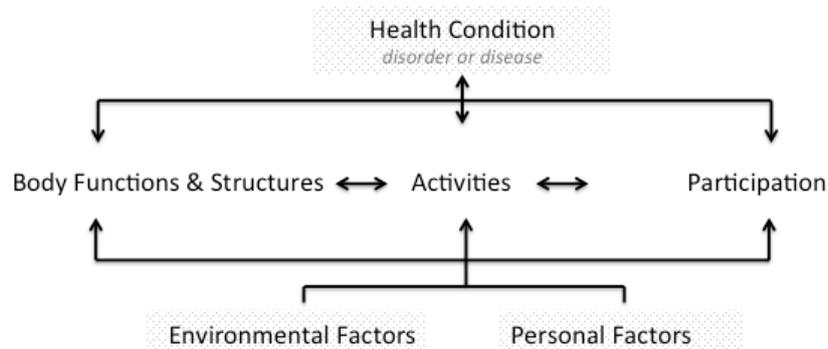
Source: World Health Organisation. (2001).

Assistive Technology

The WHO refers to assistive technology as "Assistive devices and technologies are those whose primary purpose is to maintain or improve an individual's functioning and independence to facilitate participation and to enhance overall wellbeing. They can also help prevent impairments and secondary health conditions."[8] Another useful way to think about assistive technology is that it refers to items, a piece of equipment, or a product system, whether acquired commercially, modified, or customized to use for increase, maintain, or improve functional capabilities of individuals with disabilities. It can also denote a service that directly assists such an individual in the selection, acquisition, or use of an assistive technology device.[9] Such assistance enables persons with disability to independently function and participate in everyday life, and enjoy inclusion and integration into mainstream society.[10]

Need for Assistive Technology   There is a striking lack of data in India on the unmet need for assistive technology. Access to assistive technology in individual countries can be difficult to estimate, and the Convention of Rights of Persons with Disability reports on assistive technology provide only the number of persons with disability who have access to the technology but not the total number of persons with disability who need them.[11] Furthermore, although it is acknowledged that there is a large and growing need for assistive technology within low and middle-income countries, there is a lack of research in these settings, which hinders the development of evidence-informed policy and practice.[12]

A 2016 report of the Government of India's Ministry of Statistics and Programme Implementation notes that it is essential to determine the needs of persons living with disability, including the role of assistive technology for inclusive development.[13] An understanding of assistive technology in India begs an intersectional and contextual approach. Identities such as gender, age, location, class, caste and ethnicity interact with socio-cultural norms like patriarchy shape the life chances of persons with disability. The disabled are among the most disenfranchised economically, educationally and health-wise, as well as face significant discrimination. Subalterns such as women, Dalits and poor thus become doubly disadvantaged in this regard.[14]

How Much is Required How many people require assistive devices? For India, this is an estimate that is difficult to find. It is clear that the overall need is great. The Global Disability Summit acknowledged that there is not enough robust estimation of the needs of persons with disability. The UNCRPD highlights the intersectionality of ageing and disability.[15] It noted that there are more than 1 billion people presently in need of one or more assistive products.[16][17] Ageing is intricately connected to disability as more than 46% of older persons - those aged 60 years and older - have some sort of disability. In fact, more than 250 million older people experience moderate to severe disability.[18] WHO notes that only 5 - 15% of the people requiring assistive technology have access to it in low and middle-income countries.[19] Overall, only 3% of the hearing aids that are needed are available.[20] It is estimated that only 1 in 10 people in need overall, have access to assistive products. Current extrapolations suggest that more than 2 billion people will need at least one assistive product by 2030, with many older people needing 2 or more.[21]

> It is estimated that only 1 in 10 people who need assistive devices have access to them.

In India, the prevalence figures most commonly quoted draw upon the 2011 Census. This suggests that 2.21% of India's population or 26.8 million have some form of disability. However, experts point out that these figures are too low and the realistic expectations are closer to 50 million.[22] There are practically no estimates for unmet need for assistive technology in India; from nearby Bangladesh, a study suggests that unmet need may be as high as 80 – 90%.[23]

The Study

In order that India can address its requirements for assistive technologies, a better understanding of the available information and guidance is needed. The purpose of the present study is to carry out a rapid review in support of a better understanding of the existing evidence on assistive technology in India and thereby support a suitable and effective response.

Three specific research questions were identified in the terms of reference:

1. Broadly speaking, what is the ecosystem of Assistive Technologies in India? Who are the main players and what kinds of needs do they address?
2. What are the clear research gaps in data in the context of Assistive Technologies in India?
3. How could a potential Centre for Excellence support an effective response to the growing need of Assistive Technologies in India?

Approach and Methodology Two approaches were adopted for the study: the first involved a rapid review of the published literature available on assistive technology in India; and the second drew upon local expert knowledge to gather further information, both published and otherwise. The report is a collation of both published and grey literature to develop a rapid review of the material on the subject.

Google Scholar was searched to find relevant materials. While the most recent literature was sought, in fact, literature going back to 1987 was accessed, as there was a general paucity of published materials pertaining to the Indian situation. Over 110 reports, and relevant policies were accessed through official websites of the country's government. In all, 15 experts were interviewed in order to capture their experiential insights and collect grey literature. Keywords used to interrogate the database were along the following themes: disability; assistive technology;

frameworks for assistive technology analysis; availability of assistive technology; demand for assistive technology; human factors and aging; spectrum disorders and culture; stigma; social interactions; disability and its context; disability for activities of daily life; information communication technologies and development; product design; user-centred designs; technology for learning disability; inclusive growth; economic integration; policy interventions; market players in assistive technology; up and coming incubators; key initiatives in disability; and leading organisations in disability.

Limitations   Limitations must be mentioned at the outset. One, due to the short timeframe in which the study was to be carried out, this is a rapid review rather than a comprehensive one. Two, available data and reports/papers have an emphasis on motor and visual assistive technologies, and on education and employment for the most part. Third, the preponderance of information is available from small studies on a particular type of assistive technology rather those taking a wider approach.

In the chapters that follow, we discuss the ecosystem for assistive technology in India and the key evidence available to guide present-day policy and implementation.

KEY TAKEAWAYS

- International conventions entitle persons with disability to assistive technology that ensure their full and equal enjoyment of all human rights and fundamental freedoms.

- The International Classification of Functioning, Disability and Health defines disability in terms of the challenges that s/he faces as a result of the interaction between their bodily functions and structures, activities and participation in society, and their personal and external environment.

- Assistive technology is defined by WHO as assistive devices and technologies whose primary purpose is to main or improve an individual's functioning and independence to facilitate participation and enhance overall wellbeing.

- Disability prevalence is high and growing. However there is a striking lack of data on unmet need for assistive technology.

- The study had three objectives in relation to India: (i) briefly describing the ecosystem of assistive technology; (ii) identifying clear research gaps on the subject; and (iii) uncovering how a potential Centre for Excellence might support an effective response to the growing need for assistive technology.

- Between October 2019 and February 2020, this study undertook a rapid review of available literature on assistive technology in India and interviews with key experts. In all, 115 documents from 1978 – 2019 were accessed and interviews held with 15 experts.

- This rapid review focuses on the ecosystem of assistive technology in India, identification of research gaps, and how a potential Centre for Excellence could support Indian efforts to provide an effective response to the need for assistive technology.

End Notes

[1] UN. (2017). Convention on the Rights of Persons with Disabilities. Resolution 61/106. New York: United Nations.

[2] Global Disability Summit. (2018): Official Readout Accessed at
https://drive.google.com/file/d/15PZ3CJf841KxpaTLvp3ARE_hilACPro6/view .

[3] WHO and The World Bank. (2011) World Report on Disability. Factsheet. Accessed at
https://www.who.int/disabilities/world_report/2011/factsheet.pdf?ua=1

[4] Jeffery, R. & Singal, N. (2008). Measuring Disability in India. Economic and Political Weekly, 43(12/13), 22-24.

[5] ESCAP. (2015). Disability at a Glance: Strengthening employment prospects for persons with disability in Asia and the Pacific.

[6] WHO. (2001). International Classification of Functioning, Disability and Health: ICF. Geneva, WHO Retrieved, 10 March 2019, from
https://apps.who.int/iris/bitstream/handle/10665/42407/9241545429.pdf;jsessionid=04A11665500DC9A983E067BE746143A0?sequence=1

[7] The ICF: An Overview. (n.d.). https://www.cdc.gov/nchs/data/icd/icfoverview_finalforwho10sept.pdf Retrieved, 10 March 2019, from https://www.cdc.gov/nchs/data/icd/icfoverview_finalforwho10sept.pdf

[8] WHO. (2020). Accessed at https://www.who.int/disabilities/technology/en/

[9] Alper, S. & Raharinirina, S. (2006) Assistive Technology for Individuals with Disabilities: A Review and Synthesis of the Literature. Journal of Special Education Technology.

[10] WHO and The World Bank. (2011) World Report on Disability. Factsheet. Accessed at
https://www.who.int/disabilities/world_report/2011/factsheet.pdf?ua=1

[11] Srisuppaphon D., Sriboonroj A., Riewpaiboon W. & Tangcharoensathien V. (2017). Effective implementation of the UNCRPD by Thailand State Party: challenges and potential remedies. BMC International Health Hum Rights.

[12] Tangcharoensathien V., Witthayapipopsakul W., Viriyathorn S. & Patcharanarumol W. (2018). Improving access to assistive technologies: challenges and solutions in low- and middle-income countries. WHO South-East Asia J Public Health [serial online].

[13] Verma, D., Dash, P., Bhaskar, S., Pal, R.P., Jain, K. & Srivastava, R.P. (2016). Disabled Persons in India: A Statistical Profile. Ministry of Statistics and Programme Implementation, Government of India.

[14] Janardhana, N., Muralidhar, D., Naidu, D. & Raghevendra, G. (2015). Discrimination against differently abled children among rural communities in India: Need for action. Journal of Natural Science, Biology and Medicine, 6(1), 7.

[15] UN. (2007). Convention on Rights of Persons with Disabilities. Department of Economic and Social Affairs. Accessed at
https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html

[16] WHO. (2011). Summary the World Disability Report. WHO and The World Bank.

[17] . Global Disability Summit. (2018). Official Readout Accessed at
https://drive.google.com/file/d/15PZ3CJf841KxpaTLvp3ARE_hilACPro6/view

[18] UN. (2015). Ageing and Disability. Department of Economic and Social Affairs. Accessed at
https://www.un.org/development/desa/disabilities/disability-and-ageing.html

[19] WHO. (2010). Assistive devices/technologies. Geneva: World Health Organization.

[20] WHO. (2004). Guidelines for hearing aids and services for developing countries. Geneva: World Health Organization.

[21] WHO. (2018). Fact sheets details on assistive technology. (2018). Accessed at https://www.who.int/en/news-room/fact-sheets/detail/assistive-technology

[22] The World Bank. (2007). People with disabilities in India: From Commitments to Outcomes. Human Development Unit, South Asia Region. Accessed at
http://documents.worldbank.org/curated/en/358151468268839622/pdf/415850IN0Disab1ort0NOV200701PUBLIC1.pdf

[23] Pryor, W., Nguyen, L., Islam, Q.N., Jalal, F.A. & Marella, M. (2018). Unmet Needs and Use of Assistive Products in Two Districts of Bangladesh: Findings from a Household Survey. International Journal of Environmental Reseach and Public Health. Accessed at
https://www.google.com/search?q=unmet+need+for+assistive+devices+india&oq=unmet+need+for+assistive+devices+india&aqs=chrome..69i57.208403j0j7&sourceid=chrome&ie=UTF-8

Chapter II
EVIDENCE BASE ON ASSISTIVE TECHNOLOGY

In Chapter 2, we discuss the evidence available to support the development of assistive technology suited to the Indian situation. In order to identify the best possible way in which evidence can be discussed, various models and frameworks that are used in the assistive technology space were reviewed. What we were looking for was a framework that would support development of a map that could identify evidence availability and inform future data needs.

HAAT Framework

Cook and Hussey's Human Activity Assistive Technology (HAAT) model first mooted in 1995, is a widely recognized framework for assistive technology provision. (See Figure 2). The functional outcome of an assistive technology system is defined as, "someone (person with a disability) doing something (an activity) somewhere (within a context)".[24] The HAAT framework describes the process by which assistive technologies that are the most optimal for a person with disability can be selected.[25] The HAAT framework thus highlights the performance of the entire system within which assistive technology is located rather than the isolated evaluation of the human performance. In doing so, the HAAT framework provides the basis of discussion of evidence availability more generally.

The HAAT model is one of the earliest models of Assistive Technology in the field of rehabilitation engineering. It is built on Bailey's Human Performance Model used in human factor engineering, incorporating two substantial changes. First, assistive technology is set as separate and important element having a direct and interdependent relationship with the other three elements i.e. human element, activity element and the context element.[26] Second, the context occupies a more prominent position as does its association with the other elements. Context is not described simply as the location and physical environment in which an activity occurs. There is an embedded impact of social, cultural and institutional factors as well. There is a "dynamic interaction between initial three factors and the pervasive influence of the context on them, both individually and collectively, with humans identified as a central focus".[27]

> Cook and Hussey's HAAT framework first mooted in 1995 highlights the performance of the entire system within which assistive technology is located rather than the isolated evaluation of human performance. It considers the following aspects: context; activities; human factors; and engineering factors.

The HAAT framework considers the following in discussing assistive technology: (i) context in which use is to take place; (ii) activities for which the assistive technology is to be used; (iii) human factors that determine readiness to utilize assistive technology; and (iv) engineering considerations of the assistive technology. Context comprises the social and cultural context as well as institutional context (e.g., infrastructure and legislation); and physical variables. Activities are divided into three

broad categories of self-care, productivity, and leisure comprising of communication and access to information, mobility, cognitive activities, daily living, education and employment, and recreational activities. The human factor captures the distinction between a person's abilities, from her/ his skills in using assistive technology, to motivation that the person would require to use the technology.

Figure 2: The HAAT Framework

Source: McDonnel, K. (2018).

Engineering considerations comprise the following components: activity specification (task specification and user requirement), design issues (design approach and technology selection), system technology issues (system interfaces and technical performance) and end user issues (ease and attractiveness of use, cost of the device, mode of use, training requirements and documentation).

In the sections that follow, we discuss the evidence available for each of these aspects that must go into the development of assistive technologies.

Context

The design and subsequent success of assistive technology interventions is appreciably affected by the background in which it is deployed. Context comprises of the social and cultural context – both society-wide as well as the user's individual social and cultural context; infrastructure, legislative and

assistive technology context; and the local setting namely, location, environment and physical variables.

Cultural Context   A person's native culture, language, beliefs, institutional restraints, customs must be taken into account as they relate directly to the person, and to the larger community. Research on assistive technology generally focuses upon functionality and usability of the devices, yet technology use does not happen in a social vacuum.[28] Personal preferences in the social context tend to dictate how and whether a device is used. Defining a culture is complicated but Ripat and Woodgate (2011) define culture in the perspective of disability and assistive technology as, "…culture refers to the beliefs, values, meanings and actions that shape the lives of a collective of people, influencing the ways people think, live and act. These beliefs, values and ways of understanding are socially constructed and specific to the culture in which they are found".[29]

Krishnan, Venugopalan and others (2009) undertook a study that described how the cultural practice of removing footwear creates a challenge for the visually impaired people as finding their footwear

> A person's native culture, beliefs, institutional restraints, customs must be taken into account as they relate directly to the person and to the large community. Research on assistive technology usually focuses on functionality and usability of the devices, yet the technology does not happen in a social vacuum.

would require touching a lot of shoes, sometimes performed on hands and knees.[30] The project aimed to design a prototypical device that could assist visually impaired individuals to locate their footwear through electronic means. Selection criteria for the technology comprised four important factors: maximum detection distance; low maintenance and cost requirement; low power consumption and minimum size and weight of the device. McPherson (2014) talks about the challenges to access hearing assistive technology devices in developing countries. Such change can only be achieved over time and with sustained input at the societal and individual level. He refers to training programs and curriculum for hearing health workers to change the attitude of the individuals towards disability.[31] Popularization of online learning along with increasing penetration of telecommunications in low and middle-income countries have paved a way for internet based hearing health modules. This is expected to break the current tendency of dichotomizing hearing devices fitting programs as either 'audiologist test' or 'community-based'. Modules include material that extends usual audiological scope of practice – although this has social, cultural and ethical implications that require consideration.[32]

Social Context   Similarly, autism is a condition that has impacted lives of many families around the world and is prevalent in cultures, races and social classes in more than 80 countries.[33] A substantial discussion on autism across cultures is presented by Grinker's (2007) 'Unstrange Mind' which focuses on his experience as a father raising a girl with autism, while discussing the experiences of families living with autism in South Korea, South Africa and India.[34] Grinkler asks the reader to understand Autism as shaped by culture and historical framework. Bourjarwah and others (2011) discuss how the understanding of people with autism can differ considerably across societies and impact how they are integrated into a community.[35] This is in line with research that has shown that differences in practices and values in societies, cultures and socio-economic standing, which leads to significant variation in the experience of autism.[36] The study concluded that family structure, linguistic environment and religion are the most prominent cultural factors in developing South Asian countries in shaping the perceptions and expectations of individuals with autism.

Physical Context   A functional perspective on the mobility needs of women in India identifies how an individual with decreased and inefficient mobility is faced with many environmental and sociocultural barriers impacting her or his ability to participate fully in life.[37] Determining functional mobility requires asking when, where, how and for what purpose individual must move to perform the activities of daily living successfully. Halender (1993) identifies the necessity of addressing the needs of the persons with disabilities nestled within the context from which they operate, before designing any new rehabilitation intervention or technology.[38] A comprehensive approach that addresses the functional status, social and cultural considerations, physical environment, personal physical dimensions and institutional constraints is expected to maximize the match between ride and the wheelchair.[39] The purpose of the study was to present formal research about women in disabilities which was descriptive in nature and sensitive to the local cultures. The data provided the preliminary finding that the functionality and quality of life as determined in a society for women is highly relevant to the mobility needs of these women.[40]

Pal et al. (2017) discuss the physical environment in reference to fit and usability of assistive technology.[41] The mixed method field study of smartphone adoption by 81 visually impaired people in Bangalore, India proposes a nuanced understanding of usefulness and usage based on need related social and economic functions. They move away from the reductionist technology acceptance model which only discusses whether a technology is adopted or abandoned. Instead he argues that there is a greater need to focus on the human agency within the necessity of adopting certain mainstream devices, for instance the smartphones. They conclude that there is growing irrelevance of frameworks that fail to account for history of use or the user's trajectory through various technology and writes, "Broadening adoption investigations to include functions of usefulness can help in understanding exactly where technology is working and where we need more effort. What matters in technology adoption then is not whether a technology is adopted, but rather how it is — and what that can tell designers and practitioners about the needs of users".[42]

Institutional Context   Mohammed and Jamil (2015) speak about changes required in the institutional framework of the country to create an economic inclusion for all sections of the society.[43] They believe that promoting entrepreneurship among the disabled population is a way to achieve this. Kitching (2014) also highlights the importance of entrepreneurship among persons with disabilities and discusses how this can be achieved through the support of the government.[44] Government support can create favourable conditions and environment for persons with disabilities. Kitching associates favourable environment to policies related to legislation, infrastructure, legal framework, taxation, regulations, financing etc.

The available evidence on context highlights the importance that social, cultural, physical or institutional context play in design and adoption of assistive technology. Context not only show how coming in of assistive technology is perceived and accepted in a society but the sociocultural standing associated with assistive technology may mean that it may not be made accessible once it has been made available. Experts interviewed highlight the importance of looking at assistive technology from a broader perspective, creating an end-to-end ecosystem in India with the government focusing on the holistic development of assistive technology They point to the need to provide training that acquaints researchers with existing and new technology, remarking, "while the local socio-cultural context is an important factor to consider, the use of technology can be disruptive for someone who is used to traditional methods."[45]

Activities

An essential feature of the HAAT framework is the recognition that assistive technology must support activities that persons engage in as part of their daily life. This varies across age groups (e.g., child, young adult, older person); by geographical location (e.g., rural, urban); or may be exceptional, as in the case of extreme/ competitive sports. Assistive technology has a role in helping persons to carry out their activities when they face difficulties. Literature on assistive technology as it relates to activities that persons with disability might need, is difficult to come by. The discussion on disability in reference to various activities does exist among certain organizations, e.g. the Indian Institutes of Technology (IITs), Torchit, Saksham Yuva, the Department of Employment in Haryana and the Paralympic Committee of India. However this by no means adds up to ample literature in the area. Experts interviewed attest to the lack of researchers working on activity based needs for assistive technology.[46]

Assistive Technology in Education   A systematic review by Pal and Lakshmanan (2012) of evidence on accessibility of education in India suggests a positive correlation between the use of assistive technology and better occupational and financial outcomes.[47] Vashistha et al (2014) while talking about the access to education among low-income, visually impaired people reveals the limitations of braille books and audio recording in India and the disparity in the demand and supply of custom made assistive technology devices that lead people to create their own audio recordings for content creation.[48] The availability of braille books, audio recordings for providing persons with disabilities with educational content in India has faced physical and financial constraints.[49] Another problem is of the unavailability of assistive technology devices like screen readers, audio recording etc. in regional languages. Hurst and Tobi (2011) argue that the high cost of the devices results in disabled stakeholders using general-purpose devices. The choice to use commodity cell phones for visually impaired persons rather than custom made cell phones is one example of an inexpensive solution with better adoption rates for the technology.[50]

Ahmad (2015) in his landmark study talks about the gap in inclusive education between developed and developing countries that is created by the (non)availability of good quality customisable assistive technology.[51] He refers to the skewed research on success stories of inclusive education in the developed world, while countries in Asia, Europe and Africa deal with difficulties in the implementation of inclusive education. The most common difficulties are limited governmental support, ineffective policies and legislation, inadequate funding, insufficient trained teachers and support staff, political instability, and economic crisis; the ineffective and inefficient use of assistive technology is seen to be a major obstacle hindering inclusion.[52] [53] [54] [55]

Aging and Assistive Devices   The growing average age of India is a medical success story but comes with its own challenges. It demands that Indian society adapt in the areas of public health policy to maximize the functional capacity of older people and increase their social participation.[56] In India, assistive technology is accompanied by a negative connotation which hinders its use among the older population. Goyal and Dixit (2008) feel that this could be remedied by categorizing assistive technology devices differently (as wellness or enabling devices).[57] The approach to assistive technology becomes very different when it deals with recreational activities especially among the older population of the country. It can help the persons with disabilities to communicate well and participate in the social environment. However, this may not be the case among aging population

due to reasons ranging from hesitation to use devices that are labelled as 'aids for persons with disabilities' or the unwillingness to use assistive aids/appliances at this stage in life. Studies exploring the intention of elderly population to use devices to maintain their independence discuss the socio-cultural factors, the financial considerations, considerations of gender in terms of accessibility to assistive technology.[58] Goyal and Dixit (2008) list out the technology interventions in the field of elderly care for the end users keeping in line with the deliberation and consultations on home design, networking avenues, recreation and health among others (See Figure 3).[59]

Figure 3: Enabling and Wellness Assistive Technology for the Elderly

Requirements	Interventions
Health care & nutrition	
Nutritious & easily digestible food	• Awareness programmes on nutritious diet, fitness activities and traditional medicines • Compilation & propagation of recipes of appropriate food for elderly people and suitable for different regions
Medicare units	• Simple medical kits for in-house check-ups • Mobile units with Indian system of medicines, physiotherapy and alternative therapies, gadgets, counselors, etc.
Assistive devices	• Vision aids, hearing aids, respiratory aids, fracture implants, fall detectors, bed alerts, door monitors, hip protectors, talking washing machines, wearable monitoring technologies
Rehabilitation	• Low-cost wheel chair, walker • Commode pots, chairs, beds • Robot to aid care-givers to lift elderly people with weak muscles
Designs	
Community living	• Community old age homes/day care centres with centralized facilities for dining, dish washing, cloth washing, fitness, recreation • Communication facilities for conversation with family members, relatives, friends, etc. through phone, email, internet • Special designs for kitchens, utensils, bathrooms, loafts, stairs, doors & windows, furniture, electric fittings • Facility for solar-based heating/cooling & lighting • Provision of nutritious food, herbal products/medicines
Barrier-free and low-stress accommodation	• Special designs for kitchens, utensils, bathrooms, loafts, stairs, doors & windows, furniture
Simple and easy to operate appliances	• Special designs for gas stove, utensils, telephones, geyser, water filters, washing machine, food warmer, desert cooler/blower, etc.
Clothing	• Weather-proof, skin friendly, comfortable and aesthetically attractive clothes • Wipes, diapers, sanitary and incontinence products • Bed linen, absorbent underpads, supportive braces • Stockings, transfer lifts and belts
Footwear	• User-friendly, functional, clinically effective & efficient (wide fittings, soft leather uppers, lightweight shoes, velcro fastenings, stretchy uppers, washable shoes & slippers) • Athletic and canvas shoes
Transportation & mobility	• Mobility aids, spinal braces
Recreation, Entertainment & Welfare	
Recreation/ entertainment	• Audio/video CDs on traditions, historic movements, pilgrimage & tourist places, religious songs
Day-to-day functions	• Simple device for bank/post office transactions, IT return filing, travel bookings, contact with doctor, complaints with police/legal cells/security services
Security against misplacement	• Walking stick with on-board GPS & facility for SOS alarms
Security against invasion	• Security alarms • Device for raising alarms in case of emergencies

Financial security	• Entrepreneurship and income generation programmes, e.g.
	  ○ Textile design, furniture design, interior design
	  ○ Toy making, candle making, weaving, knitting

	○ Nursery raising, floriculture, organic food from kitchen gardens ○ Publishing, pottery, hand made paper ○ Repair centres for assistive devices
Networking	
Compilation and networking of resources	• Development of portal on elderly issues • Mapping of resources and sharing among user groups • Creation and management of effective helplines for elderly

Source: Goyal, V.C. & Dixit, U. (2008).

Having the right assistive technology device may translate to a life with the opportunity to be employed and earn a living. The research on disability and access to jobs has mostly been restricted to the developed world. In the past decade has there been a considerable focus on economic effects of disability on labour markets, the relationship between disability and poverty.[60] [61] [62] There have been some ethnographic studies that have highlighted disability in the context of development. Pal and Lakshmanan's (2012) study was based on open-ended interviews incorporating survey information on demography, number of years using screen readers, conform level, access to technology information, workspace experience etc. to 37 visually impaired respondents. It has contributed to the on-going conversation on the positive correlation between access to employment and assistive technology.[63]

Assistive Devices for Sports   Wheelchairs are generally accessible in high and middle-income countries. However, access to mobility devices for sports activities is difficult even in high-income countries such as the USA due of lack of funding. Appropriate wheelchairs for basic mobility have become available in India only in the recent years. The situation is worse for low-income countries. It has been estimated that between 20 - 130 million require access to wheelchairs in developing

countries.[64] The 'Paralympian' presents recent events in the field of sports, highlighting sports in the presence of disability in the developing countries. Aurthier et al. (2007) highlight in their paper, the process of developing an affordable wheelchair for low income countries. He designed a sports wheelchair for low-income countries using material and components that would be easily available in these countries.[65] The fabrication process in the construction was simple enough to be adopted by students with no experience and virtually zero supervision.[66] This shows how the consideration for assistive technology for sports as an activity among persons with disability has been gaining momentum in low to middle income countries.

Not only in physical disability, there is also evidence of speech modification through the use of assistive technology devices can aid children with dyslexia.[67] There is evidence that Augmentative and Alternative Communication (AAC) devices have been very helpful in catering to the communication needs of children with developmental conditions like Autism.[68] Experts in the field noted that the awareness of different assistive technology for different activities is rising and newer products demonstrate an awareness of user requirements. The overall ecosystem of assistive technology seems to be expanding as the discourse on disability in relation to various activities is swelling.[69]

Human Factors

Assistive technology enables a person to carry out activities of daily living and supports learning to acquire various skills. The human component of the model encompasses ability as well as skills acquired; some add the notion of motivation to human factors.[70] This section summarizes the evidence available on human factors as they relate to assistive technology in India.

Assistive Devices for Developmental and Learning Disability   A paradigm shift towards universal and inclusive design is making technology with enabling features available in markets. For example, two systems have been developed at International Institute of Information Technology, Hyderabad in collaboration with teachers and parents of children with autism – AutVisComm as a communication system developed on tablets, and Autinect as a set of activities developed to teach children with Autism social skills. The two applications have been designed to act as early intervention to help children with autism gain social skills.

> A paradigm shift towards universal and inclusive design is making technology with enabling features available in markets.

Sampath et al (2013) talk about the increasing influence of technology to complement traditional therapy.[71] This may be even more effective in autism because of the affinity that individuals with autism have for technology.

Nagavalli and Juliet (2016) address their research to dyscalculic children with a range of math learning disabilities (verbal, operational, lexical, ideognostic, practognostic). They point out that the treatment of dyscalculia should address all the areas of the disorder with a central focus on educational intervention to improve study skills.[72] Nagavalli and Juliet are of the opinion that assistive technology could help children with disabilities to learn independently and perform better in the class. Computed Assisted Instructions are known to motivate students with dyscalculia by providing individual instructions, carrying out precise monitoring for teachers along with drill and practice type activities in maths. They have in their paper, provided an extensive list of assistive devices for dyscalculia divided into broad categories of multimedia and multisensory resources. A

number of researchers also propose the use of computer technology and other forms of information technology to 'enhance and equalize the ability of individuals with disabilities' to access education.[73]

Assistive Devices and Physical Disability   Technology opens opportunities that were closed to children with disability in which touch technology with educational applications have simplified the development of skills and education. Singh and Kaur (2015) discuss the use of touch technology to educate students with physical disability. They note that the 'app' phenomenon is very helpful in increasing participation, and the level of interaction in the lives of the persons with disability. The study showcases the development of skills and motivational incentives through the use of e-learning tools embedded in android applications.[74]

The availability of evidence on safety and efficacy of the Wheelchair Skills Program in Canada motivated Cooper and Kirby (2007) to explore its applicability in India.[75] Although there are many users of the wheeled mobility devices in India, a large proportion of them who require such devices do not have access to them – one estimate puts the global number as high as ~95% of the estimated 10 million excluding older populations.[76] Cooper and Kirby highlight the problems associated with the limited reach of Wheelchair Skills Programs in India like unavailability of the program in regional languages, lack of wireless connectivity, impassable sidewalks. These reasons demotivate the majority of the population in need of Wheelchair Skills Program to avail them. Simmons et al. (1995) acknowledge the importance of Wheelchair Skills Programs as well and conclude their study 'Wheelchairs as mobility restraints…' with the statement, "Improving wheelchair skills with targeted intervention programs, along with making wheelchairs more 'user friendly' could result in more wheelchair propulsion with resultant improvements in the resident's independence, motivation, freedom of movement and quality of life".[77]

Adoption of Assistive Devices   Critical analysis of the nature of evidence creates a space for person-centred methodologies dealing with people, environment and technology against individualized outcome. Pal and Lakshmanan (2012) elaborately discuss the testimonials of the people wherein they make a direct correlation between the motivation of a person to avail assistive devices and her/his access to assistive technology. Besides people in direct contact, there was an aspirational effect between use of assistive technology devices by non-connected peers for persons with disability to start adopting and using assistive technology devices.[78] They also talk about the availability of assistive technology and the skills acquired by its use, and make a direct link from skill to increase in status and prestige especially in the Indian context. They say, "the inability to study the sciences puts a psychological burden on the individual. The access to assistive technology plays an unusual role in this case – since learning to use a computer is often seen in the same terms as learning engineering. Thus, even if the individual is dissuaded from studying a technical subject at an early stage in life, the later access to technology is often seen as transformative".[79]

> There is a direct correlation between the use of assistive technology by their peers and the motivation to avail it and continue using it.

Rogers and Fisk (1991) make an expansive tour on technology usability, adoption and design from the perspective of the discipline of human factors.[80] The research applies human factor principles for training and design to reduce the difficulty experienced with technology arising from normative age difference in the abilities of people. Drawing on the survey data among the general population, they point out that the everyday consumer products pose a greater difficulty for the older than the

younger population. Even though these differences are not consistent, complaints on the design flaws among the older population were higher than the younger population. This could be a possible outcome either cohort effect (stiff upper lip) or may have represented survival of the fittest. For training, they provide examples to reiterate how best to employ design training interventions that work. Willis and Schaie (2003) show the narrow transfer of technology and elaborate on how training interventions such as those suggested by Roger and Fisk are viable to improve the performance of the older population on complex problem-solving tasks.[81] An expert notes, "Abilities enhanced due to assistive technology implementation have allowed greater access to persons with a disability to everyday activities of daily life, education, employment, leisure and recreation. For example, simple assistive technology to identify a brush with visual cues like tactile strips or different colour, support children with visual or cognitive impairments to choose their own brush to begin a morning. And skills on the other hand, can get enhanced with the use of assistive technology right from life skills by accessible instructions, content delivery and access. It has improved mobility with aids like smart cane and its variants among persons with visual impairments detecting obstacles though our traffic and moving population on roads and pavement use culture has to be corrected right from childhood."[82]

Needs of the people are often complex. Assistive technology is an interface between the person and the series task that they would like to complete. This emphasises the need of a model that is person-centric and supports the relevance of the HAAT framework to gather the evidence on the human factors. McCarthy, Pal and Cutrell (2013) showcase the adoption and the continued use of screen readers among visually impaired people in India. They discuss the factors that drive early adoption some of which are text to speech voice quality, low prices of market dominated software applications, availability of regional languages, existence of technical support, voice quality and the existence of a community of users.[83] The study discusses two theoretical perspectives – first through the applications of the economics of switching behaviour, and the second, about novice and expert approaches toward new product adoption.[84] The motivation towards the adoption of technology differs for the novice and the expert. The novice users of screen readers opt for the salient features of the products available, for instance Text-to-Speech (TTS) voice and Job Access with Speech with a Text-to-Speech) JAWS TTS output. Text-to-Speech is a primary output for people with visual impairment and hence its voice quality is sure to act as a motivation for technology adoption for novice. The expert screen reader places very little emphasis on the voice quality and more on the fundamental performance factors, for instance application support above all else. Ksethri (2004) discusses the costs associated with learning a new program or the sunk costs associated with ceasing to use an already learned program, which plays a relevant role in software switches.[85]

Innovations in household devices and the average increase in the age of the population in India means that people are becoming familiar with the use of technology in the performance of activities of daily living.[86] The majority of the older population lack access to information and computer technology, there is hope that accessibility will become less of a barrier in the times to come. Where accessibility is the starting point, motivation is a critical piece of puzzle, particularly when it comes to adoption and use of technology. Everyday technology may help older people to live independently by supporting the basic activities of daily life. Ability (e.g. spatial ability) has shown to be an important mediator of success in using technology. Specific abilities may be more proximal determinants of successful technology use.[87] The more important thing would be to have better design and training principles to further the effort of technology adoption as the population ages. A

new way forward is by creating a new pool of assistive technology professionals viz., those that are tech-savvy as well as academicians operating in the field of disability.[88]

Engineering Considerations

Assistive technologies, also known as extrinsic enablers, provide a basis of improvement of human performance in the presence of disability. This section covers the evidence on development of engineering considerations in assistive technology in India.

> Assistive technology can be
> (i) No-Tech: adaptation of behaviour or method to communicate
> (ii) Low-Tech: easy to use, low cost, do not use a power source
> (iii) Med-Tech: easy to operate, but use a power source
> (iv) High-Tech: complex and programmable, use computers and/ or electronics

Types of Assistive Technology   Experts stressed that assistive technology does not require esoteric, complicated engineering, rather it is a mind-set that looks for solutions to everyday difficulties encountered by those with challenges. In this vein, one classification describes assistive technology as having three levels: (i) Low-tech: options are easy to use, are of low cost and typically do not use a power source; (ii) Med-tech: easy to operate but usually use a power source; and (iii) High-tech: usually complex and programmable, and include items that require computers and/or electronics, to perform a function.[89] Others introduce another level - No-tech: which is the adaptation of behaviour or method to communicate e.g., using gestures instead of speaking.[90]

Alternative and Augmentative Communication Devices   To aid individuals with communications difficulties, Alternative and Augmentative Communication Devices (AAC) systems are developed. Sampath, Agarwal and Indurkhya (2013) describe their experiences of developing tools for children with autism. Two systems were developed one of which is AutVisComm - an assistive communication device developed on tablets while the other is Autinect - a set of activities to teach social skills with the use of Microsoft Kinect as a controller.[91] The study starts out by conducting a survey to determine the preferences of these platforms of Indian parents. Over 70% of the 20 parents surveyed indicated a preference for devices that are portable, socially acceptable, have high utility purpose and low cost. The involvement of the teachers, parents and children from the inception stage is considered to be crucial for effective interface design. This observation has relevance in the Indian context in which specialised support may not be available often. Sampath and others (2013) show through the development of two applications that cognitive profile of the children with autism ought to be a major consideration for interface and interaction design.[92]

Madhuri and others (2013) from the Department of Biomedical Engineering at Sri Ramaswamy Memorial institute of Science and Technology present a mobile vision-based sign language device for automatic translation of Indian sign language into English speech to assist the speech impaired people to communicate. They used a real-time vision-based system to recognise finger spelling continuous Sign Language using a single camera to track the users unadorned hands.[93] The system is an interactive application program using LABVIEW software incorporated into a mobile phone. The limitation of the application lies in the misinterpretation of a sign that was similar to another sign in gesture or posture resulting decreased accuracy of the system.

Information Communication Technology   Older people are known to be more prone to illnesses, although the advances in technology, health and medicine have increased the average age of the

person. There is a growing need for information communication technology based applications that support independent living as the aging population of the country grows. There are enabling technology that can be used in a way that complements and extends the existing service delivery.[94]

Basu et al. (2008) at the Department of Computer Science and Engineering, IIT Kharagpur have developed a multilingual education and communication tool for children with cerebral palsy and speech impairment to cater to Indian populations that cannot either afford the expensive AAC tools or the tools that do not cater to their regional languages.[95] The communication/education tool was designed using Java programming language. Icons were stored in a database structure implemented using Java programming. The icon based gallery was found to be effective for AAC users from simple concepts like 'apples' to a relatively complex concept of 'a busy street'. The icon language needs to be supported by intelligent processing that can translate icons to words and phrases that can eventually be used in generating coherent and meaningful sentences.[96][97]

Although text readers are now available in Indian markets, diagrams that form part of the explanation of concepts are not translatable to voice description. This limits the choice that persons with visual impairment can take up.[98] Lipika and others (2017) at the Centre of Excellence at Tactile Graphics at IIT Delhi developed end-to-end, cost effective techniques for making tactile graphics that are affordable and can be mass produced.[99] 3-D printing technology was used for mould making. Key design considerations that were applied were: simplification of the design; resizing of the diagrams to ensure that they are distinguishable by touch; decomposition of the diagrams into two parts etc. The Centre conducted testing sessions in three blind schools and five inclusive schools to evaluate the effectiveness and usability of the diagrams. Feedback was collected using a questionnaire to understand the bottlenecks and the requirements of the user group. Because students had limited exposure to tactile diagrams, it was initially difficult for them to understand the diagrams. This improved as exposure was lengthened.

Human-Computer Interface Devices   Human-computer interface (HCI) acts as a good facilitator in the development of assistive technology. Recent research has shown development of assistive technology that incorporates HCI into human physiology. The primary function of HCI is to generate control signals for external devices based on real-time scrutiny of measured biological signals.[100] While some persons with disability may have very low or no voluntary muscle movement, their cognitive functions are intact. The purpose of HCI in these cases is to amplify signals from weak functional muscle movement to carry out tasks hitherto impossible. For example, a tool developed by Swami and others (2012) uses electro-oculogram (EOG) signals for interactive innovation for the rehabilitation of persons with severe disability, especially neural disability.[101] The EOG provides a non-invasive method for recording the full range of eye movements. Besides the clinical use of the EOG, it has inspired further developments of practical devices. However, most of the devices have slow processing and complex design which makes the use of such devices unsuitable in real-time. The wireless transmission tool makes it robust for real-time implementation for diagnostics. Since the majority of the disabled population retain their control over ocular motor systems, these signals are the most likely candidates for HCI.

Slowik et al. (2009) from University of Detroit Mercy designed assistive technology to cater to visually impaired persons on problems that arise out of cultural practices prevalent in India.[102] People in India remove their footwear when entering temples, houses because of prevalence of

sitting on the floor to eat or pray which becomes problematic for people with visual impairment. It involved finding his or her pair of footwear by touching each individual pair which is not only unhygienic but is also not deemed desirable. The device incorporates a normal cane and a complementary device location on the footwear. The selection criteria to be used for designing the prototype of the cane with RFID system focus areas were: (i) maximum detection distance; (ii) low maintenance; (iii) low power consumption and (iv) minimum weight the device to make the technology design accessible to end-users. A Radio Frequency Identification System was designed that used two sources: (i) an active tag that requires a power source, and (ii) a passive tag that re-radiates the signal power received by the interrogator. The Radio Frequency Identification System tags are durable and low cost which can be taped easily onto the footwear or inserted inside the sole of the sandals/shoes by a visually impaired person. Fitting multiple pairs of footwear with the tags and linking them with the same interrogator provides the ability to choose footwear in real-time according to their needs.

Figure 4: Maximising detection distance through antenna design
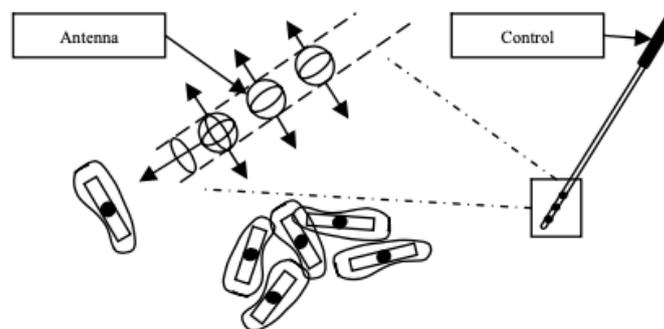
Source: Slowik, R., Krishnan, M., Venugopal, P., Yost, S. A. & Das, S. (2009).

Mulholland and others (2000) have tried to address the needs of women with disabilities in India through the development of appropriate technology. Appropriate technology, according to them, must address all design parameters keeping in mind the Indian context, for instance wheelchairs to cope with rough terrain, wheelchair and tricycle position the rider at table height which means that dismounting would be necessary to perform ground height activities, the ability of the device to cover long distances.[103] There is a need to find an optimal balance between individual's needs, therapeutic or medical concerns, technical and engineering constraints. The technology group of International Centre for the Advancement of Community Based Rehabilitation based in Queen's University, Canada collaborated with the National institute of Design, Ahmedabad to develop a wheeled ground mobility device for women with lower extremity disabilities in India. The study used the first full scale working model of the device called GADI2 to gain feedback from women to determine the functional mobility needs of the women. Function and quality of life were the prominent areas of improvement. Mulholland and

Figure 5: Picture of the GAD12

Source: S.J Mulholland et. al. (2000).

team believed that feedback and recommendation from potential users is an important part of the design process.[104]

Based on the discussion above, it is clear that while patchy information exists, there remain significant areas of gap in constructing a suitable assistive technology response to the needs of any one population group. The lack of publications in the field is seen as a major barrier.[105] Each solution that is sought to be created has to be backed by fresh background research. Little research has been conducted on emerging needs, even less so on solutions that will be required on a mass level as ageing and non communicable diseases begin to make disability more commonplace.

KEY TAKEAWAYS

- The HAAT framework provides a useful tool to discuss the whole system that must be taken into account when researching and developing assistive technology.
- The four components of the HAAT framework relate to the context in which the use of assistive technology is to take place; activities for which the assistive technology is to be used; human factors which determine readiness to utilise the assistive technology; and engineering considerations of the assistive technology. Many of the studies relate to activities of education and employment. Less focus is available on leisure and recreational activities or even, activities of daily life.
- The ability and interest in adopting assistive technology is an important prerequisite to its ultimate use. Universal and inclusive design has much to do with developing the skills to use assistive technology.
- Technology must be of use in a way that is at ease with the person's environment – both physical and socio-cultural. The institutional environment within which it is delivered is a key to effective distribution and utilisation.
- Engineering considerations are paramount to the effectiveness of the assistive technology; however they were rarely discussed except as descriptions in the studies accessed.
- Assistive technology can be No-Tech, Low-Tech, Med-Tech or High-Tech ranging from technology that does not require a device all the way to those that require computing devices.
- Engineering solutions that have been developed in India use a range of engineering approaches including AAC, ICT and HCI.

End Notes

[24] Cook, A. & Hussey, S. 1995. Assistive Technologies: Principles and Practice. St. Louis: Mosby Year Book, Inc.

[25] Cook, A. & Hussey, S. 1995. Assistive Technologies: Principles and Practice. St. Louis: Mosby Year Book, Inc.

[26] Bailey, R. (1989). Human performance engineering. Upper Saddle River, NJ: Prentice Hall

[27] Cook, A. & Miller Polgar, J. (2008). Cook & Hussey's assistive technologies: Principles and practice (3rd ed.). St. Louis: Mosby Elsevier

[28] Shinohara, K. & Tenenberg, J. (2009). A blind person's interactions with technology. Comm. ACM. 52 (8), 58-66

[29] Ripat J. & Woodgate R. (2011). The intersection of culture, disability and assistive technology. Disability and Rehabilitation: Assistive Technology 6(2):87-96.

[30] Slowik, R., Krishnan, M., Venugopal, P., Yost, S. A. & Das, S. (2009). Work in progress - description of a service learning project to design assistive technologies to aid the visually-impaired in India. 2009 39th IEEE Frontiers in Education Conference.

[31] McPherson, B. (2014). Hearing assistive technologies in developing countries: background, achievements and challenges. Disability and Rehabilitation: Assistive Technology, 9(5), 360–364.

[32] Easwar, V., Boothalingam, S., Chundu, S. et. al. (2013). Audiological practice in India: an internet-based survey of audiologists. Indian J Otolaryngol Head Neck Surg; 65(Suppl 3):636–44

[33] Daley, T. C. (2002). The Need for Cross-cultural Research on Pervasive Developmental Disorders, Transcultural Psychiatry 39(4): 531- 550.

[34] Grinker, R.R. (2007). Unstrange Minds: Remapping the World of Autism. New York: Basic Books.

[35] Boujarwah, F. A., Nazneen, Hong, H., Abowd, G. D. & Arriaga, R. I. (2011). Towards a framework to situate assistive technology design in the context of culture. The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility - ASSETS '11.

[36] Wallis, K. & Pinto-Martin, J. (2008). The Challenge of Screening for Autism Spectrum Disorder in a Culturally Diverse Society. Acta Pediatrica, 97, 539-540.

[37] Mulholland, S. J., Packer, T. L., Laschinger, S. J., Olney, S. J. & Panchal, V. (1998). The mobility needs of women with physical disabilities in India: A functional perspective. Disability and Rehabilitation, 20(5), 168–178. doi:10.3109/09638289809166078

[38] Helander E. (1993). Prejudice and Dignity: An Introduction to Community- Based Rehabilitation. New York: United Nations Development Programme,

[39] Taylor S.J. (1987). Evaluating the Client with Physical Disability - Wheelchair Seating. American Journal of Occupational Therapy.

[40] Kapadia K. Siva and Her Sisters: Gender, Caste, and Class in Rural South India. Boulder CO: Westview, 1995

[41] Pal, J., Viswanathan, A., Chandra, P., Nazareth, A., Kameswaran, V., Subramonyam, H. & O'Modhrain, S. (2017). Agency in Assistive Technology Adoption. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17.

[42] Pal, J., Viswanathan, A., Chandra, P., Nazareth, A., Kameswaran, V., Subramonyam, H. & O'Modhrain, S. (2017). Agency in Assistive Technology Adoption. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17.

[43] Mohammed, A. U., & Jamil, S. A. (2015). Entrepreneurial Barriers Faced by Disabled in India. Asian Social Science, 11(24).

[44] Kitching, J. (2014). Entrepreneurship and self-employment by people with disabilities. Background Paper for OECD Project on Inclusive Entrepreneurship.

[45] KII_08

[46] KII_09

[47] Pal, J. & Lakshmanan. M. (2012). Assistive technology and the employment of people with vision impairments in India. In the Fifth International Conference on Information and Communication Technologies and Development, ICTD.

[48] Vashistha, A., Brady, E., Thies, W. & Cutrell, E. (2014). Educational Content Creation and Sharing by Low-Income Visually Impaired People in India. Fifth Association for Computing Machinery.

[49] Vashistha, A., Brady, E., Thies, W., & Cutrell, E. (2014). Educational Content Creation and Sharing by Low-Income Visually Impaired People in India. Fifth Association for Computing Machinery.

[50] Hurst, A. & Tobias, H. (2011). Empowering individuals with do-it-yourself assistive technology. In The 13th International ACM SIGACCESS Conference on Computers and Accessibility, ASSETS.

[51] Ahmad, F.K. (2015). Use of assistive technology in inclusive education: Making room for diverse learning needs. Transcience, Vol. 6, No. 2.

[52] Chitiyo, M. (2007). Special education in Zimbabwe: Issues and trends. The Journal of the International Association of Special Education, vol. 7, no. 1.

[53] Ellsworth, N. J. & Zhang, C. 2007. Progress and challenges in China's special education development. Remedial and Special Education, vol. 28, no. 1.

[54] Gronlund, A., Lim, N. & Larsson, H. (2010). Effective Use of Assistive Technologies for Inclusive Education in Developing Countries: Issues and challenges from two case studies. International Journal of Education and Development using Information and Communication Technology (IJEDICT), Vol. 6, Issue 4.

[55] Singal, N. (2006). Inclusive education in India: International concept, national interpretation. International Journal of Disability, Development and Education. Vol 53, No. 3.

[56] World Health Organisation. (2012). World Report on Disability. ISBN 978 92 4 068521.

[57] Goyal, V.C. & Dixit, U. (2008). Technology Interventions for Elderly People. HelpAge India-R&D Jl. Vol. 14, No. 2

[58] Pain, H., Gale, C.R., Watson, C., Cox, V., Cooper, C. & Sayer, A.A. (2007). Readiness of elders to use assistive devices to maintain their independence in the home. DOI: 10.1093/ageing/afm046.

[59] Goyal, V.C. & Dixit, U. (2008). Technology Interventions for Elderly People. HelpAge India-R&D Jl. Vol. 14, No. 2.

[60] Mitra, S. & Sambamoorthi, U. (2008). Disability and the rural labor market in India: Evidence for males in Tamil Nadu. World Development., Elsevier. volume 36, Issue 5.

[61] Harriss-White, B. (2002). Poverty and Disability: with special reference to rural South Asia. World Development, Elsevier. Vol. 33(6).

[62] Dalal, A.K. (2010). Disability–Poverty Nexus. Psychology & Developing Societies. Vol. 22(2).

[63] Pal, J. & Lakshmanan, M. (2012). Assistive technology and the employment of people with vision impairments in India. In the Fifth International Conference on Information and Communication Technologies and Development, ICTD.

[64] Kim, J. & Mulholland, S.J. (1999). Seating/wheelchair technology in the developing world: Need for a closer look. Technol Disabil 1999;11:21 – 27.

[65] Authier, E. L., Pearlman, J., Allegretti, A. L., Rice, I., & Cooper, R. A. (2007). A sports wheelchair for low-income countries. Disability and Rehabilitation, 29(11-12), 963–967.

[66] Aurthier, E.L. et al. (2007). A sports wheelchair for low income countries. Informa UK Ltd. Publications.

[67] Nagarajan, S.S. et al. (1998). Speech modifications algorithms used for training language learning-impaired children. IEEE Transactions on Rehabilitation Engineering, 6:257–268.

[68] Sampath, H., Sivaswamy, J. & Indurkhya, B. (2010). Assistive systems for children with dyslexia and autism. ACM SIGACCESS Accessibility and Computing No. 96

[69] KII_06

[70] Lenker, J. A. & Paquet, V. L. (2003). A Review of Conceptual Models for Assistive Technology Outcomes Research and Practice. Assistive Technology, 15(1), 1–15.

[71] Sampath, H., Agarwal, R. & Indurkhya, B. (2013). Assistive technology for children with autism - lessons for interaction design. Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction - APCHI '13.

[72] Nagavalli, T. & Juliet, P. (2016). Technology for Dyscalculic Children. SSCE. Salem

[73] Stumbo, N.J., Martin, J.K. & Hendrick, B.N. (2009). Assistive technology: Impact on education, employment, and independence of individuals with physical disabilities. Journal of Vocational Rehabilitation. IOS Press.

[74] Singh, A. & Kaur, A. (2015). Case study of touch technology Used for teaching physically disabled students. 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology in Education (MITE).

[75] Kirby, R. L., Kirby, R. L. & Cooper, R. A. (2007). Applicability of the Wheelchair Skills Program to the Indian context. Disability and Rehabilitation, 29(11-12), 969–972.

[76] Pearlman J., Cooper R. A., Zipfel E., Cooper R. & McCartney M. (2006). Towards the development of an effective technology transfer model of wheelchairs to developing countries. Disabil Rehabil: Assist Technol.

[77] Simmons S. F., Schnelle J. F., MacRae P. G. & Ouslander J.G. (1995). Wheelchairs as mobility restraints: predictors of wheelchair activity in non- ambulatory nursing home residents. J Am Geriatr Soc

[78] Pal, J. & Lakshmanan M. (2012). Assistive technology and the employment of people with vision impairments in India. In the Fifth International Conference on Information and Communication Technologies and Development, ICTD.

[79] Pal, J. & Lakshmanan M. (2012). Assistive technology and the employment of people with vision impairments in India. In the Fifth International Conference on Information and Communication Technologies and Development, ICTD.

[80] Fisk, A.D. & Rogers, W. (1991). Towards an understanding of age-related memory and visual search effects. Journal of Experimental Psychology: General, 120, 131-149.

[81] Charness, N. & Schaie, K.W. (2003). Impact of Technology of successful Aging. Springer Publishing Company, New Year, Ch. 1.

[82] KII_05

[83] McCarthy, T., Pal, J. & Cutrell, E. (2013). The "Voice" Has It: Screen Reader Adoption and Switching Behavior Among Vision Impaired Persons in India. Assistive Technology, 25(4), 222–229.

[84] McCarthy, T., Pal, J. & Cutrell, E. (2013). The "Voice" Has It: Screen Reader Adoption and Switching Behavior Among Vision Impaired Persons in India. Assistive Technology, 25(4), 222–229.

[85] Kshetri, N. (2004). Economics of Linux adoption in developing countries. IEEE Software, 21, 74–81

[86] KII_01

[87] Charness, N., & Schaie, K.W. (2003). Impact of Technology of successful Aging. Springer Publishing Company, New Year, 15-27.

[88] KII_06

[89] Slough, K., Agius, M. & Engleman, M. (nd). Presentation. A Crash Course on Assistive Technology Evaluations. East Carolina University.

[90] KII_05

[91] Sampath, H., Agarwal, R. & Indurkhya, B. (2013). Assistive technology for children with autism - lessons for interaction design. Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction - APCHI '13. doi:10.1145/2525194.2525300

[92] Sampath, H., Agarwal, R. & Indurkhya, B. (2013). Assistive technology for children with autism - lessons for interaction design. Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction - APCHI '13.

[93] Madhuri, Y., Anitha, G., & Anburajan, M. (2013). Vision-based sign language translation device. 2013 International Conference on Information Communication and Embedded Systems (ICICES).doi:10.1109/icices.2013.6508395

[94] Goyal, V.C. & Dixit, U. (2008). Technology Interventions for Elderly People. HelpAge India-R&D Jl. Vol. 14, No. 2.

[95] Basu A., Sarkar S., Chakraborty K., Bhattacharya S., Choudhury M. & Patel, R. (2008). Vernacular Education and Communication Tool for the People with Multiple Disabilities

[96] Reiter E. & Dale R, Building Natural Language Generation Systems (Studies in Natural Language Processing), Cambridge University Press, 2000.

[97] Basu A., Sarkar S., Chakraborty K., Bhattacharya S., Choudhury M. & Patel, R. (2008). Vernacular Education and Communication Tool for the People with Multiple Disabilities

[98] KII_01

[99] Lipika, J. K., Kunal K., Kumar, R., Chanana, P., Rao, P.V.M. & Balakrishnan. M. (2017). Tactile Diagrams for Science and Mathematics: Design, Production and Experiences of Students with Blindness. National Conference -Inclusive Schooling, AssisTech at IIT Delhi.

[100] Gandhi, T., Trikha, M., Santhosh, L. & Anand, S. (2010). Development of an expert multitask gadget controlled by voluntary eye movements, Expert Syst. with Applications, vol. 37, pp. 4204-4211.

[101] Swami, P., Singh, R., Gandhi, T. & Anand, S. (2012). A novel embedded approach for the development of wireless electro-oculogram based human-computer interface. 2012. 2nd IEEE International Conference on Parallel, Distributed and Grid Computing.

[102] Slowik, R., Krishnan, M., Venugopal, P., Yost, S. A. & Das, S. (2009). Work in progress - description of a service learning project to design assistive technologies to aid the visually-impaired in India. 2009 39th IEEE Frontiers in Education Conference.

[103] Mulholland, J.S., Packer, T. L., Laschinger, S. J., Lysack, J. T., Wyss, U. P. & Balaram, S. (2000). Evaluating a new mobility device: feedback from women with disabilities in India. Disability and Rehabilitation, 22(3), 111–122. doi:10.1080/096382800296962

[104] Mulholland, J.S., Packer, T. L., Laschinger, S. J., Lysack, J. T., Wyss, U. P. & Balaram, S. (2000). Evaluating a new mobility device: feedback from women with disabilities in India. Disability and Rehabilitation, 22(3), 111–122. doi:10.1080/096382800296962

[105] KII_05

Chapter III
THE ECOSYSTEM OF ASSISTIVE TECHNOLOGY

Any solution, if it is to reach market, must be developed within a supportive ecosystem. First, there must be recognition of the problem and estimation of its size. Second, assuming the first is in place, policy enablers must have an intention to address it. Thirdly, there needs to be demand from those who require the assistive devices. And finally, there need to be people willing to invest time and effort on developing and marketing the solutions. In Chapter 3, we examine the ecosystem of assistive technology in India.

Size of the Problem

A fundamental difficulty to developing a robust response on assistive technology in India lies with an incomplete information base to work from. There is limited data on disability in India.

Uncertainties in Prevalence Data   To make matters more obscure, data from the two available sources - the Census of India and the National Sample Survey - are not comparable to each other because of differences in the definition adopted and data collection techniques used. The Census and National Sample Survey definitions of four out of five major impairments are radically different.[106] The figure that is most commonly used in India is that from the 2011 national Census, which indicates that persons with disability constitute 2.21% of the Indian population. In contrast, WHO estimates that today, about 15% of persons worldwide are living with disability of some degree.[107]

Further, some experts challenge the Census estimates of 2011, and say that the number should have been closer to 40 million in 2011 and could rise to 60 million in 2021, an estimated 50% increase.[108] They also point to the issue of temporary disability which could affect anywhere between 400,000 – 500,000 people per year.[109] More persistent inquiry at the village level is expected to provide a better mapping of those with disability. For example, when identifying beneficiaries after the Odisha super cyclone, the numbers identified with disability were 20 times higher than those registered at the district level.[110]

Little credible information exists apart from the prevalence data on disability, and even that is commonly accepted to be unreliable. In India, Census and National Sample Survey data that is available indicates that disability is more common in rural areas (2.24%) than urban areas (2.17%); and that disability is more common among men (2.4%) than

Figure 6: Nature of Disability in India, Census of India 2011

18.4, 18.8, 7.9, 18.9, 7.6, 2.7, 20.3, 7.5

- Seeing
- Hearing
- Speaking
- Movement
- Mental illness
- Mental retardation
- Multiple disabilities
- Other
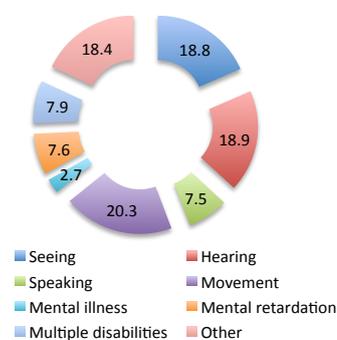
women (2.0%). Among those with disability, the types of disability are reported in these proportions: (i) seeing 18.8%, (ii) hearing 18.9% (iii) speaking 7.5% (iv) movement 20.3% (v) mental retardation 7.6% (vi) mental illness 2.7%, (vii) multiple disabilities 7.9% (viii) other 18.4%. (See Figure 6).

Disability is Rising   It is expected in India as in other developing countries, that the prevalence of disability will continue to increase due an ageing population, increase in chronic health conditions such as diabetes, cardiovascular disease, cancer and mental health disorders as well as injuries and violence.[111] Data from the Institute of Health Metrics and Evaluation's Global Burden of Disease study shows that the causes of disability have changed dramatically between 2007 and 2017.[112] (See Figure 7). It is clear that there is a growing share of non-communicable diseases linked to death and disability, partly owing to their increasing incidence, as well as to the overall increase in longevity of both men and women in India. (See Figure 8).

> According to the 2011 Census, which collates information on eight types of disability, India's differently-abled population stands at 2.68 crore. The World Bank's estimates peg this number at a much higher figure.

Figure 7: What causes the most death and disability combined?
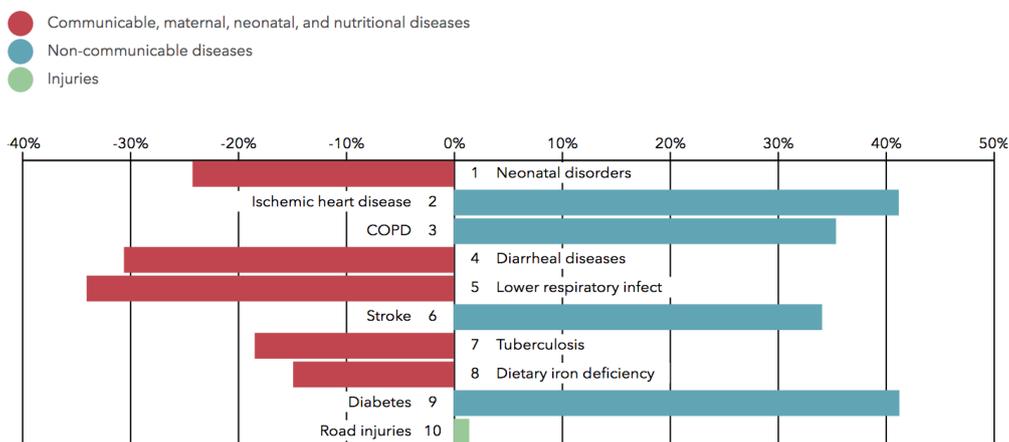
Source: Institute for Metrics and Evaluation. (2019).

Figure 8: Increasing average years of life in India
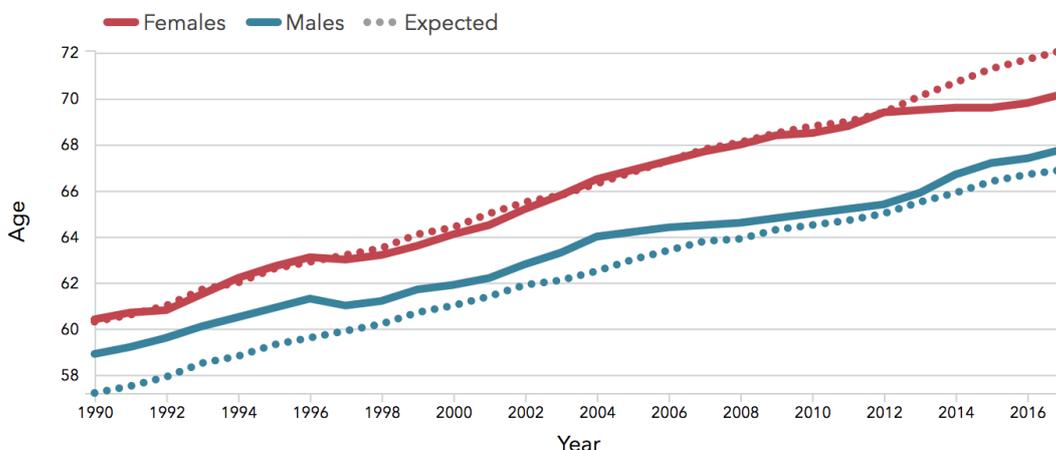
Source: Institute for Metrics and Evaluation. (2019).

Data of this kind has implications for any efforts to develop and make assistive technology devices for persons with disability available and accessible. The differential in estimates of disability prevalence by India and WHO indicate the need to develop more robust estimates for the country.[113] [114] The nature of the distribution across various 'types' of disability provide clues as to the kinds of needs that Indian society has, but these must be further refined if they are to be useful. Finally, the greater prevalence of non-communicable diseases and increasing longevity spell trouble for the Indian public health system; both translate to a higher requirement for assistive technology solutions.

Data on Requirement for Assistive Devices   Experts attest to the lack of data on assistive technology in India. "The numbers we have would suggest that 6% of our population require assistive devices. But we haven't been able to narrow that down - what type of assistive device, what age group, etc."[115] Persons with disability are not homogenous, they have different wants and needs".[116] Data is also required on the present state of play on aids and appliances being used by persons with disability. Such data is presently lacking. Much of the data in this space is related to input type data and there is no consolidation of even input data across organisations who are distributing assistive technology devices and individuals who receive them or buy their own devices. This means that any estimation of need is appreciably flawed.[117]

Policy Framework

The Government of India has several laws and policies in place to guide the provision of assistive technology. Nevertheless gaps remain, as this section outlines.

International Commitment   The international framework describing the role that governments might play to support integration, and assist the ease of living of persons with disability, is the UNCRPD.[118] India became a signatory to the UNCRPD in 2007 and ratified it in the same year.[119] Articles 4, 20 and 26 of the UNCRPD ask States to promote the availability of appropriate devices and mobility aids and provide accessible information about them. The Standard Rules on the Equalization of Opportunities for Persons with Disabilities also call upon States to support the development, production, distribution and servicing of assistive devices and equipment and the dissemination of knowledge about them. To achieve access to these, governments and other signatories need to carry out measures related to policy, legislation, research, development, production, training, information, use and cooperation.[120] In 2016, India passed the Rights of Persons with Disabilities Act. This Act, while speaking to the rights of persons with disability, recognises that such persons must have access to assistive technology devices. Nevertheless, the passage of the Act as well as its prior ratification of the UNCRPD signals India's resolve to address the needs of those with disability.

Eight Guiding Principles of the UNCRPD

1. Respect for inherent dignity, individual autonomy including the freedom to make one's own choices, and independence of persons.
2. Non discrimination
3. Full and effective participation and inclusion in society
4. Respect for difference and acceptance of persons with disability as part of human diversity and humanity
5. Equality of opportunity
6. Accessibility
7. Equality between men and women
8. Respect for the evolving capacities of children with disability and respect for the right of children to preserve their identities

Compliance with the UNCRPD requires that assistive technology be equitably available, accessible and affordable irrespective of gender, age or impairment. However, according to many rehabilitation specialists in lower-income countries, the need for assistive technology outweighs availability.[121] Estimates of availability are as low as 5 - 15% of requirement in low- and middle-income countries.[122] The 2011 World Report on Disability reports that the accessibility challenges are reinforced in low- and middle-income countries because of inadequate policies and lack of provision of medical rehabilitation, welfare services, negative societal attitudes towards persons with disability and vocational training.[123]

Domestic Commitment   The rights of persons with disability are enshrined in the Constitution of India. Articles of the Constitution that guarantee life, liberty, right to equality and freedom from discrimination on any count, apply equally to those with disability as those without. India has had a law addressing the rights of persons with disability since 1995.

The Rights of Persons with Disabilities Act was signed in 2016 after revisions to the Persons with Disabilities Act of 1995 after a great deal of debate and delay. The 2016 Act talks about the rights and empowerment of persons with disability through inherent dignity, individual autonomy, non-discrimination, participation and inclusion in the society, equality of opportunity, accessibility and the rights of children with disability to preserve their identity. The principles in the Act reflect a paradigm shift in thinking about disability as a social welfare concern to a human rights issue. In addition, other laws are in place to assist persons with disability, namely the National Trust for the Welfare of Persons with Autism, Cerebral Palsy, Mental Retardation and Multiple Disabilities Act, 1999; and the Rehabilitation Council Act of 1992. The provision of social security, equal participation in the society, living independently and accessibility are the central principles present across these acts. Government of India will also assist persons with disability in securing durable and modern aids and appliances guided by ISO standards to ensure their independence in various activities leading to physical psychological development and social inclusion.[124]

The Assistance to Disabled persons for Purchase/Fitting of Aids and Appliances (ADIP) Scheme, 2011 reflects the government's commitment to persons with disability. The Ministry of Social Justice and Empowerment implements the ADIP scheme by providing grants to agencies of the central/ state government and non government organisations. The scheme aims to reduce the impact created by disability in an individual's life by enhancing the economic potential of people with disability by making durable, modern, scientific and suitable aids and appliances accessible.[125] As per the scheme assistive devices are available to persons with disability in families with earnings specified to be below INR 15,000 per month. Any person with disability is entitled to aids and appliances under the ADIP scheme. Under the scheme, both small and mega camps are held at various locations across the country by government and non-government organization through which persons with disability are contacted and distribution effected. Schemes cover school going children, the elderly and other persons with disability. Distribution figures run into the lakhs per year.[126]

However, a 2013 study by the (then) Planning Commission found a number of constraints that hinder the effective implementation of the ADIP scheme. Among them are weak institutional coordination, low utilization of the funds, unavailability of good quality aids and appliances according to the international standards, lack of poor and updated data on the number of persons

with disability, lack of maintenance of the assistive devices as they become non functional with no prospect of servicing etc.[127] Experts interviewed remarked that due to the nature of the distribution events, not enough effort is made to educate persons on the correct use and maintenance of their assistive technology device.[128] They noted that while the ADIP scheme helps organisations to scale up production of assistive technology devices because distribution takes place through government institutions for persons with disability; the scheme has so many constraints that make it close to impossible for organisation to be empanelled.[129] While acknowledging that assistive technology is a dynamic space which is evolving, it was stressed that initiatives should cover the entire population of persons with disability rather than have pockets of excellence to which people would have to travel to receive services.[130]

Government Institutions

The Government is a key player and has invested in research, design and supply of assistive technology devices, developing policies and schemes to enable their accessibility and availability to people who need them. It is clear that assistive technology is now at the front of the government's vision with the NITI Aayog organizing discussions on the subject.[131] [132] The Department of Empowerment for Persons with Disabilities (DEPwD) under the Ministry of Social Justice and Empowerment is the nodal department responsible for new policies and schemes in the area of disability. There are seven National Institutes under the DEPwD of which three operate in the space of locomotor disability, one on intellectual disability, one specialising in speech and hearing impairment, one working in the visual impairment space and one on multiple disabilities.[133] It is expected that a National Institute for Assistive Technology and support centre for persons with disability will be set up at Raipur, Chhattisgarh.[134] The increasing participation of the government has been acknowledged by the experts interviewed, with one noting that, "Disability has come centre stage because of the present government - the Prime Minister has been actively involved in this regard. A greater number of appliances are available for the visually and hearing impaired, for example, the introduction of cochlear implants for children from the time of birth till the age of 5 years. The policy framework too has become much more robust: funding has increased four to five times; government reservations for the disabled has increased from 3% to 4%; the number of schemes for the disabled have increased".[135]

Punarbhava, Swavlamban and Accessible India Campaign   A national interactive web portal on disability, Punarbhava provides a gateway to information for persons with disability and all concerned with the sector. This portal has created a distinct niche in cyber space to find information, discuss issues, network, find employment, look for appliances and assistive devices, seek redressal of grievances, undergo training, research and study, and so much more. Swavlamban is a directory of Aids and Assistive Devices maintained by the DEPwD. The Accessible India Campaign launched in 2015 under the DEPwD aims to achieve universal accessibility for persons with disabilities and to create an enabling and barrier-free environment for them by making public utilities and buildings accessible to persons with disabilities. [136] Accessibility of infrastructure through the campaign is an important (prior) step to make assistive technology devices for locomotor disability successful.[137] [138] Access to information is key to inclusion of persons with disability. Respondents were very appreciative of those websites which have become accessible. However, there have been significant gaps in following up on the targets of the campaign.[139] [140] The slow response from state governments to make government websites accessible prompted the DEPwD to initiate Education

and Research Network or ERNET. Education and Research Network has identified 917 websites to be made accessible, of which 104 were live in 2018.[141]

Centre for Assistive Technology and Innovation   The Centre for Assistive Technology and Innovation (CATI) was established in 2015 at the National Institute of Speech and Hearing or NISH, Kerala, India. This was the first Assistive Technology Centre in the country. It operates a programme that caters to the accessibility and accommodation needs of students and clients of the National Institute of Speech and Hearing (NISH). The programme is directed to support independent living needs of persons with disability, including needs assessment, device demonstrations, training, customisation, loans and financing of products, and service/maintenance of assistive technology solutions to facilitate . The Centre also serves as a resource centre for assistive technology solutions where technology developers can collaborate to encourage product development. The Centre for Assistive Technology and Innovation at NISH operates to meet the assistive technology needs of persons with disability, especially accessibility and accommodation needs of the students and clients of NISH.[142]

The National Trust   The National Trust is a statutory body of the Ministry of Social Justice and Empowerment, Government of India, set up under the 'National Trust for the Welfare of Persons with Autism, Cerebral Palsy, Mental Retardation and Multiple Disabilities' Act (Act 44 of 1999). The National Trust's mission is to create an enabling environment for persons with disability through comprehensive support systems which can also be done by collaborating with other Ministries, etc., which will lead towards the development of an inclusive society. The National Trust has established a National Resource Centre - Sambhav - at Action for Ability Development and Inclusion for the display of available assistive devices in New Delhi to demonstrate the possibility of independent or assisted living for persons with developmental disabilities through the use of aids and assistive devices and technology.[143] These centres showcase a sample bedroom, kitchen, bathroom, toilet etc. which are disabled friendly and accessible to persons with disabilities. Various assistive devices, including learning kits, aids related to mobility and communication are displayed, which are useful to improve the quality of life of persons with disability. Sambhav Centres are proposed to be established in other cities of the country having population more than 5 million. The Niramaya Scheme of the National Trust provides insurance cover to persons with the four index conditions (Autism, Cerebral Palsy, Mental Retardation and Multiple Disabilities) covered by the Trust. Unfortunately, the cover of the health insurance provided for assistive technology under the scheme is small - the beneficiary is entitled to a maximum of Rs. 100,000 for assistance which varies based on the nature of assistance requested: hospitalization/surgery, non hospital medical treatment, transportation costs or additional medical treatment . This needs to be enhanced significantly to be of use to beneficiaries.[144]

National Innovation Foundation-India   The Foundation has recognised ideas/ innovations about assistive technology by grassroots innovators and students which could prove to be a game changer for the elderly, especially those with disability. The country's First Assistive Technology Conclave, 2019 focused on Tech Start-ups for Disability which brought the best assistive technology start-ups, visionaries and thought leaders together and to discuss topics that will help shape the future of assistive technology ecosystem, and its impact on the world.

National Council of Educational Research and Training   This educational body has tried to use assistive technology in the space of education. Management institutes such as Indian Institutes of

Management at Bangalore and Ahmedabad are using assistive technology to make their spaces more inclusive. In Delhi University, Miranda House College has used technology to make their campus accessible. They have used digital technology to help visually impaired people to navigate the campus. Disability organisations are reportedly working on a national database of persons with disability so that they can be reached with actual solutions. For this purpose, disability organisations are working with the government to create such a database through upcoming Census 2021.[145]

State initiatives   Disability is on the concurrent list of the Constitution, making it not only the responsibility of the Union government, but also the State government.[146] For instance, the Kerala Social Security Mission has been proactively engaged in prevention, education, employability of the disabled through an initiative called Snehasanthwanam wherein monthly assistance of Rs. 700/- is provided to caregivers of Endosulfan victims under a special Aswasakiranam Scheme.[147] Tamil Nadu has five schemes in place pertaining to disability in leprosy cured, hearing impairment, blindness, intellectual disability and muscular dystrophy while the Kerala state initiative deals with intellectual disability. State government schemes that deal with populations with disability are few. The majority of schemes that fall under the state government purview are an extension of the schemes by the central government.[148]

Non Government Institutions

Several NGOs work in the field of disability; some are peer based organisations, seeking to make things better for their membership of persons with disability; others are devoted to addressing one or another disability type. Described below are examples of three NGOs working in the space.

The Association of People with Disabilities (APD India) APD India is an NGO has been working to transform lives of underprivileged people with disability since 1959. Based in Bengaluru, Karnataka, the organisation runs extensive programs in rural and urban Karnataka to enable, equip and empower children and adults with a range of disabilities including locomotor, spinal cord injury, speech and hearing, cerebral palsy, and to some extent, mental health issues. To date, they have impacted over 50,000 lives of persons with disability.

Mobility India This NGO is committed to improving the lives of persons with disabilities through relevant and comprehensive community programs and facilitating access to services related to rehabilitation and assistive devices. Its programmes include research and development of appropriate assistive technology and improving its access at an affordable cost, developing appropriate human resources in the field of disability, rehabilitation and assistive technology at national and international level and capacity building of grassroots organizations in the field of disability. The National Conference on Assistive Technology for All 2030 held in August 2019 was hosted by Mobility India. The Conference focused on the theme: 'Improving access to quality and affordable assistive technology for everyone, everywhere.' The theme emerges from the UN 2030 agenda for sustainable development, which places "good health and well-being for all at all ages as the centre of a new development vision."[149]

The National Centre for Promotion of Employment for Disabled People (NCPEDP) This is a non-profit, voluntary organisation, working as an interface between the government, industry, international agencies and the voluntary sector, towards empowerment of persons with disability. NCPEDP works on five core principles, also called the five pillars of the organization, namely: (i) education; (ii)

employment; (iii) accessibility; (iv) legislation/ policy; and (v) awareness/ communication. NCPEDP stresses the need to move away from traditionally held views of charity and welfare to those of productivity and empowerment of persons with disability. Despite the presence of various other stakeholders in India (NGOs, disability associations, disability experts) apply traditional methods to help persons with disabilities.[150] NCPEDP is working with its partners to create and implement a strategy to get the Government of India to adopt a procurement policy that specifically requires the purchase of accessible goods and services. It has in the past, engaged with the Ministry of Finance on issues of concession/exemption of excise duty on assistive technology and devices for persons with disabilities and on the need of allocating a greater proportion of the Union and State Budgets on initiatives and programmes for the empowerment of persons with disabilities.

Developing and Marketing Assistive Technology

Multiple actors are involved in designing, developing, manufacturing and provisioning of assistive technology in India. Currently the assistive technology industry is specialized, producing products that mainly serve high-income markets. The Artificial Limbs Manufacturing Corporation of India (ALIMCO), established by the Government's Ministry of Social Justice and Empowerment, provides assistive aids to those with disability and the elderly in India. ALIMCO produces 355 different kinds of assistive aids for orthopedically, visually, and hearing impaired people and partners in various government schemes. One such is the Rashtriya Vayoshri Yojana which supports aids to elderly beneficiaries, generally poor people.[151]

> ALIMCO, a public sector entity, is India's largest manufacturer and distributor of assistive technology devices.

However, many report that the devices ALIMCO makes figure on the lower end of the assistive technology spectrum and suggest that they are more concerned about distributing large numbers rather than ensuring that these devices meet the needs of the people.[152] [153] Some see the focus on low-tech devices as legitimate, maintaining that the present challenge is to ensure that there is greater coverage of the country than a focus on higher end technology devices.[154] Nevertheless, the volumes of wheelchairs needed in India has prompted the government to seek collaboration with the National Institute on Disability and Rehabilitation Research and wheelchairs designers in the US to improve the quality of wheelchairs manufactured and distributed in India. A collaboration has been undertaken to produce quality wheelchairs over a period of four years.[155] An example is the standing wheelchair that will be developed in partnership with a company in Chennai which would manufacture and market the product.[156]

Key Academic Players Key players in research and development of assistive technology are some of the premium academic institutes in the country. At least four of the Indian Institutes of Technology (IIT) in Delhi, Chennai, Kharagpur and Mumbai; National Institute of Technology Durgapur have played a key role on the design and development side of assistive technology.[157] [158] Despite the key role that the academic institutions have played in developing assistive aids and devices, they have not been successful in taking it to scale and to market due to large disconnect between the innovators and the market.[159]

IIT Madras's Rehabilitation Research and Device Development (R2D2) laboratory has been involved in research related to human movement, the influence of orthotic and prosthetic devices on human movement, and the design and development of mechanisms, products and assistive devices for

people with impairments. AssisTech at IIT Delhi is an inter-disciplinary group of faculty, research staff and students that is engaged in using modern technology for finding affordable solutions for the visually impaired. The focus is on mobility and education which are fundamental to enable any person to live independently with dignity. Apart from working on specific solutions based on needs identified by the users themselves, they hope to create an eco-system that helps to sensitize and ignite young minds towards real day-to-day challenges of the differently abled.

As another example, braille books in India are available for visually impaired students only in text and do not have diagrams to illustrate the concepts. An expert notes how this limits the avenues for a student who stays unacquainted with subjects that rely heavily on explanations through diagrams. AssisTech at IIT Delhi has set up a solution for developing tactile diagrams that the visually impaired could understand. AssisTech has also developed a 'Smart Cane' to aid mobility for visually impaired. In fact, respondents remarked that academic institutions like IIT Madras are central to innovation in assistive technology but they fail to make it into a successful business venture.[160] This results in poor availability and accessibility as there is no way for the population that needs the aids to avail it from a physical market place."[161]

R2D2 and AssisTech have been making significant inroads in terms of assistive devices development in order to make affordable technology available. "A likely area into which assistive technology must expand is artificial intelligence. Premier engineering institutions like the ones mentioned above are expected to make some progress in the area. Artificial intelligence has the benefit that it doesn't tire, making it the ideal solution of 24 by 7 care for persons with significant disability".[162]

Accounting for Context   For ground level implementation, the ecosystem for assistive technology must support assessment, selection, product procurement policies, training, maintenance and support. ADIP and other state-owned schemes must be constantly updated in this regard, and facilitate start-ups to evaluate their products, enhance distribution and support networks for sustainability. This will foster research in the space of assistive technology and development in the country.[163]

Cultural practices of persons needing assistive technology devices need to be factored in while designing and developing assistive technology. A recent pilot study by IIT Madras discussed issues in assistive technology that users faced with the lower limb (knee-ankle-foot) orthosis in South Indian states of Tamil Nadu and Karnataka. Most of the users reported pain-related issues associated with the brace along with pain while performing the basic activities of daily life in India such as squatting, kneeling, riding a bicycle, walking on sand, walking on mud and cross-legged sitting were the top six."[164] In a study to provide assistive international software to India that makes computer usage possible for the population with disabilities, Jhangiani (2006) stated that "during localization of software it is important to understand the needs and requirements and target the culture of users."[165]

> The response to disability must be contextualised to India if it is to be useful. Simply importing technology may not provide the solutions needed for the population.

Designing for diverse users from different cultures poses a challenge. In order to build systems that are usable universally, designers must account for different types of technology, user diversity and gaps in user knowledge.[166] Research has failed to address a broad range of technology type such as sensory and cognitive aids.[167] Sharma et al. (2014) showed the lack of assistive technology facilities

for hearing impaired users in the institutions/ libraries.[168] Not much is documented about availability and accessibility of assistive aids for children with developmental disorders such as autism and dyslexia[169], and for learning disabilities like dyscalculia.[170] In addition, it is also necessary to take into account the supportive services that may or not be available. For instance, the success of powered technology depends heavily on the ability of the country to provide charging outlets and the orientation of the people for ready acceptability.[171]

Not only does assistive technology have to be 'fit-to-purpose' for each user, the user must receive

> Assistive devices need to be 'fit-to-purpose' and their use be supported by a user education programme .

appropriate and adequate training that permits her/ him to make use of the device. Respondents attest to the need of training for assistive devices post sales.[172] [173] In fact, drop out from use may be as high as 80 - 85% due to inadequate education to use the device and insufficient attention to its customization to the physical and cultural context.[174] To provide assistive technology devices at scale, costs are incurred to identify users, market to them as well as to build capabilities of the provider organisation. Further, cost is also incurred on providing the device since many, if not most, users are not able to afford assistive technology; and finally, costs are also implicated in the training required to see that the user is able to use the device effectively.[175]

The challenge of adapting imported technology to the local conditions of the country and settings was reiterated by experts. They felt that most of the high-end, imported devices may not be usable in Indian settings as they were "not suitable for our terrain, our climatic conditions etc."[176] Therefore, while focusing on making assistive technology available, it is important that usability is not overlooked. Some rehabilitation specialists maintain that usability and accessibility are two sides of the same coin. A study on applicability of the wheelchair skills program in the Indian context highlighted the need to address the community based obstacles observed by the researchers. For example, the curbs did not provide a surface for wheeled locomotion and sidewalks, where present, were often impassable. Moreover, most of the wheelchair users did not use lightweight modular wheelchairs, or electrically powered mobility aids. Thus, training tips needed to be redesigned to address the context specific issues to make the program relevant and useful for the Indian wheelchair users.[177] *Innovators in India*   Initiatives have also been taken by some to develop assistive aids suitable for the Indian elderly. Manufacturers like Dhingra Surgicals, Navchetan Orthopedic Appliances, Surgical electronics, Narwal Orthopedic and Rehabilitation Aids, Surgico-Furn (India) Ltd., SAGE (Everest Engineers) and organisations like Bhagwan Mahaveer Viklang Sahayata Samiti are working consistently on developing mobility aids, prosthesis, tricycles, wheelchairs, commode pot chairs, cervical aids, abdominal supports, various hand and leg supports, orthopedic shoes, calipers, etc. to help the elderly participate actively in social life. Some such ideas/innovations include a chair with shower system for elderly to take bath independently, a walker with height adjustable front leg to climb stairs, a walking stick with features like counting of steps, medicine reminder, locator, emergency alarm, fall detector, and automatic torch, shoes with a negative heel to alleviate knee pain among elderly, and modified wheelchair that can be converted into crutches by various innovators operating to make lives better for persons with disabilities.[178] Megalingam et al. (2012) have proposed a system HOPE with sensors to monitor heart rate, body temperature, tilt and fall and send the data to caregiver in case of emergency.[179] Mohan Kumar et al. (2012) have developed multipurpose wheelchair, which also assists in defecation, cleaning, and changing of clothes. In the

wheelchairs, a provision of adjustable armrest, backrest, and leg rest has also been made to provide comfort to users while resting.[180] An ergonomic wheelchair with features like back recliner and standing mechanism has also been designed by Oram. A device for managing urinary incontinence in old age has been developed by Ramesh et al. A bed rail to assist the elderly for getting in and out from bed has been developed at IIT Mumbai. A tablet-based system to check the well-being of the elderly has been designed and assessed by Ray et al.[181] Sarkar and Das (2017) conceptualized modularity in powered wheelchair for elderly with mobility impairment.[182]

GRID Model for Technology Development

Traditional models of research and development may not work effectively in cost-sensitive markets. The GRID model is based on the four pillars of Grants-Research-Industry-Dissemination to involve academia, funding agencies, industry partners and users to develop the appropriate assistive device. The network of government and non-government and private organizations under the GRID model provide effective solutions to develop quality assistive technology solutions to persons with disability in developing countries. The standing wheelchair developed as part of a graduate student project at Indian Institute of Technology, Madras is a clear example.[183] The GRID model was applied to successfully translate the concept into the market. The involvement of important stakeholders from the early stage of model building ensures all viewpoints have been taken into consideration for proper dissemination among end-users, user groups, rehabilitation centres, therapists fitting and training personnel.

Development, advancement and adaptation of various assistive technology keeping in mind the Indian context ensuring its affordability is crucial.[184] Creating awareness among stakeholders - designers, architects, technologists and other specialists, industry and service providers, etc. for the needs and constraints of the user is also required. Yet several experts pointed out that the market is highly fragmented. There is no pooling of demand as persons with disability are economically weak and do not have much purchasing power. The supply chain is likewise weak and the industry struggles with the issues detailed above. Finally, even when there is development of a solution it cannot be productized because of the small market size and lack of rehabilitative programmes.[185] [186] Even though there is import of new technology to the country, the government is not very aware on the procurement strategies for distribution.[187]

> Traditional models of research and development may not work effectively in cost-sensitive markets. The Grants-Research-Industry-Dissemination or GRID model could be used to develop appropriate assistive technology devices.

The control of intellectual property rights is a major barrier to a country struggling to establish its own assistive technology programme. Issues such as 'Freedom-to-Operate' and 'Infringement of Intellectual Property Rights' are not well understood by the innovators in India.[188] Many innovations are built to operate on existing software platforms. Technology accessibility is usually constrained by intellectual property rights. Even if hardware were to be produced in country at low cost, it would require the platform in order to be functional, thus driving up its cost. This makes even locally produced solutions often too expensive to reach the masses.[189] Many of the organizations developing technology solutions are either sponsored or self-funded. However, innovators may not be best placed to take their innovative solutions to market.[190] Several start-ups are enthusiastically converting good intentions and technological competence into sector specific assistive devices. The

estimated cost of development of technology in the private sector is often expensive. **The problem with innovation by academia is that they are not willing to consider the needs of the people. They sell their innovations to private entities which hike up the cost. Government providers such as ALIMCO then have to purchase such assistive technology at quite a high price.**[191]

Financing Assistive Technology Start-Ups   In recent years, innovators and venture capitalists have ventured into the assistive technology space alongside the government. Social Alpha is a venture capitalist by Tata Sons and is focussed on enabling meaningful impact through science and technology for persons with disability. As venture capitalists and incubators, organizations are always keeping an eye out for up and coming innovations in the space of assistive technology and help them by providing resources and a platform. The Assistive Technology Accelerator is an incubator supporting three start-ups that have been very successful in the recent times- Eye-D, Innovision and Inclov. The BIRAC-Social Alpha Quest for Assistive Technologies, supported by Mphasis is a search for the top 10 innovative and entrepreneurial teams in the country that have developed market-ready assistive technology and inclusive solutions. Barrier Break (Digital Accessibility Consulting) was founded on three basic principles – technology, hiring people with disabilities and a for-profit model.

Experts note that, "There is an influx of social entrepreneurs in the market place operating in assistive technology in India."[192] The entry of innovators and social entrepreneurs will help bring funding for research and development of new affordable technology for the Indian population. This may help make assistive technology more easily available and accessible to persons with disability. But the importance of government financing in the early days of the industry cannot be gainsaid as, "a for-profit assistive tech business model needs encouragement for product innovation and invention with the influx of funds and a lack of that in India keeps the industry where it is."[193]

An expert stressed the need for start up funding support, citing the Kerala Start Up Mission as a good example of a government agency supporting entrepreneurship and incubation in the country.[194] One out-of-the-box incentive for start up centres was proposed by one expert who said, " .. the government now pushing for Institutes of Eminence to be set up. My proposal is that it should be made mandatory for institutes that want such a tag have centres for inclusive education."[195] Another perspective on similar lines notes that if government would like the future to be inclusive in the true sense of the word, it should mandate that all procurement carry technical specifications that make the service inclusive for persons with disability.[196]

Gaps that Remain

Despite the increased role and awareness about disability and the need of assistive technology, certain anomalies remain. India does not have an assistive technology act for persons with disability as of now, unlike the US, where such an act had preceded the disability act. This acted as a spur to manufacturing of assistive technology devices as assistance became available to persons with disability for the exclusive purpose of providing such devices.[197] This is linked to the call to establish standards in the field of assistive technology devices, which would

> A number of weaknesses afflict the system: reach, accessibility, affordability, customisation to need, customisation to Indian conditions, training for use and post sales servicing.

help the start ups orient themselves to meet the basic minimum requirement for a good quality assistive device.[198]

Reasons for Concern   The growing focus on easy accessibility to assistive technology to those requiring them makes a critical review of the evidence, central to driving improvement and robust policy decisions in this regard. Assessment of existing policies and programmes are crucial to ensure that effective services are in place for persons with disability. A 2016 report of the Government of India's Ministry of Statistics and Programme Implementation identified that it is essential to determine the social needs of persons living with disability, such as the role of assistive technology for inclusive development.[199] Yet others argue, "Government funding has increased for research and development in this space." The government has invested in good high-speed braille presses and every state has one or maybe even more than one business.[200] Nonetheless, it is generally accepted that the tools of policy such as information dissemination, availability of goods and services, pricing of goods and services, and regulation have not been fully leveraged to create the policy environment in which assistive technology is nurtured and those in need of it, are enabled to access it.[201] [202] [203]

Concern was also expressed with respect to naive adoption of policies of the West to India. An example was provided of the creation of residential 'blind schools' in India which have been unable to cater for much of the blind population of the country due to various reasons (lack of training among the teachers to deal with the blind students, lack of study material etc.), while imposing a high cost to the exchequer.[204] Other areas that found mention from experts interviewed include: the need to bring the Ministry of Social Justice and Empowerment closer to the Ministry of Health and Family Welfare to account for the accessibility and availability for assistive devices as a public health matter as a greater number of persons with chronic health issues face disability in their later years. [205] [206]   A concern among providers is the variable Goods & Service Tax levied by the government; this varies from 0 – 18% depending on the nature of the support provided, making the tax returns process cumbersome. This is sure to create an impact on the pricing of assistive technologies as well as the reluctance of the seller to service the sector because of the multifactorial nature of the pricing process.[207]

Insufficiency, Affordability and Reach   Commonly available assistive technology are spectacles, hearing aids, walking canes, wheelchairs and canes for the visually impaired.[208] Callipers for polio affected persons; prosthetics and artificial limbs are also available, but mostly for the lower limbs. Options for the upper limbs were limited.   Experts noted that there is a growing need of customisable devices as the wide spectrum of devices available in India, the options are limited on side of the spectrum due to rudimentary design with obsolete technology provided at low cost. These devices do not meet the needs of the people. At the other end, are imported and expensive devices that are not accessible to most persons with disability owing to their high cost."[209]

From a user perspective, the following were cited as the role of government to ensure availability: (i) to encourage development of assistive technology; (ii) provide subsidies especially given that persons with disability tend to be economically weaker; (iii) ensure affordability and geographical availability; and finally (iv) consideration of Indian context and disability type in the process of technology development (v) to make sure that the government space is digitized and accessible.[210]

To enable availability and accessibility to assistive technology, it is important to create such products and services that are equally accessible to the persons in need for them. However, availability of

high-quality and affordable assistive products is a serious problem for many especially in a middle income country like India.[211] The point is not just to distribute state of art equipment to people who need them but to look at the utility of those devices in certain socio-economic and environment factors.

The insufficiency of assistive technology in India is reiterated by others who call attention to the fragmented assistive technology market wherein the interventions for certain disabilities are more prevalent than others.[212] Another interviewee mentioned that if assistive technology is to prove to be of help, all three need to work together – developers, aggregators and grassroots organisations.[213] Affordability was identified by many specialists as a key component of making assistive technology available and accessible to the end users in India. To add to the availability debate, experts noted that, "while a lot of technology was available from overseas, it tends to be frightfully expensive. Therefore, many people in India find it difficult to acquire it."[214] Rural areas and certain geographies such as tribal belts, isolated regions of the country seem to be less serviced than others, raising concerns about equity issues.[215]

Greater Awareness is Needed   Little information is available regarding the demand for assistive technologies. Many persons with disability depend on assistive devices to enable them to carry out daily activities and participate actively and productively in community life. Training on how to use assistive technology was also linked with accessibility to populations who need the devices. In a visual rehabilitation clinic in New Delhi, the majority of the research participants were aware of only 2 - 3 devices of the 42 assistive technology devices available for their use. Also, only three devices were reported as having moderate utilization. The researchers concluded that to enable maximum use of residual vision with the help of visual based devices, it was important to not only ensure their availability but, also training them in the use of these assistive devices.[216] These sentiments were echoed: "The white cane for visually impaired was available to a large number of people as it was not very expensive but the lack of training on how to use it limited its accessibility."[217]

Similarly, in a review of assistive technology for the elderly in India, Kumar and others (2009) concluded that the elderly were ignorant about the availability of majority of the aids with the exception of certain hearing aids. Though some innovative aids had been developed in recent years like walker for climbing stairs, multipurpose wheelchair, wheelchair that can be converted into crutches, bed rail, etc., they have not been availed by the elderly. Other than the lack of awareness about the aids, the elderly were not very informed on how to procure these devices.[218] Likewise, screen readers such as NonVisual Desktop Access were freely available online, but their awareness and use among the elderly were poor. The other reason for limited use of screen readers could be the non-availability of the readers in the different regional languages. Another aid for the visually impaired i.e. braille is available in major Indian languages however the screen readers are only available in three or so major languages. The lack of such nuanced features that make it more acceptable among the Indian population is a challenge that needs to be addressed.[219]

It is also important to address demand side barriers to improve the gaps in access to and use of assistive technology.[220] Other important barriers are lack of funding for aids and devices; high cost of devices; and lack of distribution networks that makes it difficult to access assistive technology devices. Since assistive technology falls between the purview of both - state and centre, this complicates the scaling up of industries operating in the assistive technology space.[221] This affects

the pricing of the devices which eventually affects the accessibility. As a result, persons with disability have to fall back on inefficient technology provided through the ADIP scheme due to high costs of devices that are available in the private market.[222] Other problems relate to financing of sustainable services such as transportation, accessible architecture, communication, development of standards for goods and services, etc.[223]

Debates and Discussions   Assistive technology is a much-neglected area and has sparked debates on whether India needs to develop 'appliance' or 'tools'. The appliance vs tool debate refer to the need to use common-use devices (appliances) as the means to achieve the purpose rather than highly customised devices (tools) which require a great deal of learning on the part of the person with disability in order to reap benefits.[224] A solution to this may be provided by designing three kinds of assistive technology devices. "Firstly, products which are exclusively designed for the blind; second are products and appliances that can be put to alternative use in order to facilitate visually impaired people; and the third is the type of products will can be used by everybody, such as smart phones." This refers to the universal design principle in which a product or service is designed in such a way that it is equally usable by persons with disabilities as well as persons without disabilities.[225] This will help eliminate the need to create multiple products or services to cater to the same requirement of people belonging to different categories. This is highly useful in not only creating accessible systems, but also curtailing expenses and reducing redundant efforts. Respondents mentioned the need for customizable designs that can be mass produced.

Cause for Optimism   The growing focus on assistive technology has also led to greater optimism about the future of disability. While talking about the changing ecosystem, an expert remarked "I wouldn't have said this 20 years ago. But now I tend to believe that there would be a day when assistive technology would make a totally blind person, not feel that he's lost his sight, you know. So, I think that's the potential that assistive technology can provide and that is beginning to happen …".[226] People with disability have also devised simple to use solutions to their everyday needs. For example, one lady who needs to direct the rickshaw in which she travels to her gate, has fixed a doorbell onto the gate. When she feels that she is close to home, she presses the remote until within the distance in which the doorbell can pick up the signal. In this way, she can get the auto-rickshaw to take her to her doorstep. These are ingenious ways of using technology, not designed for the blind, but blind people are using.[227]

Even though assistive technology have created a positive impact on the lives of persons with disabilities, the lack of access to it not only affects the lives of the concerned persons with disability, but also their family and society-at-large. Without appropriate assistive technology and device, the persons with disability are isolated and segregated from every sphere of life. Furthermore, they regularly encounter stigma, discrimination and inequalities. Therefore, to enable persons with disability to fulfil their potential in a more inclusive and enabling society, the first step is to ensure their access to assistive technology and devices and all forms of required rehabilitation services.[228] A key factor in the use of assistive technologies is the motivation to use them based on perceived utility and need and the awareness on availability.[229]

Collaboration between the government and NGOs is essential to reach large numbers. Using the public health sector as a delivery mechanism helps to "ensure last mile reach because in many cases, the lack of market penetration is the only reason that the numbers of people who have not been

served with these assistive devices is huge."[230] Despite the prospect of using the government systems to deliver solutions, many reiterated that systems would need to be upgraded if new and upcoming technology were to be distributed to persons with disability through this channel.[231] An example came from IIT Delhi which has developed a Smart Cane. The device is considered very successful, but has reached only 70,000 of a potential 5 million users in India.[232]

KEY TAKEAWAYS

- Data does not provide the full picture of disability in the country. Available figures are widely accepted to be an underestimate of the problem and are challenged.

- Data on distribution of disability across geographies and income is lacking as is data on nature and extent of disability. Disability in India is expected to grow sharply due to rising longevity, non-communicable disease and injuries.

- A commensurate rising requirement for assistive technology devices is expected. Further, one expert notes the lack of information on the wants and needs of the persons with disability, making resource allocation likely to be disproportionate to demand.

- India's law and policy framework is quite robust, marking the country's desire to address the needs of those with disability. However critical areas remain to be addressed, notably an assistive technology Act and standards for assistive technology devices.

- There is a network of government institutions in place. In 2015, the Centre for Assistive Technology and Innovation was set up and the Accessible India campaign launched. Government-run ALIMCO provides the bulk of the assistive technology devices in India.

- Several non government organizations work to generate and aggregate demand for assistive technology in India. Nonetheless there needs to be much more attention to creating widespread awareness of assistive technology and its benefits among the populace.

- There are several initiatives and start-ups in the assistive technology space. But the laboratory to market linkages are weak and often fail the developer.

- Some venture capitalists are beginning to appear in the environment – but more and better studies could help define the contours of the market. Several policy changes are likely to be required to make the market attractive to serious investors.

End Notes

[106] Awasthi, A., Pandey, C. M., Dubey, M. & Rastogi, S. (2017). Trends, prospects and deprivation index of disability in India: Evidences from census 2001 and 2011. Disability and Health Journal, 10(2), 247–256.

[107] World Health Organisation and The World Bank. (2011) World Report on Disability. Factsheet. Accessed at https://www.who.int/disabilities/world_report/2011/factsheet.pdf?ua=1

[108] KII_12

[109] KII_12

[110] KII_11

[111] National Health Portal of India. (2017). Accessed at https://www.nhp.gov.in/disease/non-communicable-disease/disabilities

[112] Institute for Health Metrics and Evaluation. (2019). Accessed at http://www.healthdata.org/india

[113] KII_06

[114] KII_10

[115] KII_01

[116] KII_11

[117] KII_03

[118] De Witte, L., Steel, E., Gupta, S., Delgado Ramos, V. & Roentgen, U. (2018). Assistive technology provision: towards an international framework for assuring availability and accessibility of affordable high-quality assistive technology, Disability and Rehabilitation: Assistive Technology.

[119] Guiding Principles of the Convention. n.d. UN DESA. Accessed at https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/guiding-principles-of-the-convention.html on 09 December 2019.

[120] Borg, J., Lindstrom, A. & Larsson, S. (2011). Assistive technology in developing countries: a review from the perspective of the Convention on the Rights of Persons with Disabilities. Prosthetics and Orthotics International.

[121] World Health Organisation and The World Bank. (2011) World Report on Disability. Factsheet. Accessed at https://www.who.int/disabilities/world_report/2011/factsheet.pdf?ua=1

[122] World Health Organisation. (2010). Assistive devices/technologies. Geneva: World Health Organization.

[123] World Health Organization & The World Bank. (2011). World Report on Disability. Geneva: World Health Organization. Accessed at http://www.who.int/disabilities/world_report/2011/report.pdf.

[124] Inclusiveness and Accessibility Index: A Toolkit for Organisations to promote Inclusiveness of Persons with Disabilities. Ministry of Social Justice and Empowerment, Government of India accessed at http://disabilityaffairs.gov.in/upload/uploadfiles/files/Inlcusiveness%20and%20Accessibility%20Toolkit.pdf

[125] Scheme of Assistance to Disabled Persons for Purchase/Fitting of Aids/Appliances (ADIP SCHEME). Ministry of Social Justice and Empowerment, Government of India accessed at http://disabilityaffairs.gov.in/upload/uploadfiles/files/sipda/adiprevised010414.pdf

[126] 61st Report of the Standing Committee on Social Justice and Empowerment (2017-18). (2018). Review of the Functioning of Artificial Limbs Manufacturing Corporation of India accessed at http://164.100.47.193/lsscommittee/Social%20Justice%20&%20Empowerment/16_Social_Justice_And_Empowerment_61.pdf

[127] Evaluation study on the ADIP Scheme. (2013). Programme Evaluation Organisation, Government of India accessed at http://planningcommission.gov.in/reports/peoreport/peo/eva_adip1501.pdf

[128] KII_03

[129] KII_09

[130] KII_03

[131] KII_08

[132] KII_04

[133] KII_03

[134] Disability Affairs, Department of Empowerment for Persons with Disabilities. (2018). Setting up of District Disability Rehabilitation Centre in the Identified Districts. Accessed at http://disabilityaffairs.gov.in/upload/5dcd19cf509e9RevisedDDRCScheme.pdf

[135] KII_12

[136] KII_03

[137] KII_03

[138] KII_05

[139] KII_08

[140] KII_13

[141] The Economic Times. (2018). Accessible India Campaign: No good response from States to make websites accessible to differently-abled. Accessed at https://economictimes.indiatimes.com/news/politics-and-nation/accessible-india-campaign-no-good-response-from-states-to-make-websites-accessible-to-differently-abled/articleshow/62577894.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

[142] Centre for Assistive Technology and Innovation at National Institute of Speech & Hearing. http://www.nish.ac.in/cati

[143] Swavlamban, Directory of Aids and Assistive Devices, Dept. of Empowerment of Persons with Disabilities, Ministry of Social Justice and Empowerment http://swavlamban.info/index.php/en/#

[144] KII_13

[145] KII_01

[146] KII_03

[147] Kerala Social Security Mission, Government of Kerala. Accessed at: http://www.socialsecuritymission.gov.in/schemes.php

[148] Unique Disability ID, Ministry of Social Justice and Empowerment. Accessed at: http://www.swavlambancard.gov.in/schemes/search

[149] National Conference on Assistive Technology for All 2030. Mobility India, Bangalore. Accessed at https://mobility-india.org/national-conference/

[150] KII_02

[151] More detail available at www.alimco.in

[152] KII_04

[153] KII_07

[154] KII_12

[155] Zipfel, E., Cooper, R. A., Pearlman, J., Cooper, R. & Mccartney, M. (2007). New design and development of a manual wheelchair for India. Disability and Rehabilitation, 29(11-12), 949–962.

[156] KII_04

[157] KII_07

[158] KII_05

[159] KII_04

[160] KII_02

[161] KII_01

[162] KII_13

[163] KII_05

[164] Bapat, G. & Sujatha, S. (2019). Identification and analysis of Knee-Ankle-Foot orthosis design requirements based on a feedback survey of orthosis users in India. Disability and Rehabilitation - Assistive Technology.

[165] Jhangiani, I. (2006). Usability and accessibility issues in the localization of assistive technology. Proceedings of the 8th International ACM SIGACCESS Conference on Computers and Accessibility - Assets '06, 299–300

[166] Jhangiani, I. (2006). Usability and accessibility issues in the localization of assistive technology. Proceedings of the 8th International ACM SIGACCESS Conference on Computers and Accessibility - Assets '06, 299–300

[167] Matter, R., Harniss, M., Oderud, T., Borg, J. & Eide, A. H. (2016). Assistive technology in resource-limited environments: a scoping review. Disability and Rehabilitation: Assistive Technology, 12(2), 105–114.

[168] Sharma, G. & Kumar, S. (2014). Assistive Technologies for people with disabilities in National Capital Region Libraries of India. Library Philosophy and Practice.

[169] Sampath, H., Sivaswamy, J. & Indurkhya, B. (2010). Assistive systems for children with dyslexia and autism. ACM SIGACCESS Accessibility and Computing No. 96.

[170] Nagavalli, T. & Juliet, P. (2016). Technology for Dyscalculic Children. SSCE. Salem. Artificial Limbs Manufacturing Corporation of India (ALIMCO). www.alimco.in

[171] KII_12

[172] KII_09

[173] KII_10

[174] KII_06

[175] KII_01

[176] KII_04

[177] Kirby, R. L., Kirby, R. L. & Cooper, R. A. (2007). Applicability of the Wheelchair Skills Program to the Indian context. Disability and Rehabilitation, 29(11-12), 969–972.)

[178] Maurya, C.M., Maurya, N. & Das, A.K. (2019). Awareness, Availability and Accessibility of Assistive Technologies for the Elderly in India: A Review. Springer Nature Singapore Pte Ltd

[179] Megalingam, R.K., Unnikrishnan, D.K.M., Radhakrishnan, V. & Jacob D.C. (2012): HOPE: an electronic gadget for home bound patients and elders. In: 2012 Annual IEEE India Conference (INDICON).

[180] Mohan Kumar R., Lohit, H. S. & Ranjan Mishra, M. (2012). Design of Multipurpose Wheel Chair for Physically Challenged and Elder People. in SAS TECH. 2012. Volume 11, Issue 1.

[181] Maurya, C.M., Maurya, N. & Das, A.K. (2019). Awareness, Availability and Accessibility of Assistive Technologies for the Elderly in India: A Review. Springer Nature Singapore Pte Ltd

[182] Sarkar, S., & Das, A.K. (2017). Design modularity in the assistive devices for elderly people. In: Chakrabarty, A., Chakrabarty, D. (eds.) Research into Design for Communities, vol. 1, ICoRD 2017, Smart Innovation, System and Technologies.

[183] Sujatha, S., Bapat, G. M. & Dash, S. S. (2019). GRID: a model for the development of assistive devices in developing countries. Disability and Rehabilitation: Assistive Technology

[184] Sarkar, R. (2018). Supporting participation and inclusion of individuals with Disabilities through Assistive Technology. Research Review International Journal of Multidisciplinary

[185] KII_06

[186] KII_04

[187] KII_05

[188] Kumar, K. S., Tejswi, A. & Tejswi, S. (2010). Patent Laws and Research Exemption Imperatives – Do Scientists Have Enough Freedom to Operate? Current Science, vol. 99, no. 11.

[189] Sundar, S. (2018). Bridging Multiple gaps: Strengthening India's research Protocols for Assistive Aids. The Hindu Centre for Politics and Public Policy.

[190] KII_04

[191] KII_12

[192] KII_05

[193] KII_02

[194] KII_05

[195] KII_01

[196] KII_08

[197] KII_06

[198] KII_05

[199] Verma, D., Dash, P., Bhaskar, S., Pal, R.P., Jain, K. & Srivastava, R.P. (2016). Disabled Persons in India: A Statistical Profile. Ministry of Statistics and Programme, Government of India.

[200] KII_01

[201] KII_04

[202] KII_02

[203] KII_08

[204] KII_01

[205] KII_07

[206] KII_13

[207] KII_13

[208] KII_04

[209] KII_04

[210] KII_10

[211] KII_04

[212] KII_02

[213] KII_07

[214] KII_01

[215] KII_07

[216] Senjam, S.S., Foster,S., Bascaran, C. & Vashist, P. (2019). Awareness, utilization and barriers in accessing assistive technology among young patients attending a low vision rehabilitation clinic of a tertiary eye care centre in Delhi. Indian Journal of Opthalmology.

[217] KII_01

[218] Maurya, C.M., Maurya, N. & Das, A.K. (2019). Awareness, Availability and Accessibility of Assistive Technologies for the Elderly in India: A Review. Springer Nature Singapore Pte Ltd.

[219] KII_01

[220] Tangcharoensathien, V. et. al. (2018). Improving access to assistive technologies: challenges and solutions in low- and middle-income countries. International Health Policy Program, Ministry of Public Health, Thailand.

[221] KII_09

[222] World Health Organization. 2011. World Report on Disability, pg. 63. [http://www.who.int/disabilities/world_report/2011/report.pdf?ua=1].

[223] World Health Organization. 2011. World Report on Disability. [http://www.who.int/disabilities/world_report/2011/accessible_en.pdf].

[224] KII_04

[225] KII_01

[226] KII_10

[227] KII_10

[228] Sarkar, R. (2018). Supporting participation and inclusion of individuals with Disabilities through Assistive Technology. Research Review International Journal of Multidisciplinary.

[229] KII_10

[230] KII_04

[231] KII_02

[232] KII_01

Chapter IV
CONCLUSION & RECOMMENDATIONS

Assistive technology enables persons to undertake activities that they could not otherwise carry out to their own satisfaction, thus improving their functioning and independence, and enhancing their overall sense of wellbeing. It helps persons with disability to overcome that, which hinders their fullest enjoyment of life. Assistive technology devices can range from simple, as in walking canes, to complex, as in speech aids. Access to assistive technology serves as the gateway to education, employment, social inclusion and other opportunities to participate in civic life.

This rapid review was undertaken to meet three objectives in the context of assistive technology in India:

1. Understand research gaps
2. Outline the ecosystem of assistive technology
3. Discuss how a Centre of Excellence could support an effective response

In this chapter, we provide a summarisation of the findings of our review of the literature and mapping of the ecosystem of assistive technology in India. The chapter then discusses the implications of these findings in the context of setting up of a Centre for Excellence by the Government of India.

Research Gaps

Need for Assistive Technology   The prevalence of disability is growing rapidly. Among the major causes are injury due to conflict or accident, ageing and chronic non communicable diseases. These are expected to increase exponentially in the years ahead, making a response to disability an immediate concern. But robust size data on the need for assistive technology in the world is lacking. It is not known how many people require assistive technology devices worldwide; modest estimates suggest that in 10 years' time more than 2 billion persons worldwide will require assistive technology. Nor is data available on unmet need for devices, but the most common understanding is that only 10% have access to them.

Availability of Research Studies   Research on assistive technology in India is inadequate, albeit not entirely absent. Small scale research is available – most studies are with a small number of participants or descriptions of the development process of a certain technology. Many of the studies are carried out by researchers in countries other than India, or as collaborations between foreign and Indian researchers. Robust research on the demand for rehabilitative and palliative services involving assistive technology has not been undertaken. Global generalisations indicate that over 90% of demand may remain unmet – with the expected increase in numbers due to increasing longevity and non communicable diseases in India, this may expand further.

The HAAT Framework   The Human Activity Assistive Technology or HAAT framework provides a useful way to classify studies for the review. Its use allows insights into the extent and nature of evidence base available on assistive technologies. The HAAT framework pays attention to four aspects of assistive technology: (i) the physical, social, cultural and economic context in which it is sought to be used (ii) the nature of activities for which it is intended to be used; (iii) the human factors that enable its use; and finally, (iv) the engineering aspects of the assistive technology.

Context in Disability   Local cultural practices are often the key in determining the requirement and readiness to use assistive technology. The context in which persons with disability live and operate has rarely been researched with a perspective to assistive technology. Typically, studies that discuss the context in which people live and wish to use assistive technology in have been carried out as an adjunct study to the development of a particular aid or device rather than to develop its own understanding. Most of the studies that have been accessed, relate to mobility and visual impairment with several others relating to modification of mobility devices for the elderly. New devices are available that can distinguish between a selection of footwear by the blind, eliminating the need to touch them and to train persons newly fitted with hearing aids. Other studies take an ethnographic approach and discuss the widely different experiences of families with children with autism in different parts of the country. Studies suggest that there is need to explore human agency in adoption of mainstream devices such as smartphones to overcome disability. Likewise, a functional perspective of mobility needs of women indicates that a comprehensive understanding of context is required to respond to these needs. Institutional responses from government would go a long way in ensuring that entrepreneurship among those with disability to solve their poverty is urgently needed.

Activity as a Component of the HAAT Framework   A key feature of the HAAT framework is that it shines a spotlight on the activity for which a particular assistive technology device is being used. Studies accessed related primarily to assistive technology devices that aid in education or employment. However, little attention has been paid to other aspects of a person's life such as everyday living, leisure and recreation, participation in social life, etc. Education in particular is an area of concentration. Many studies discuss the availability of braille and audio books. Several obstacles contribute to difficulties in providing assistive technology to students with disability, ranging from limited government support to insufficient teachers. Increasing longevity has meant a growing population of persons with disability. A major concern among this group is to increase, or at the very least, to maintain social participation through assistive technology. Studies have highlighted the relationship between disability and earning capacity. A study in the context of blindness for example, discusses the correlation between employment and assistive technology. Wheelchairs are one of the most iconic forms of assistive technology, but even these have limited distribution among those who need them. In the context of sports, these are even more difficult to come by. AAC devices have been used in autism to improve communication. Yet, it must be said that there is a rising awareness about assistive technology devices among the population of potential users.

Human Factors   The ability and interest of potential users in adopting assistive technology is an important prerequisite to its eventual use. Very little is available on the human factors which may modify the use of assistive technology devices, particularly, ability to pick up new skills and motivation for use. Universal and inclusive design is an attribute that supports the development of skills easily. Approaches such as Computer Assisted Instructions, Touch technology etc. have been

used to address physical and developmental challenges. Once taken up however, not all technology continues to be used. One observation from India is that environmental factors may reduce the eventual utilization of wheelchairs that have been received by persons with mobility challenges. Some have promoted person-centred methodologies which leverage aspiration to improve uptake. Older people may show greater reluctance to try and later adopt assistive technology. But studies have shown that those who do adopt them demonstrate improved social participation. Early adoption of screen readers for example, could be the result of several factors. For older populations, everyday technology such as lifts, staircase climbers etc. may play an important role in adoption. *Engineering Solutions* Not all assistive technology requires sophisticated engineering. A useful way to classify assistive technology is as follows: (i) No-Tech: adaptation of behaviour or method to communicate; (ii) Low-Tech: easy to use options of low cost, and typically do not use a power source; (iii) Med-Tech: easy to operate, powered devices; and (iv) High-Tech: complex and programmable devices that require computers/ electronic to perform a function.

The cognitive profile of the user is an important consideration in engineering design. Similarly, experts often take careful account of the environmental conditions that the engineering must solve for. One example is the ground mobility solution for women with lower extremity disability. Studies discussed in the section range from AutVision; Autinect; automatic translator devices for the Indian sign language; solutions for the elderly; multilingual education and communication tools; and sports wheelchairs. Use of technologies such as HCI, EOG and RFID has yielded practical solutions. One study suggests that in cost sensitive markets, the GRID model can support innovation. Examples include the recently developed standing wheelchair and tactile diagramming devices developed in India. Studies often present only a description linked to the particular device, but few studies are available that discuss engineering aspects for their own sake i.e., pros and cons of various engineering approaches. As a result, a holistic picture of the field is not available and little guidance is available to the researcher or manufacturer seeking to identify areas in which more work could be done.

An Ecosystem Outline

The Role of Government India has been an early signatory of the UNCRPD. At home, India has had a law relating to disability in place since 1995, which was recently revised and replaced in 2016. Several other Acts of Parliament such as the National Trust Act, the Rehabilitation Council of India Act etc. have helped to develop systems to respond to the needs of those with disability. A separate department has been designated under the Ministry of Social Justice and Empowerment – the Department for Empowerment of persons with Disability. The Centre for Assistive Technology and Innovation has been established in 2015 at the National Institute for Speech and Hearing in Kerala.

There is a network of national institutes, digitization of disability certification has taken place, the National Innovation Fund has recognised and awarded innovators in the space etc. Many schemes such as ADIP are available to those with disability – facilitatory information is available from Punarbhava, Swavlamban etc. websites that have been put in place. Several schemes are of many years' standing, and argument may be made about whether or not the support that they provide is sufficient or needs to be updated. An important national resource centre is ALIMCO, responsible for the bulk of production and distribution of assistive technology in India, producing over 350 different kinds of aids and appliances. ALIMCO's motto is to stay simple and distribute widely. But questions

are raised about the suitability and sturdiness of its aids and appliances. There are few developers or producers in the private sector except in niche areas such as spectacles, wheelchairs, walking canes etc.

India does not have an assistive technology Act, nor are standards for assistive technology devices in place. With disability expected to grow rapidly in coming years, there is need to bring the Ministry of Social Justice and Empowerment closer to the Ministry of Health and Family Welfare. It is generally accepted that much more remains to be done to ensure that all policy tools are brought to bear on the issue.

Private Sector Response   There are a number of non-government organisations that are seeking to plug the gaps in the government response. Some support networks of persons with various forms of disability; others seek to create assistive technology devices that can solve for the problems faced by persons with these challenges. There are a few for-profit players in the assistive technology market. Even the most successful present-day devices distributed through the government have had limited market penetration. Most agree that the market is fragmented and needs are very diverse.   In addition, disability often results in lower income. Thus the demand for assistive technology and purchasing power of persons with disability do not support a for-profit response.

All agree that steps must be taken for the development, advancement and adaptation of assistive technology keeping in mind the needs of the Indian context, in particular affordability. There is lack of awareness among designers, architects, technologists, engineers, industry, and service providers making the development of new technology for persons with disability sluggish. The supply chain is weak and there is a paucity of rehabilitative programmes which incorporate assistive technology solutions. Legal concerns that add to cost and distribution need to become widely known and appreciated. Experts also point to the need for the government to keep pace with and procure new technology entering the market for distribution. A few venture funds have begun investment in this space - the effect of this newly available capital is yet to be felt.

Challenges to Accessibility and Last Mile Reach   Several challenges remain to be addressed. In order to make assistive technology accessible, there needs to be greater awareness among persons with disability and their caregivers. Information regarding aids and their utility, source of availability, cost, operating cost, support services etc. must be pushed. For this, a better understanding must be developed regarding the size and nature of the problem. In order to help researchers and manufacturers better respond to the need, the context in which the assistive technology must operate, the activities for which it is required and the skills and abilities of its users should be the subject of studies, along with studies on accessibility, affordability and inclusivity of devices. With the context in India being as diverse as it is, this is no mean task – devices are needed for both the 'new India' as well as the old, if market penetration is a desirable goal. Present day drop out rates from assistive technology that has been adopted, is reportedly as high as 80% – studies are required to understand why this is so and what can be done to correct the situation.

Key Debates and Discussions   The role of government as an enabler of solutions rather than purveyor must be fully explored. A key debate that has important implications in the India context is the appliance *vs* tool debate given its present situation and expected rapidly increasing need. Does India need tools that are built-from-scratch, custom-designed and require significant training for the user to be able to use it effectively? Or should the focus be on producing appliances that are built

on existing technological platforms, easy to adopt and require minimal or no training for use? Should India adopt an either-or policy or assign some expectation of distribution of research and development on either side of this debate?

Implications for a Centre of Excellence

The research gaps and current ecosystem of assistive technology in India that have been summarised above provide learning for a potential Centre of Excellence. They point clearly to recognition that the field of assistive technology in India has so far been scantily charted, and much remains to be done to develop a considered response. The main implications for a Centre of Excellence are captured below:

1.   There are several reasons why a structured response to disability in India is difficult to construct. To begin with, the extent and contours of the problem have not been fully understood. Data on disability in India is both limited and questioned. The two largest datasets describing disability in the country are not consonant and hence robust comparisons cannot be drawn or lessons taken away. Further, extrapolations as to the likely size of the problem in the foreseeable future have not been carried out. Finally, data on the nature and extent of disability is lacking. Distribution of the problem also needs to be better understood – what is the nature of the disability, in which geographies and in which income groups. A Centre of Excellence could address these data gaps.

2.   Data is also required to develop the aids and appliances required for the populations affected by disability. The HAAT framework provides a useful way in which to approach the problem. A key area of understanding is the activities for which the tools are required. At this point in India's response to the problem, it may well be that a careful prioritization is required so that the most urgent needs are addressed. Better understanding is also required of the abilities and motivation of those with disability, both across age and across cultures. More needs to be known about the context in which the assistive technology is expected to be used – both physical and sociocultural; as well as the institutional context in which it is sought to be delivered. Finally, engineering considerations need to be applied and discussed, both in the context of development of technology, but also in of themselves; so the science that would be useful in development of assistive technology, needs to be both basic and applied. These areas could form the basis for the organising the departments of the Centre for Excellence.

3.   India has a good track record of putting disability-sensitive laws in place and is compliant with international conventions. A Centre for Assistive Technology and Innovation was established in 2015 in Kerala. Many policies have also been put in place although whether they have been fully implemented could be challenged. Owing to the poor income profile of persons with disability, realistic subsidies for modern-day assistive technology devices need to be put in place. In particular, experts point to the absence of an assistive technology Act and standards for assistive technology. Also of concern is the lack of formal mechanisms for coordination between Ministry of Social Justice and Empowerment and the Ministry of Health and Family Welfare, both important in the formulation of appropriate policy tools for assistive technology. Studies that support these areas of policy consideration for the Government would be another area that the Centre of Excellence could address.

4.   Laboratory to market connections remain weak, despite the emergence of green shoots with respect to assistive technology in India. Platforms for discussion and networking are sorely needed so that ideas can be exchanged and business partnerships can be fostered. There are vexed legal issues with respect to software use that need to be explored and understood better. Likewise, financial solutions to support a burgeoning manufacturing industry must be considered for a fuller response to the disability problem in India. Better understanding of geography and income distribution would also permit formulation of policies and options that support accessibility and last mile reach. The Centre of Excellence would be the appropriate institution to carry out studies relating to market realities; policy making that supports better laboratory-market linkages and ensures wider and more accessible distribution of assistive technology devices.

5.   It cannot be stressed enough that India is presently on the cusp of a new epidemiological profile of her population. The emergence of non communicable disease as a major feature affecting India's population, the rising graph of injuries related to traffic and other activities, and the increasing longevity of her people are adding to the expanding requirement for a strong and considered disability response. There is need for many more studies to support this need, both to develop and manufacture assistive technology devices as well as to put suitable policies in place. Key debates and discussions need to be had so that a clear path can be charted. A key input that the Centre of Excellence could provide is to develop clear forecasts of the need for assistive technology among various subsections of India's population. Further, the Centre could also commission studies that consider the debates that inform the development of assistive technology devices in India with a view to advising government on the appropriate approach at this time. This would help lead the way to in distributing assistive technology devices effectively.

In Conclusion

A strong push to develop India's work on assistive technology is urgently required to ensure that the needs of a growing complement of persons with disability are met and productivity of India's work force is continued. Most experts would agree that the numbers of those with disability are likely to be much higher than is presently known. There is an expected rapid increase in the conditions that result in disability. Add to this the underlying context of India – a country with low per capita income and where demand for health services outstrips its delivery. It is clear that better information is required and policies put in place that strongly encourage market players to participate in this sector. In order for the assistive technology market to function, and function efficiently, all parts of it – basic and applied research, knowledge translation, manufacturing and marketing must be well connected through a common platform. The present lack of linkage between key actors in the space must to be addressed so that efficiencies can be achieved.

With a large number of engineering institutions, a vibrant research community, innovative manufacturing capabilities and a government committed to improvements, India has the wherewithal to make this happen.

Annexure I

#	Respondents	Organization
1	Akila Surendran	Centre for Assistive Technology & Innovation, NISH, Trivandrum
2	Albina Shankar	Mobility India, New Delhi
3	Anil Joshi	IBM, Gurugram
4	Anil Prabhakar	Indian Institute of Technology, Chennai
5	DR Sarin	Artificial Limbs Manufacturing Corporation of India
6	George Abraham	The Score Foundation, New Delhi
7	K.G. Satheesh	Centre for Assistive Technology & Innovation, NISH, Trivandrum
8	M Balakrishnan	AssisTech, IIT Delhi
9	Mukesh Doshi	Indian Association of Assistive Technologists
10	Nikunja K. Sundaray	The National Trust
11	Prateek Madhav	Assistive Technology Accelerator, Bangalore
12	Ram Kumar	National Institute for the Empowerment of Persons with Intellectual Disabilities, Noida
13	Shankar Subbiah	Agate Infotek Private Limited, Chennai
14	SK Tripathi	Artificial Limbs Manufacturing Corporation of India
15	Sujatha Srinivasan	Rehabilitation Research and Device Development Lab, IIT Madras

Annexure II

Relevant Publications

McDonald, R. Thomacos, N. & Inglis, K. (2013). Review of current and emerging assistive technologies for the reduction of care attendant hours: cost effectiveness, decision making tools and emerging practices. MONASH University: Medicine, Nursing and Health Sciences & Institute for Safety, Compensation and Recovery Research.

Peterson-Karlan, G. R & Parette, H. P. (2007). Evidence-Based Practice and the Consideration of Assistive Technology Effectiveness and Outcomes. Illinois State University

Smith, R. O. (2016). The Emergence and Emergency of Assistive Technology Outcomes Research Methodology. Department of Occupational Science & Technology, College of Health Sciences & Rehabilitation Research Design & Disability Centre, University of Wisconsin-Milwaukee.

Online Resources

Devex is a media platform for the global development community. It is also one of the largest provider of recruiting and business development services for global development

Newz Hook is an accessible news channel with a focus on disability related news. The website is accessible to visually impaired screen reader users promoting sign language news for deaf.

Punarbhava website is an attempt to provide consolidated information, discuss issues, network, find employment, list of availabe appliances and tools, seek redressal of grievances, undergo training, research and study etc.

Incubators in Assistive Technology in India

ARTILAB Foundation is a young and dynamic social sector organisation dedicated towards fostering accessible innovation in the disability sector.

Assistive Technology Accelerator is an incubator created with a vision to improve the lives of disabled people by creating an ecosystem that can help assistive technology start-ups to scale up

SocialAlpha is a non-profit start-up incubator funded by Tata Trusts offering a fellowship program for aspiring entrepreneurs in the development sector.

Government Interventions

Disability Related Technology, Products and Issues by Department for empowerment of Persons with Disabilities, Ministry of Social Justice and Empowerment programme is expected to create holistic development of the individuals and their families and create an enabling environment for the empowerment of the persons with disabilities.

[Scheme of Assistance to Disabled Persons for Purchase / Fitting of Aids and Appliances](#) (ADIP) will assist the needy disabled persons in procuring durable, sophisticated and scientifically manufactured, modern, standard aids and appliances to promote physical, social and psychological rehabilitation of persons with disability by reducing the effects the disabilities and at the same time enhance their economic potential.

[Scheme of Financing Assistive Devices to Enhance the Employability or Increased Opportunity of Self Employment of Persons with Disability](#) by National Handicapped Finance and Development Corporation will assist the needy disabled persons in procuring aids and appliances by providing concessional loans.

[Scheme of Sports & Games for the Disabled](#) is a Central Sector Scheme being introduced by the Ministry of Youth Affairs & Sports in 2009-10 during the XI Plan Period. The objective of the Scheme is broad-basing participative sports among the disabled.

[Scheme for Trans-Disciplinary Research for India's Developing Economy](#) (STRIDE) by University Grants Commission, Ministry of Human Resource Development will strengthen research culture and innovation in higher education institutions for socially relevant, locally need-based, nationally important and globally significant projects.

[Technology Interventions for Disabled and Elderly](#) (TiDE) by Department of Science and Technology is a programme to promote research and development of Assistive Technology for empowerment of elderly population and divyangjan in India. TIDE Programme provides Grant-in-Aid support to Knowledge Institutions, recognized R&D Labs and S&T based Voluntary Organizations for design and development of Assistive Devices, Processes and Protocols for improved Autonomy, Quality of Life and Social Inclusion of target beneficiaries

Key Initiatives and Programmes in Assistive Technology

[Agate Infotek](#) works in the space of assistive technology to create accessibility for children and adults with special needs by creating awareness to assistive tools adaptive devices, methods, software, accessible opportunities available.

[Anushruti Academy for Deaf](#) (AAD) is a social initiative of the Indian Institute of Technology, Roorkee. The school delivers quality education to differently able children with speech and hearing impairments in Uttarakhand.

[Artificial Limbs Manufacturing Corporation of India (ALIMCO)](#) is a central government Public Sector Enterprise with the objective of benefiting persons with disability by manufacturing rehabilitation aids and by promoting, encouraging and developing the availability, use, supply and distribution of artificial limbs and other rehabilitation aids to the disabled persons of the country.

[AssisTech](#) is an inter-disciplinary group of faculty, researchers and students from Indian Institute of Technology, Delhi engaged in using modern technology for finding affordable solutions for persons with disability in India.

[Centre for Disability Sports](#) will be set up at Gwalior in Madhya Pradesh. The proposal regarding setting up of it has been approved by the Government. The objective of the Centre is to ensure

effective participation of Persons with Disabilities in sports activities and enable them to compete in different sporting events at national and international level.

Embright Infotech works to create technology for Autism care and contextual and immersive learning.

Enable Makeathon (EMx) is a programme for fostering research to product happening in Assistive Technology with evidence based problem statement collected, analysed and products developed. EMx works with start-ups and innovators to design, prototype, test the assistive technology product and take their product to the market.

Enability Foundation for Rehabilitation is a not for profit company that focuses on delivering assistive technology solutions catering to the activities of education, communication, mobility, daily living, leisure and employment to the marginalized and disadvantaged sections of society.

Human Factors and Sociotechnical Systems Studios (HFSS Studios) at IDC School of Design, IIT Bombay, aims to incorporate the human as a system component without making it mechanistic in nature.

Indian Association of Assistive Technologists (IAAT) is an independent, non-political, not-for-profit member association of rehabilitation (health) professionals and providers of assistive devices and/or services to people with disabilities and elderly people to live independently.

IBM India Research works towards inventing technology that is more human, empathetic and adaptive to everyone's age and ability. The accessibility checklist includes techniques and guidance covering software, documentation and web content.

Mobility India's vision of an empowered and inclusive community, points to a future in which there is greater equity and neglected sections specifically people with disabilities, elderly population and other disadvantaged groups are part of the development process.

National Institute for the Empowerment of Persons with Intellectual Disability (NIEPID) is an autonomous body under the administrative control of Department of Empowerment of Persons with Disabilities. NIEPID is dedicated to provide quality services to persons with intellectual disability.

National Institute of Speech and Hearing (NISH) is an autonomous organization registered as a society by the Social Justice Department, Government of Kerala. NISH is a comprehensive multi-purpose institute focusing on the identification, intervention, rehabilitation and education of individuals with disabilities

Score Foundation was step up with the objective to change the mindset of people towards blindness and visual impairment. Score foundation aims to provide equal opportunity, contribution and space for visually impaired.

TTK Center for Rehabilitation Research and Device Development (R2D2) group is involved in research related to human movement, the influence of orthotic and prosthetic devices on human movement, and the design and development of mechanisms, products and assistive devices for people with impairments.

The Centre for Rehabilitation Engineering and Assistive Technology (CREATE) is a multidisciplinary translational research and educational initiative of IIT Madras. It was conceived as we began interacting with NGOs and inclusive schools.

The National Trust is a statutory body of the Ministry of Social Justice and Empowerment, Government of India, set up under the "National Trust for the Welfare of Persons with Autism, Cerebral Palsy, Mental Retardation and Multiple Disabilities' Act.

WORTH Trust produces various assistive devices essential for the education of children with visual disabilities at highly subsidized prices maintaining international quality standards

Leading Assistive Technology in India

Arise is a manual wheelchair with an inbuilt feature that allows the user to independently rise to a standing wheelchair.

Avaz is a picture and text based communication app for children and adults with communication difficulties

BleeTech Innovations offers design and technology solutions for the deaf community. The BleeTV app and BleeTV Library showcases variety of information and learning content in Indian Sign Language

Dubsnub offers audio description services in more than 70 languages through an extensive partner network of audio describers, transcribers and production managers.

Eye-D is working in the field of visual impairment to provide affordable technological solutions with assistance from different groups.

Innovision has launched a multi-language digital braille called Braille Me, designed for the visually impaired with quick access to books, files and notes at affordable prices.

Jellow Communicator is a friendly Augmentative and Alternative Communication (AAC) solution that uses icons to aid communication in people learning to speak or with difficulty with speech and language.

Saarthi Assistive Mobility Device is designed to work both inside and outside helping peope with visual impairment navigate well. Torchit operating in the space of visual impairments aims to provide Indian made mobility devices to the people.

Tactopus is a muti-sensory learning aid for children of ages 3+ with a focus on children with visual, developmental and learning disabilities.

Thinkerbelllabs has come up with the tactile hardware module coupled with soft human voice guiding students. Annie^{TM} is a companion app that enables a student to learn to read, write and type braille on their own.

The seven products of voice and speech systems designed by Vagmionline to cater to the needs of people with voice, speech and hearing deficiencies.