ISSN 2349-6193
Impact Factor: 2.805

IJESMR

International Journal OF Engineering Sciences & Management Research

TECHNOLOGY FORESIGHT STUDY ON ASSISTIVE TECHNOLOGY FOR LOCOMOTOR DISABILITY

Surya Prakash [*1] & Jyoti soni[2]

[*1]Department of Mechanical Engineering, Devi Ahilya vishwavidyalaya, Indore, India

[2]Department of Mechanical Engineering, Devi Ahilya vishwavidyalaya, Indore, India

Keywords: Disability, Horizon Scanning, Delphi, Assistive Technology, Impairment, Foresight and locomotor.

ABSTRACT

Physical disabilities restrict a person to participate in their desired activities and sometime, fully prevent participation. The person with disabilities (PwDs) have no other option than to rely on various devices ,gadgets; tools etc. ,collectively termed as Assistive Technologies(ATs), to get themselves mainstreamed through such supports. This research examines the current status of various ATs for PwDs in India and looks back to trace their evolution, to foresee the ATs likely to evolve by 2035 and offer a hope, to possibly reduce the gap between disabled persons and the normal to maximum extent. For secondary data, examination of available literature, Horizon Scanning and Patent Databases (WIPO, USPTO & IPINDIA) has been used and an opinion survey for primary data. With the help of experts, hailing from industry, R&D institutions ,academia, NGO, government etc, Delphi study has been conducted. The experts were asked to speculate the likely time-frame of adoption/commercialization of these ATs and were provided with broad trend of evolution of technology in past decades to help them in responding. The findings of Delphi exercise, bringing out potential assistive technologies with their time-frames, have been reported in this study.

INTRODUCTION

Disability is the after effect of an impairment that may be physical, cognitive, mental, sensory, emotional, developmental, or some combination of these, that imposes restrictions on a person's ability to participate or being part of something which is considered "normal" in his/her way of life. Impairment may be present from birth, or strike during a person's lifetime. According to the United Nations Organizations (UNO), disability is the interaction between persons with impairments, impediment, attitudinal, and environmental barriers that restricts their complete and effective involvement in society on an equal basis with others. The expressions indicate a shift from a medical model to the social model of disability (UN Report on "Right of Person with Disability", 2006).For World Health Organization (WHO), a disability is a term which covers impairments, activity limitations, and involvement restrictions. Impairment is a problem in body function or structure; an activity limitation is a problem encountered by an individual in executing a task or action; while a participation restriction is a problem faced by an individual in getting involved in life situations (Schulze, 2010). Disability has been looked at from two different models: according to medical model certain physical, intellectual, psychological or mental impairments of a person is disabled and can adjust to the environment through cures, treatment and rehabilitation. Social model with its focus on the society looks at disability as the one which imposes undue restrictions on the behaviour of individuals with impairment.

In India, disability is one of the most important issues to deal with. We are in the process of helping PwDs to lead dignified and fulfilling lives we have to look seriously and critically at any strategy, including the use of new technologies. In India, this population is grouped into eight different types, depending on the disabilities that limits them from being a normal compatriot, and are as Visual impairment, Hearing impairment, Locomotor disability, Mental illness ,Mental retardation, Multiple disabilities (such as a sensory disability together with locomotor disability).According to Census of India, 2011, 75% of PwDs live in rural areas. 49 percent of them are literate and only 34 percent employed. Figure 1 gives the relative proportion of different categories of disability as per Census 2011.

In order to make these people socially and economically involved, there is a persistent need of special tools or technology, i.e. Assistive Technology so as to enhance their participation in desired activities and thus make them independent to the maximum extent. With a need to empower the people with disability, governments and organizations all over the world have framed various norms and policies. US, Europe, Canada, WHO, etc. have been pioneering the enabling policies and have influenced the shaping of policies in other countries. Table 1 gives an overview of such interventions in India, evolved to improve the status of persons with disability (Manual on Disability Statistics, 2012).

ISSN 2349-6193
Impact Factor: 2.805

IJESMR
International Journal OF Engineering Sciences & Management Research

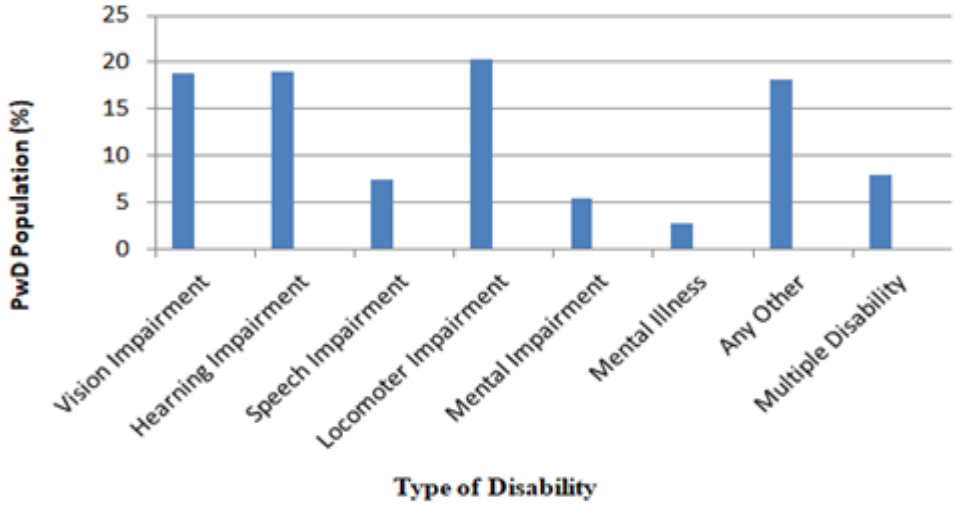

Fig 1: Relative proportion of PwDs as per census India 2011

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

Locomotor Disability
A person's inability to execute distinctive activities related to movement of limb resulting from affliction of bones, joints, muscles tissue or nerves. The signs of locomotor disability or paralysis, unsteady movement of limbs, poor muscle control, and loss of limb and so on.

Assistive Technology (At)
A device or piece of equipment or product which can be acquired commercially off-the-shelf, modified or customized to enhance or improve the functional capabilities of persons with disabilities is called Assistive Technology. It however, does not comprise a medical device that is surgically implanted, or an alternative to such device (Georgia Department of Education, 2007). More specifically AT includes alternative or adaptive specialized hardware and software, including input and output devices. Assistive Technologies are an extended concept, covering virtually anything that can be used to compensate for lack of certain abilities varying from 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 such as Braille's and computers with specialized software for assisting dyslectics to read. The decisions regarding the use of AT devices and implementing their uses thus have to follow systematic examinations of various ethical issues from the perspectives of the person with disabilities (Wool ham et al., 2006). These ATs have evolved in response to the need and their characteristics/features/capabilities have been influenced by changes in technologies. As such futures of Assistive Technologies have been of considerable interest to stakeholders.

Technology Foresight (Tf)
Foresight is the ability to foresee, predict or plan for the future, which is also called vision in management or business context. Technology Foresight is the prediction methodology for identifying the possible technological development in the future. In technology foresight, producers and users of science and technology in the innovation system come together to develop a common vision or scenarios for the future (Martino, 1993).
The broad aim of Technology Foresight is to determine emerging genetic technologies likely to produce the greatest economic and social advantage. Japan has been involved in extensive foresight work since the 1970s.It was started for the first time in India in 1995. According to Ben Martin**,** Technology Foresight is the process which involved a systematic attempt to look into the long-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging of generic technologies likely to produce the greatest economic and social benefits (UNIDO, 2005).

As discussed above, there is widespread recognition that emerging technologies are likely to have a great impact on the industry, the economy, society, and the environment over the coming years. These technologies are highly dependent for their development on progress or advances in science. If one can identify emerging

ISSN 2349-6193
Impact Factor: 2.805

IJESMR
International Journal OF Engineering Sciences & Management Research

technology at a very early stage, government and others can target resources and inputs on the strategic research areas needed to ensure fast and effective development. The aim of foresight is to identify potentially relevant emerging technologies as early as possible, to begin their future development and exploitation.

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 of user 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

ISSN 2349-6193
Impact Factor: 2.805

IJESMR

International Journal OF Engineering Sciences & Management Research

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 a timeline and looked at with the most recent developments, gave an idea of possible ATs of the future. It delineates 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 in India 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 for a 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

ISSN 2349-6193
Impact Factor: 2.805

IJESMR
International Journal OF Engineering Sciences & Management Research

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

Table 3 shows the time-frame of futuristic assistive technologies based on the expert's opinion.

In the time-frame of 0-10 years, three technologies- shock absorbing wheelchair, hand free wheelchair and folding crutch-chair are likely to commercialize or adopted. The technology, as per experts is known but is not getting adopted because of the fear of the new.

A lot more changes can be expected if we further our time-frame by another 5 years. Development of technologies like prosthetic controlled by muscle activities, 3D printed prosthetic, modular prosthetic limb, 3D printed wheelchair, and Smartphone-controlled bionic prosthetic, 3D printed exoskeleton, crutches having joints will allow disable people to work more effectively in a competitive environment. It suggests that technology based on 3D will get adopted in India between 10-15 years, offering the benefits of customization to PwDs. According to experts, these technologies have already been deployed in a few developed countries and this augurs well for its adoption in the Indian market soon.
In the time-frame of 5-15 years, new technologies such as 4D technology and brain-computer interface (BCI) will emerge and potentially be a game-changer for the PwDs in India. Brain-controlled prosthetic, mind control exoskeleton and brain control bionic, could become commonly available.

Brain implant is one of the most critical milestones achieved in term of technology and is likely to impact disability sector in India between 5-20 years. It is expected that it can help people with disability to regain the movement of their paralyzed limbs. This technology is in a nascent stage, even in countries like USA, UK etc. so it's highly unlikely for technologies based on brain implants like NeuroBridge and free hand system to get adopted/ commercialized in India in next 10 years.

ISSN 2349-6193
Impact Factor: 2.805

IJESMR

International Journal OF Engineering Sciences & Management Research

As discussed earlier, BCI is used to operate prosthetic or bionic limbs, but as per as experts' opinion, it is very complex to implement the same for exoskeleton even though it is successful in the laboratory; the reason for this might be the size of exoskeleton that makes it difficult to operate with the help of brain or thought.
With the advancement of the technology, it is also expected that few technologies will get replaced with other technology. One Delphi panellist has opined that there is a possibility of wheelchair getting replaced completely by the exoskeleton. Also, as both bionic and prosthetic are almost same in working, bionic will replace prosthetic in coming years because 3D technology will make it easy and economical manufacturing.

All the technologies identified in this study have a potential that can irreversibly change the status of PwDs in India. However, the challenge would lie in taking these technologies to the needy, which might be geographically or financially challenged. Necessary interventions may have to be devised by the government to facilitate and make affordable these technologies to help PwDs living in either rural or urban area and give them independence and dignity.

REFERENCES

1. *Al-Onizat, S.H., 2016. Measurement of Multiple Intelligences among Sample of Students with Autism, and Intellectual Disability Using Teacher Estimation and Its Relationship with the Variables: The Type and Severity of Disability, Gender, Age, Type of Center. International Journal of Education, 8(1), pp.107-128.*
2. *Baker, P. M., & Moon, N. W. (2008). Wireless technologies and accessibility for people with disabilities: Findings from a policy research instrument. Assistive Technology, 20(3), 149-156.*
3. *Bharucha, A. J., Anand, V., Forlizzi, J., Dew, M. A., Reynolds, C. F., Stevens, S., & Wactlar, H. (2009). Intelligent Assistive Technology Applications to Dementia Care: Current Capabilities, Limitations, and Future Challenges. The American Journal of Geriatric Psychiatry: Official Journal of the American Association for Geriatric Psychiatry, 17(2), 88–104*
4. *Georgia Department of Education,(2007). The Quality Indicators in Assistive Technology Consideration Consortium. <http://www.gpat.org/Georgia-Project-for-Assistive-Technology/Pages/Considering-assistive-Technology-for-Students-with-Disabilities.aspx>*
5. *Kosman & Kasati, (2015). Identifying Trends and Challenges in Relations to Physical Wellbeing for Active Healthy Ageing.*
6. *Martino, J.P., 1993. Technological forecasting for decision making. McGraw-Hill, Inc..*
7. *Moon (2015). <Retrieved from https://www.engadget.com>*
8. *Parsons, S., Daniels, H., Porter, J., & Robertson, C. (2006). The use of ICT by adults with learning disabilities in day and residential services. British Journal of Educational Technology, 37(1), 31-44.*
9. *Parsons, S., Yuill, N., Brosnan, M., & Good, J. (2015). Innovative technologies for autism: critical reflections on digital bubbles. Journal of Assistive Technologies, 9(2), 116-121.*
10. *UNIDO (2005). Technology Foresight Manual. <http://sts.sagepub.com/content/19/3/275.refs?patientinform-links=yes&legid=spsts;19/3/275> (accessed November 2014).*
11. *United Nations Publications (2002). International Practice in Technology Foresight. < https://books.google.co.in/books/about/International_Practice_in_Technology_For.html?id=GWu1IS9jJz4C&redir_esc=y>*
12. *Woolham, J., Gibson, G., & Clarke, P. (2006). Assistive technology, telecare and dementia: some implications of current policies and guidance. Res Policy Plan, 24, 149-64.*
13. *Woolham, J. (Ed.). (2006). Assistive Technology in Dementia Care: Developing the Role of Technology in the Care and Rehabilitation of People with Dementia: Current Trends and Perspectives. Hawker Publications*

ISSN 2349-6193
Impact Factor: 2.805

IJESMR
International Journal OF Engineering Sciences & Management Research

TABLES

Table 1: Key points from prominent initiatives of the government for PwDs in India

Government of India Initiatives	Highlights
Assistance to Disabled Persons for Purchase / Fitting of Aids and Appliances (ADIP	➢ Aims at helping the disabled persons by bringing suitable, durable, scientifically manufactured, modern, standard aids and appliances within their reach
National Trust for Welfare of Person with Autism, Cerebral palsy, Mental retardation and multiple Disability Act, 1999	➢ Has a provision for legal guardianship of the four categories of the persons with disabilities and for creating an environment to enhance their independency as much as possible.
National Policy for Person with Disabilities, 2006	➢ Development of assistive technology, promotion of research etc.
National Knowledge Commission, 2009	➢ All schools must be designed and geared for inclusive education, which means that all systems must be oriented to enable the greatest possible access to children with different needs and abilities. This needs major changes in both infrastructure and pedagogical methods.

Table 2: Keywords used for searching patents

Technology	Keywords
Prosthesis	Prosthesis, Prosthetic, Artificial Limb, Prosthetic Leg, Prosthetic Arm or Hand
Wheelchair	Wheelchair, Chair car
Exoskeleton	Exoskeleton, Exoskeleton Walker, Exosuit, Exoframe, Artificial Body Covering
Bionics	Bionic, Bionic Prosthetic, Bionic Limb, Bionic Arm, Bionic Leg
Crutches	Crutches, Forearm, Underarm, Platform, Leg Support)
Orthotics	Orthoses, Orthotics, Braces, Splint, Wrist Support, Ankle Brace
Brain Implant	Brain Implant, Neural Implant

Table 3: Shows the time-frame of futuristic assistive technologies based on the expert's opinion

Assistive Technology	Time Frame					
	0-10 Years	0-15 Years	5-10 Years	5-15 Years	5-20 Years	No Consensus
Robotic Arm Controlled By Muscles Activities		✓				
Fully Integrated Prosthetic Limbs and Bionic Implants		✓				

ISSN 2349-6193
Impact Factor: 2.805

IJESMR
International Journal OF Engineering Sciences & Management Research

3D-printed Iron Man prosthetic		✓				
Adjustable Length Prosthetic Foot		✓				
Brain-Controlled Robotic Arm				✓		
Modular Prosthetic Limb		✓				
A Brain-Computer Interface That Lasts for Weeks				✓		
Prosthesis Powered From Body Heat or Energy						✓
3D Printed Wheelchair		✓				
Shock Absorbing Wheel for Wheelchair	✓					
Hi-tech Wheelchair for Rough Terrain				✓		
Hands-Free Wheelchair	✓					
Smart Controlled Bionic		✓				
Bionic Prosthetic That Can Feel Grip Strength					✓	
Cyber legs				✓		
Bionic Leg Prosthesis Controlled by Subconscious Thought or Brain				✓		
Free Hand System - To Revive Paralyzed Hand					✓	
Neuro Bridge - For Limb Movement					✓	
Underarm Crutch With Power Generation Function		✓				
Folding Crutch Chair	✓					
Crutches Having Joint		✓				
Robo-Ankle Flexes Artificial Muscles		✓				
3D Printed Exoskeleton		✓				
Bionic Exoskeleton					✓	
Motorized Pants for Stroke Victims		✓				
Mind Control Exoskeleton						✓
Exoskeleton Cum Wheelchair						✓
Household Robots		✓				
Compressible Assistive Product						✓