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Research on the Future of Assistive Technology for People with Locomotive Disabilities

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ABSTRACT
Physical impairments may limit or prohibit a person from engaging in many of life's activities. Assistive technologies (ATs) provide essential aids for people with disabilities (PwDs), who would otherwise struggle to participate fully in society without them. This study looks at the history and present state of assistive technologies (ATs) for people with disabilities (PwDs) in India in order to predict how ATs would develop by 2035 and provide some optimism that the gap may be narrowed as much as possible by that year. A survey was utilized to collect primary data, while a search of the patent databases (WIPO, USPTO, and IPINDIA) and an analysis of scholarly articles provided secondary data. Experts from a wide variety of fields (business, academia, government, NGOs, etc.) participated in this Delphi survey. The experts were given a general trend of the advancement of technology over the previous decades to enable them make predictions about the expected time-frame of adoption/commercialization of certain ATs. In this article, we provide the results of a Delphi exercise that identified possible assistive technologies and estimated when they would become available.

INTRODUCTION
Limitations on a person's capacity to take part in or experience anything seen as "normal" in that person's culture are the result of a disability, which may be the result of a physical, cognitive, mental, sensory, emotional, developmental, or any combination of these impairments. A person's impairment might be present from birth or develop at any moment. The United Nations Organization (UNO) defines disability as the interplay between a person's impairment(s), impediment(s), attitudes toward them, and the environment(s) in which they live, all of which work together to prevent them from fully and effectively participating in society on an equal footing with others. According to the UN Report on the "Right of Person with Disability" (2006), these phrases represent a transition away from a medical approach toward a social model of disability.According to the World Health Organization (WHO), the word "disability" encompasses impairments, limits on activities, and restrictions on participation. An impairment is a physical or mental deficiency; an activity limitation is difficulty in performing an activity; and a participation restriction is difficulty in engaging in life activities (Schulze, 2010). The medical model of disability holds that a person who has particular physical, intellectual, psychological, or mental disabilities may adapt to the environment with the help of cures, treatment, and rehabilitation. The social model, which puts the emphasis on the larger community, views disability as the factor that limits the participation and participation of people with impairments.

One of India's top priorities is accommodating people with disabilities. To aid people with disabilities in leading independent and satisfying lives, we must examine all approaches, including the potential of emerging technology, with due diligence and critical thought. In India, people with disabilities are classified into one of eight categories based on the extent to which their impairments prevent them from leading independent lives: those with visual impairments, those with hearing impairments, those with disabilities affecting their ability to move around, those with mental illnesses or mental retardation, and those with multiple impairments.75% of people with disabilities in India reside in rural regions, according the 2011 census. Only 49% of them can read and write, and only 34% have jobs. Figure 1 shows the percentage of people with various types of disabilities, according to the 2011 Census.

There is a continuing need for specialized equipment or technology, known as Assistive Technology, to help these individuals take engage in society and the economy in ways that are meaningful to them. Governments and organizations from across the globe have drafted a wide range of standards and regulations with the goal of enhancing the independence of individuals with disabilities. The United States, Europe, Canada, the World Health Organization, and other organizations were early adopters of reforms that made it possible for people to live and work more freely. As seen in Table 1, many initiatives in India have emerged to better the lives of people with disabilities (Manual on Disability Statistics, 2012).

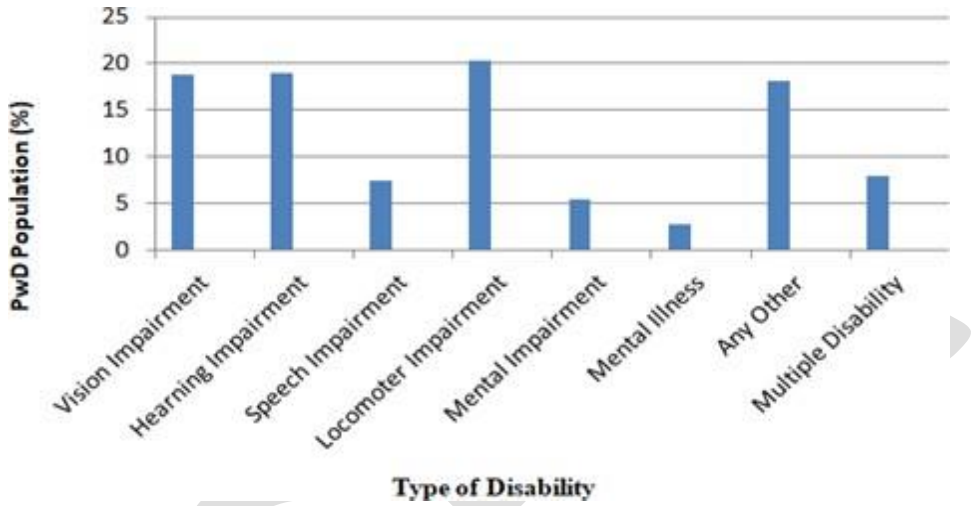

Fig 1: Relative proportion of PwDs as per census India 2011

In this study, we are dealing with locomotor disability, Assistive Technology, Technology Foresight.

Locomotor Disability

Impairment of a person's ability to do certain tasks involving limb movement due to disease or injury to the skeleton, joints, muscles, or nerves. Symptoms such as difficulty walking or paralysis include shaky limb movement, weak muscles, and even amputation.

Assistive Technology (At)

Assistive technology is any tool that may be purchased commercially off the market, adapted, or developed to help a person with a disability live as independently as possible. However, it does not include a surgically implanted medical device or a replacement for one (Georgia Department of Education, 2007). More precisely AT encompasses alternate or adaptable specialized hardware and software, including input and output devices. Low-tech devices like crutches or a special grip for a pen to more advanced devices like hearing aids and glasses to more personalized devices like Braille's and computers with specialized software for assisting dyslexics to read are all examples of Assistive Technologies. As a result, choices on the acquisition and use of AT devices must be preceded by thorough analyses of relevant ethical concerns, as seen from the eyes of the individual with a disability (Wool worth et al., 2006). These ATs have developed throughout time in response to user demand, with advances in technology influencing their features, functions, and overall design. Stakeholders' focus on the future of Assistive Technologies is not surprising.

Technology Foresight (Tf)

In a corporate or managerial setting, the capacity to look into the future and make plans accordingly is referred to as "vision." Technology Using a technique called "foresight," one might anticipate future technical advancements. Producers and consumers of science and technology in the innovation system work together in technological foresight to create a shared vision or set of future scenarios (Martino, 1993).

Technology foresight's overarching goal is to identify the next generation of genetic technologies that will most positively impact society and the economy. Japan has been actively working on future projections since the 1970s.In 1995, it was launched for the very first time in India. Technology foresight, as defined by Ben Martin (UNIDO, 2005), is "a process that involves a systematic attempt to look into the long-term future of science, technology, the economy, and society" with the goal of pinpointing the areas of strategic research and the emergence of generic technologies most likely to yield substantial economic and social benefits.

As we've seen, experts agree that the future of business, the economy, society, and the planet will be profoundly affected by rising technology. The growth of these technologies is very reliant on scientific improvement. The ability to detect developing

technologies at a young age, government and others may concentrate on the key research topics that will provide the quickest and most fruitful results. The purpose of foresight is to anticipate and prepare for future opportunities by spotting promising new technologies at the earliest feasible stage.

LITERATURE REVIEW

One can find foresight studies in almost every sector, identifying technologies that have the potential for commercialization, but very limited number of them on ATs can be found.

Bharucha (2009) identified capabilities and limitations of Assistive Technologies and future challenges, in his study on the application of ATs in dementia care. The paper focuses on a specific group of older American afflicted by Alzheimer disease and the study reveals that dementias will triple to 13 million persons by 2050 suggesting a requirement of greater health care needs. An approach suggested by the study, to this emerging crisis, is the development and deployment of intelligent assistive technologies that compensate for the specific physical and cognitive deficits of older adults with dementia, and thereby also reduce caregiver burden. The authors conducted an extensive search of the computer science, engineering, and medical databases to review intelligent cognitive devices, physiologic and environmental sensors, and advanced integrated sensor networks that may find future applications in dementia care.

Baker & Moon (2010) discussed the barriers faced by people with disabilities and the aging while using wired or wireless information and communication technology. They focused on problems that can be solved by a variety of mechanisms, including legislation and regulations, market-based solutions, and awareness and outreach-based approaches. The article basically discussed policy research conducted by the Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC) using the Delphi polling methodology to probe stakeholders' opinions on key access barrier issues and to explore potential policy responses. Participants included disability advocates, disability and manufacturers. Respondent input informed the subsequent development of potential policy initiatives to increase access to these technologies. The findings from the Delphi suggest that awareness issues remain most important, especially manufacturer awareness ofuser needs and availability of consumer information for selecting the most appropriate wireless devices and services. Technical issues, including interoperability, speech-to-text conversion, and hearing aid compatibility, were also identified by participating stakeholders as important,

Alford & Johnston (2011) conducted the foresight studies to find out the enabling Assistive Technology for aged person. This research identified new and converging enabling bio and Nanotechnologies that may have implications for policy makers and regulators, including industry uptake and international activities that improve the understanding of the potential for enabling technologies to address major global and national problems and to understand and help resolve potential impairments.

Kosman & Casati (2015) in their study aimed at identifying trends and challenges in relation to Physical Wellbeing for Active Healthy Ageing. This foresight exposes future themes with high innovation and business potential. The purpose was to create a common outlook on the future of ICT. This paper concluded that, in the near future, technologies, networked devices, sensors, and communication will play an important role in the physical wellbeing of the elderly population.

An examination of different studies carried out on ATs brings out the fact that most of the research has been focused on older population, learning disabilities or disability in general. No foresight study could be traced specifically on locomotor disabilities, even though it contributes the highest percentage among the disabled. Locomotor impairments may cause due to the large number of physical problems such as poliomyelitis, spinal cord injuries, paralysis, cerebral palsy, muscular dystrophies, arthritis, stroke, accidents, etc., which are the major reason behind this high percentage (21%) of the population with locomotor disability. This study is an attempt to fill the gap and focuses on the foresight of Assistive Technology for locomotor disability

METHODS USED

Literature Search

It is the backbone of any research work. In this study, a literature search has resorted for data collection- basically information on (the past as well as present) technologies. It was done by some background reading of books (like Assistive Technology for Visually Impaired and Blind People, by Hersh & Johnson; Assistive technology: Shaping the Future, Craddock), articles (on the topic like assistive technology, disability, healthy ageing, foresight etc.) and encyclopaedias to get a grasp of the research topic and build a context for the study. Literature survey helped in examining the evolution of ATs for locomotor disability. This, when plotted on atimeline and looked at with the most recent developments, gave an idea of possible ATs of the future. Itdelineates the evolution of different assistive devices and their impact on disabled people.

Horizon Scanning

It is done on technologies, showing up on the global technology landscape and scan-hits shared on TIFAC's Facebook page. Database of scan-hits of the year 2014 and 2015 was used to pick promising technologies. A list of websites has been used from which relevant scan-hits were sourced. In all, 146 assistive technologies were identified and categorized on the basis of following attributes:

- Sector (artificial intelligence, biomedical, nanotechnology, information and communication technology and mechanical)
- Functionality (medical aid, mobility aid, visioning aid, navigation aid, intellectual aid, hearing aid, daily living aid, multiple aids, communication aid, holding aid, reading aids, entertainment aid, writing aids, travelling aid and leisure aid)
- Disability (locomotor disability, visual impairment, hearing impairment, mental illness, mental retardation, multiple disabilities, speech impairment, and any other).

As the focus of this study was on locomotor disability, 50 technologies out of 146 were found to be relevant as ATs for locomotor disability. A thorough study of all 50 technologies suggested that they could be placed on seven distinct technology tracks, viz. Prosthesis, Wheelchair, Exoskeleton, and Bionics, Crutches, Orthotics and Brain implant. Several technologies out of 50 had similarities in terms of their working principle, but were of different manufacturers and were taken as one for this study. Further, the technologies that were basically pharmaceuticals, clinical treatments, diagnosis or technology for regenerating organs were filtered out, as they were not ATs. 21 technologies for locomotor disability remained after the scrutiny.

Patent Search

It was another quicker way to gather information on futuristic technology, given the time constraint for the present study. In this study, international patent databases like WIPO, USPTO and Indian patent database, i.e. IPINDIA were searched to gather some futuristic ATs. Table 2 gives the keywords used for searching the patent databases. Databases for the years 2014 and 2015 were looked into for ATs which are not yet commercialized inIndia but show promise for the disability sector. In all, 4 technologies were identified from this method.

Survey

It was conducted to get insights on future Assistive Technology by 2025. The idea behind the survey was to get an expert's take on futuristic ATs that may have been missed during scanning and a literature search. 150 experts from academia, R&D, industry, government officials, etc. were asked to speculate future ATs for locomotor disability. For better understanding and clarity to the respondents, technology tracks- prosthetic, exoskeleton, wheelchair, wheelchair, bionics, crutches, and braces were spelled out in the questionnaire. The survey did not add any new technology, suggesting that scanning and patent search gave reasonably rich information. A Delphi exercise was conducted on 29 technologies (collected from scanning, patent search and four speculated by the intern) to get the convergent opinion of the panellists on likely time-frame of adoption/commercialization of the 29 technologies in India. In all, there were 38 participants in the panel (or respondents in the final round of Delphi).

In the first (of the two round Delphi) – questionnaire given, 15 technologies out of 29 had secured consensus based on the responses (75% respondents agreeing over two or three adjoining time-frames were adopted and applied as criterion to check for the consensus (Hsu & Brian, 2007; Diamond, 2014; Giannarou & Zervas, 2014). The technologies on which consensus did not emerge were sent back to the Delphi panellists in the Round 2 questionnaire, along with the group statistical response for each technology and some additional information which could help them reconsider their answer given in Round 1. Applying the same criterion as fora Round 1 response, consensus on the time - frame of more ATs after Round 2 was checked.

Popular qualitative foresight method, Delphi was used in this study. It is a consensus building tool and requires formation of an interactive panel of experts. These participants must be willing to share their expertise and work toward a consensus on matters of opinion. For this study, experts from all over the country, with experience and knowledge in assistive technology and disability sector, were approached through email to constitute the panel.

DELPHI EXERCISE

Beginning in January 2016 and ending in May 2016, the Delphi panel participated in two rounds, responding to questions which called for thoughtful and detailed responses. As discussed earlier, this foresight study is on assistive devices for locomotor disabilities, placed on seven tracks viz. Prosthesis, wheelchair, exoskeleton, crutches, bionic, braces and brain implant. The questionnaire for Round 1 was sent out to 200+ individuals from academia, industry, government, NGOs and R&D, two questions were asked of the panelists on 29 futuristic technologies identified under these tracks. The panellists were provided with timelines for each track, delineating the evolution to help them make a projection into the future and respond to the questions. The predominant respondents who turned out to be young experts from academia, industry and R&D organization were asked:

a) The time-frame in which you (they) expect technology to be adopted (commercially available) in India along with reasoned opinions.
b) The technologies (in the timeline) that will get replaced by new one.

In all, 48 responses were received in Round 1 within stipulated time; the responses were examined for consensus. At least 75% respondents agreeing over two or three adjoining time-frames were adopted as criteria for consensus, applying this criterion; consensus was obtained for 15 technologies out of 29.

The technologies on which no consensus was there were considered for the Round 2 of Delphi. All the 48 panellists of Round 1 were informed about the technologies on which consensus had emerged; this was through the questionnaire for Round 2 that included all the 14 technologies on which consensus eluded. The new questionnaire carried with it- the group statistical response, comments, objections and arguments (obtained in Round 1) for each technology, offered by the panellists- as feedback; this while maintaining the anonymity of respondents as warranted by Delphi. In a few cases, recent developments were provided as additional information, to help the panellists decide on their response in Round 1- to maintain it or alter it; thus ensuring a dialogue among participants, another feature of Delphi. After the final round of the Delphi survey (Round 2), it was observed that 25 technologies out 29 had consensus on their time-frames while 4 did not viz. Prosthesis powered from body heat, Mind control exoskeleton, Exoskeleton cum wheelchair and Compressible assistive products.

RESULT AND DISCUSSION

Experts' predictions for when various assistive technologies of the future could become available are summarized in Table 3.

There are three innovations that are expected to be commercialized or accepted over the next ten years: a shock-absorbing wheelchair, a hand-free wheelchair, and a foldable crutch-chair. According to experts, the technology is well-known but is failing to gain widespread adoption due to people's natural aversion to change.

If we extend our timeline by another 5 years, we may anticipate even more radical shifts. Disabled people will be able to compete more successfully in the workforce with the help of emerging technologies such as prosthetics controlled by muscle activities, 3D printed prosthetics, modular prosthetic limbs, 3D printed wheelchairs, Smartphone-controlled bionic prosthetics, 3D printed exoskeletons, and crutches with joints. This data predicts that during the next decade to fifteen years, 3D-based technologies will become widely used in India, providing personalized assistance to people with disabilities. Experts say the widespread use of these technologies in several industrialized nations bodes well for their eventual introduction to the Indian market.

New technologies, such as 4D technology and brain-computer interface (BCI), are on the horizon and might revolutionize life for people with disabilities in India within the next five to fifteen years. Prosthetic limbs, exoskeletons, and bionic limbs operated by the brain may one day be commercially accessible.

The brain implant is a major technological breakthrough that is expected to have far-reaching consequences for the disability sector in India during the next five to twenty years. People with disabilities may be able to use it to restore the use of paralyzed limbs. Technology based on brain implants, such as NeuroBridge and the free hand system, is unlikely to be accepted or marketed in India in the next 10 years. This is true even in developed nations.

BCI is used to operate prosthetic or bionic limbs, as discussed above; however, experts believe that it would be very difficult to implement the same for exoskeleton, despite its success in the laboratory. This may be due to the size of the exoskeleton, which makes it difficult to operate with the help of the brain or thought.

As technology improves, certain older technologies are bound to be superseded by newer ones. A member of the Delphi group has suggested that the exoskeleton may one day make the wheelchair obsolete. In addition, bionic will replace prosthetic in the next years as 3D printing makes mass production simple and cost-effective.

This research has uncovered many promising technologies that might dramatically improve the lives of people with disabilities in India. Getting these technologies to those in need, who may be resource- or geographically-constrained, would be difficult. For people with disabilities (PwDs) in both rural and urban areas to gain independence and dignity, the government may need to implement initiatives to enable and make cheap these technologies.

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