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Article

Accessible consumer electronics are essential to closing the gap in assistive technology provision

David Banes[1,]

[1] David Banes Access and Inclusion Services; david@davebanesaccess.org

Abstract: Estimates by the World Health Authority suggest that 1 billion people do not have access to the assistive technologies they require. Over the past decade, the design of products that empower people with a disability has shifted from specialised and dedicated products designed only for those with a disability to features and functions integrated into cost-effective consumer technologies for the benefit of all. The opportunity for expansion of the availability of such technologies is at risk of being ignored as a result of models of delivery that are founded in medical devices and which have failed to reflect trends in our understanding of technology and the choices and preferences expressed by persons with a disability. This research undertaken suggests that the opportunities of such expansion offer significant benefits to people with a disability and better both economic and social return on investment for authorities.

Keywords: Assistive Technology, Accessible Technology, Consumer Technologies, Provision, Policy, Funding

1. Introduction

Mobile technologies have become an integral part of modern societies and, for many people, have become the preferred means of access to employment, education, leisure, travel and public services. The manufacturers of mobile technology devices, particularly phones and tablets, have increasingly made their products accessible to the broadest possible user base, building in a wide range of accessibility and assistive functionalities. The market leaders have furthermore joined together to provide better information to consumers about the accessibility of their devices in creating the Global Accessibility Reporting Initiative (GARI) within the Mobile & Wireless Forum (MWF). GARI is a collaborative project bringing together a broad network of accessibility stakeholders and continues to evolve to respond to technological developments and feedback from the disability community. The latter included a recurring request for accessible consumer electronic devices such as mobile phones and tablets to be accepted as assistive technology (AT) and hence eligible for AT funding where such funding is available.

As a result, the MWF commissioned a team of 5 researchers to conduct an "Analysis of Funding and Provision Models for Mobile Technology for People with a Disability" in 2021. The study focused on

- analysing the social return on investment (SRoI) of mainstreaming consumer technology as AT;
- assessing the policy environment for AT provision, in particular AT deemed to be consumer technology products such as smartphones and tablets;
- examining the user needs sections of EN 501349 and Section 508 Guidelines;
- reviewing the possible alignment of GARI features with international and national classifications and codes and reviewing GARI's feature list concerning assistive technology codes and classifications;

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- analysing the eligibility and approval process for public provision of GARI devices and classification of funding models within criteria of the inclusion and exclusion of supporting access to consumer and mobile technologies;
- investigating variations in funding and provision due to the context of use, such as health, education, social welfare (independent living);
- assessing the gaps in current AT provision systems and how GARI featured devices can fill the gaps and provide recommendations on expanding rules and criteria used by governments to enable GARI featured devices to be eligible for funding.

GARI is currently the most comprehensive database on accessible devices and their features. The database includes mobile phones, tablets, wearables, apps and Smart TVs, and lists the majority of available accessible mobile phones and tablets worldwide. GARI-listed devices serve as a proxy for describing accessible mobile technologies in this research.

The study explored the above-listed aspects in six countries: the US, UK, Norway, Poland, Ireland, and Australia.

The findings support the case that accessible consumer electronics are complementary to AT in Technology and Environmental Intervention (TEI) as described by Gitlow and Flecky (2019) [1]and enable people with disabilities beyond the currently limited functional purposes of AT provision, achieving "well-being" as defined in Sen's Capability Approach model [2]. This case challenges funding authorities to consider and provide accessible mobile and consumer technologies as assistive technologies (AT) or environmental interventions (EI) to support people with disabilities to live independently.

2. Materials and Methods

The initial research focused on investigating the technical features of mobile phones, tablets, and associated software listed in GARI and analysing possible alignment with international and national classifications and codes. Furthermore, it explored user requirements for communications devices, including the requirements of EN 301 549 and Section 508 Guidelines. These standards and guidelines list Information and Communication Technologies (ICT) accessibility features for public procurement and are relevant in underpinning accessibility features for user needs. The initial research investigated the variations in funding and provision due to the context of use, such as health, education, and social welfare (independent living). Finally, it reported the preliminary findings from the above analysis, including an assessment of to what extent examples of features listed in GARI fulfil the basic requirements of assistive technology.

The findings of this research were then reviewed through the lens of underlying trends that acted as factors that impacted providing consumer digital technologies for people with a disability. We considered detail and regulations of provision from five countries to frame provision models and suggest success factors leading to conclusions with recommendations for action. The key critical finding was that technology significantly impacts the lives of people with a disability. But whilst demand is increasing rapidly, existing provision criteria and funding do not adequately reflect these trends or meet the demand. The analysis suggested a changing understanding of inclusion and the enabling role of technology. The ongoing move from dedicated (designed for disability) to accessible mainstream, inclusive consumer devices brings challenges to existing systems that appear ill-equipped to manage.

These findings were tested and validated through in-depth qualitative interviews with key stakeholders from Disabled Persons Organisations (DPOs) and disability rights advocates and policymakers. Interviews were conducted in Norway, the UK, and Poland. These interviews sought to assess the gaps in current assistive technology (AT) provision systems and how consumer devices might address this. Furthermore, it provided

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recommendations on expanding the rules and criteria used for the provision of AT to enable devices to be eligible for funding. This led to considering any social return on investment (SRoI) in identifying consumer technology as AT.

3. Findings

3.1. What is the value of mobile, portable, and consumer technologies in promoting access and inclusion of people with a disability, and how is this evolving and changing?

In a report prepared for the MWF, Banes (2019) notes that mobile technology has become a critical, core aspect of the ICT and telecommunications industry. By 2017, over 5 billion people globally were connected to mobile services [3]. This continues to grow, driven by low- and medium-income countries, including India, China, Pakistan, Indonesia, and Bangladesh. Whilst the market in the west has become saturated, significant social groups remain underrepresented, including the elderly and those with a disability. It was predicted [4] that mobile internet adoption would become the key metric to measure the reach and value created by the mobile industry, including its contribution to the UN's Sustainable Development Goals (SDGs).

Mobile technologies have become central to the experience of many. For example, during the Covid pandemic, consumer technologies, notably phones and tablets, were critical in allowing public health restrictions to be enforced. In addition, online learning, working from home, and social interaction and contact were all facilitated through such devices. Whilst this has presented challenges, it has been noted that such a "life through a screen" has some benefits to people with a disability that may have longer-lasting consequences.

Mobile technologies, notably smartphones and tablets, have dominated the technology marketplace recently. For a decade, smartphone sales have exceeded computer sales. They have increasingly become the basis of digital assistive technology, offering value for money and a low-cost diversity of applications to support the inclusion of people with disabilities. Most provide functions to support access, including text-to-speech, voice input, or word prediction. Many devices also offer additional functionality that replaces and disrupts purpose-built devices such as fall detection, AAC (alternative and augmented communication) and sound amplification.

In many cases, mobile technology is the preferred platform for inclusion projects due to widespread familiarity and availability in low- and middle-income countries (LMICs). Such devices can improve access to information and promote interaction for vulnerable populations, including those with disabilities (Barlott, Adams & Cook 2016) [5]. If this opportunity is to be realised, devices must combine affordability with accessibility and usability.

In the 2019 report for the MWF, Banes also summarised further findings related to the role of devices for inclusion. For instance, Heller, Jorge and Guedj (2011) found that mobile telephony had opened a vast diversity of new opportunities for older people with different physical restrictions due to ageing [6]. In addition, mobile technology allows ubiquitous communications and anytime access to services that they consider vital for older adults' security and autonomy. Other reports echoed such findings, including Harris (2010), who noted, "disabled people are excited by the potential benefits of using advanced technologies at home" [7].

However, they found that many devices may be abandoned early and lie unused. The cost of technologies can be prohibitive, so it is essential that people with a disability can find technology that addresses their needs, is fit for purpose, and is affordable. There is clear proof of the importance of mobile and portable technology across all domains, including employment, education, and independent living.

G3ICT (2012) noted that wireless technologies provide easy and instantaneous access and that those with disabilities can use them in various ways to live independently and conduct daily activities [8]. The increasing provision of hands-free capability, screen

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reading and text-to-speech functionality, relay services, internet browsing, home automation, emergency response and all the assistive features and services promote independent living for persons with disabilities. They note that in addition to enabling them to perform tasks such as paying bills, shopping, booking tickets, reading books, and working, mobile phones also impact the social fabric of the disability community.

The positive impact of accessible technologies appears to be broadly consistent across the spectrum of needs. Muer (2015) noted that: "Overall, information gathered through this study indicated that mobile technology appears to positively impact the quality of life of individuals with developmental or intellectual disabilities by increasing independence, self-determination, and community connectedness." [9]

Such findings are echoed in research on access for those with vision, hearing, physical or multiple needs. It should be recognised that the criteria applied by any consumer of devices, including personal preferences and aesthetics, play a role in decision making. Handsets and devices have cultural value, and models may be more or less fashionable denoting status. Where this is significant for users, there is a clear preference for mainstream devices.

The widespread use of mobile and portable technology has been acknowledged as representing a significant shift in the opportunities offered to people with a disability. The scale of penetration into traditional markets has been the basis of developing disruptive business models and delivery channels that have increased access to high-tech assistive products and profoundly impacted public policy and service delivery models. The pandemic experience described above has significantly shifted public and private services to an online model. Health, education, and social care have transitioned to a more virtual model connecting people with a disability via technology. In most cases, these have been phones and tablets. However, where such technology has not been available, people with a disability have faced a greater risk. They may have been unable to access virtual resources, requiring them to engage with traditional models identified as having a high risk of infection.

The availability of consumer devices through which services engage has been challenging for many people with a disability. Such devices have both initial and ongoing costs, and in many countries, such technologies fall outside most models of support as they are not defined as assistive products.

3.2. Key trends in AT and the potential impact on the demand for smartphones and consumer technologies

Technology pervades, and we can observe it impacting all aspects of our lives. In the past, many people with a disability required specialised and often expensive AT solutions. We now find that many of those functions and solutions are now features that are fully integrated into consumer devices. As technology evolves, we seek a common platform upon which to build using emerging technologies. Trends in AT design and use include the growth of:

- Use of mobile devices across all parts of life.
- A sharing economy and open licensing.
- Remote and online support.
- Wearable technology.
- The Internet of Things and location-based services.
- Disruptive models of service delivery.

These are underpinned by broader social and technological trends that impact people with a disability, including home working, online education and on-demand entertainment and leisure.

3.2.1. Increased demand by people with disabilities

There is a long legacy of products designed to make disabilities easier to live with, but assistive technology seems more pervasive and in demand than ever. Morrissey (2019)

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observes that as people with disabilities have access to smartphones and computers, which are increasingly affordable, they have the means to make themselves visible in a way they never could [10].

3.2.2. Mainstreaming of assistive technology into consumer products

The increased integration of accessibility features into consumer products for all has led to a range of accessible technologies designed to address the needs of diverse users. Mainstream technology companies' products are designed with built-in features that allow people with disabilities to personalise their experiences. Apple's smartphones and tablets include features such as Switch Control, Voice Over, and Live Listen and similar features are available on Android. Many of these features were developed for people with disabilities, and their designs have value for all. Other innovations such as eBook readers, fitness trackers and smart home technologies provide evidence of consumer technologies that have been harnessed for people with disabilities. This is significant as the innovations support the need for assistive technologies and the broader population's preferences for natural interfaces.

Morrissey (2019) adds that voice-activated home technology can help people with limited mobility or visual impairment [10]. For example, voice commands can turn smart lights off or on, control music and media playback, and give spoken news headlines or updates.

3.2.3. Mobility and portability of assistive solutions.

With the advent of 5G, the design of assistive technologies is increasingly characterised by pervasive and always-connected solutions. Connectivity facilitates technology availability regardless of location; we see this in action through devices such as phones, tablets, and wearables. As a result, people with a disability increasingly expect their technology to be available on demand.

3.2.4. Artificial Intelligence, automation, anticipation, and analysis

AI is driving the design of assistive technologies through data analysis, offering a predictive and personalised experience with increased automation of functions. Users are concerned about the security of their data and their privacy [11]. If companies are to retain users' trust, they will need to be transparent about the collection and use of data and demonstrate the benefits.

3.2.5. Technology for daily life

Ranging from aids for essential functions such as bathing or feeding to more complex digital tools such as environmental control systems or smart homes. These devices support those with disabilities to interact with the physical world through remote controls for doors, lighting, temperature, and other aspects of the built environment. Such control stimulates and ensures greater autonomy

3.3.6. Technology for mobility

Ensuring personal mobility requires mobility aids such as walking aids and technologies for wayfinding and orientation that provide information about the built environment to guide decision-making. Such technologies are often built upon consumer devices.

3.2.7. Technology for communication

Many technologies are available to stimulate and facilitate interaction, producing communicative utterances. These include low-tech solutions such as tape recorders or speech synthesisers. However, they are increasingly based upon everyday devices to gather and convey information in different forms.

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3.2.8. Emerging technologies

The emerging technologies that will impact these fields have been developed, assuming that a smartphone or similar device will be available to users. The function and application of the technologies are subject to the ongoing evolution and disruptive design. Some of the specific technologies that are influencing development include:

Speech Interfaces. Speech interfaces are used as input or output based upon automatic speech recognition (ASR) and natural language processing (NLP). Technology such as Amazon Echo or Google Home, and those with built-in functionality such as Apple's Siri or Google Assistant and Amazon Alexa, offer options to make an environment accessible.

Internet of Things (IoT). IoT is reshaping society by changing the daily life of users. Assisted living, smart homes, and smart health are all scenarios in which this will play a role for people with disabilities (Atzori, Iera, & Morabito, 2010) [12]. IoT enhances assistive technology by adding capabilities that support independence in communication, self-care, independent living, health care, mobility and transportation, and education and learning (Lee, 2009) [13].

Artificial Intelligence. Artificial Intelligence (AI) leads to innovation in many fields for people with disabilities. With developments in predictive text, visual recognition, and speech-to-text transcription, AI now stimulates other products and features that expand opportunities for those with disabilities. The *Seeing AI* app describes people, text, and objects verbally for those with no or low vision. *Livox* is an AAC app that allows people without speech to communicate using symbols that respond to context easily.

Augmented Reality. AR increasingly impacts rehabilitation by using virtual objects and overlays to enhance interaction with exercises and activities. It makes training more understandable and can help users understand their available devices and technologies. Virtual Reality may integrate treatment and entertainment through virtual and gamified environments. This can increase motivation and commitment to rehabilitation and other activities that a person finds challenging.

Wearable Technology. Wearable technology delivers assistive and accessible features in a variety of ways. They can act as sensors to gather data through smartwatches or fitness trackers and provide information in a non-obtrusive manner. They have a long history and include hearing aids and Bluetooth headsets, whilst smartwatches have grown in popularity and functionality during recent years. As such devices become more prevalent, forms of assistive technologies use the platforms to control other devices and give alerts and notifications, improving personal health and safety.

3.2.9. Summary

Assistive technologies can, in various ways, be high-tech or low-tech, specialist devices or mainstream platforms. They may encompass human augmentation and inclusive design. However, underlying trends have been identified.

Emerging technologies are moving from providing specialist devices designed solely for those with a specific need to an increasing blend with mainstream technology that benefits all users. This reflects the increased implementation of universal design principles and technology's pervasive nature, which often demand access in challenging settings.

In addition, mainstream technologies increasingly embrace redundancy of inputs, integrating gesture, sound, and vision, giving users greater flexibility to determine how they wish to engage with information and establish control. This further blurs the boundaries between assistive and mainstream technologies.

3.3. What are the definitions of Assistive Technology, and how do they relate to consumer technologies

Three categories of technology devices that have value for people with a disability are relevant for this research:

- **Mainstream Consumer Technology:** These technologies, such as digital television, are designed for the widest population and may include no specific features to

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facilitate their ease of use by a person with a disability. Television may not enable access to captions for people with hearing loss or audio descriptions for the blind. However, the large screen and control may work well for some people with some forms of disability. Feature phones may be examples of such technology with relevance to our discussion.

- **Accessible Technologies:** Accessible technology includes products, equipment, and systems that can be customised and provide persons with disabilities access to all services and content therein. Some examples might include smartphones with integrated speech-to-text that can be used for dictation or creating captions. Such devices are widely used, and the features may benefit any user of the equipment and are designed to be used with minimal effort to meet the needs of a wide population.
- **Assistive Technologies:** "Assistive Technology" refers to products, equipment, and systems that enhance learning, working, and daily living specifically to address the needs of persons with disabilities. Many assistive technologies are unlikely to be required for the majority of people in the population. Such technologies can include screen readers, braille output, connections to hearing aids, and alternative access technologies for those with a physical disability, including pointing devices or switch access. The World Health Organization's 2016 priority list of assistive products includes devices such as braille notetakers. Much of the functionality of what is described as assistive technology can now be delivered through the integrated features or additional apps on a smartphone or similar device.

Definitions of assistive technology products can vary considerably depending on legacy and contexts. Any review of definitions can be both helpful and bewildering. Definitions range from highly detailed descriptors as suggested by the International Organization for Standardization (ISO) to a formal definition of AT devices and services codified in US legislation as early as 1988. Most classifications of products have been driven by statute and policy to define and often limit the scope of what can be paid by an agency. Definitions often discriminate between assistive technology products and the services that support effective implementation and use of products.

The World Health Organization and its global initiative, GATE, have sought to clarify some of the terminology and related concepts. GATE defines "assistive technology" as a more encompassing concept that includes both systems and services alongside "assistive products". The GATE definitions emphasise AT as enhancing functioning and not as being medical or health interventions. However, they continue to refer to assistive technologies as a subset of health technology. This may be due to the legacy of the full breadth of assistive technology and products, including wheelchairs, mobility aids, and prosthetics.

Assistive products can be understood within the context of technology type. Smith (2017) articulated a set of four broad definitions of technology [14]. These were assistive, therapeutic, environmental, and occupational role-related technology. These were identified based on the purposes of the technology and sought to be inclusive of everyday technology used by general populations and the technologies used by people with disabilities.

Occupational related technology (ORT) refers to the technology used by everyone in everyday activities, such as the telephone, the computer, the bicycle, and the television. These most correspond to our definition of mainstream products. Environmental technologies (ET) are those publicly available in the environment, such as door handles, elevators, ramps, or signage. Therapeutic technologies (TT) seek to help remediate or improve skills such as muscle or stamina exercise equipment, cognitive training software or educational multimedia. Finally, assistive technologies (AT) are the products used individually by people with a specific disability to enhance function and address barriers to independence and participation in society.

These distinctions have some value as they differ by purpose and by the development and implementation process with implications for the consideration of alternate delivery models. Assistive products extend beyond any single domain, and in practice, such distinctions may be artificial, and products may move fluidly between such categories. Products that were initially considered to be assistive have transitioned into the mass market.

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For instance, captions are extensively used to view the video in noisy environments, and voice control provides the basis of smart speakers and hands-free operation for much of the population. Understanding the extent to which assistive technology products cross categories is essential in reviewing funding models. Any stakeholder using assistive technology products will likely bring a limited perspective based on personal experience. As we investigate consumer technologies as enabling technologies, the breadth of potential use must be considered across domains.

Further investigations of definitions can be helpful. For instance, the AbleData database in the US defines 20 categories of assistive technology products ranging from transportation, walking, safety and security, orthotics, housekeeping and recreation. As a result, the database has catalogued from 30,000 to over 50,000 assistive technology products across all categories. Other databases of assistive products and related resources include assistivetech.net and the US "national public website on assistive technology". Others include the European Assistive Technology Information Network (EASTIN) in the European Union, and the National Equipment Database (NED), run by the Independent Living Centres in Australia, which provides 24 browsable domains of assistive technology to help identify assistive products.

This overview suggests that even if we successfully create a definition of assistive technology that includes the consumer technologies held within the GARI database, further challenges may exist in relating the device to any specific domain. By their nature, such devices are pervasive and have multiple functions. This seems contrary to the traditional domain usage and may be challenging in making a simple case for inclusion.

3.4. What funding models for assistive technology can be identified

A review of funding models drawn from the USA, UK, Ireland, Germany, and Australia suggests that different approaches have emerged and evolved. These can be summarised into five groupings which are detailed below.

3.4.1. Domain-Specific Funding

In this model, funding for assistive technologies is closely related to the context and purpose of the provision. It is often evaluated and approved based upon the relevance to established goals to deliver aims within a specific setting. This leads to a high degree of fragmentation as funding for technology, and assistive technology is available through various routes as in the UK. The funding route changes as the user setting changes, either through life stages or context. Broadly, applications for assistive technology fall under "adaptations to the equipment used" or "special equipment or software". As a result, whilst the assistive solution may be funded, the device is less likely. Domain-specific funding is also the basis of some provision in the US through various federal and state programs and including the Office of Special Education and Rehabilitation Services (OSERS), Office of Special Education Programs (OSEP and the Rehabilitation Services Administration (RSA).

Ireland demonstrated a different domain-specific model where funding for assistive technology is provided to schools under an Assistive Technology Scheme. Funding is provided to schools towards the cost of computers and assistive technologies for education. Equipment is provided for those with complex disabilities who, to access the curriculum, require AT that they do not already have or cannot be provided through the school's existing IT provision. Similarly, the Department of Education provides grants to schools to allow for the purchase of computers and AT for use by students with a disability in second-level schools. It seeks to provide students with technology that will enhance their education and, therefore, must be essential to access the curriculum. The scheme does not cover telephone, smartphones, televisions, internet access or phone connectivity charges. In this example, the equipment is kept in the school. However, a student may be allowed to use the equipment at home, but the equipment remains the school's property and will usually be passed on to another student or another school if the first school no longer needs it.

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3.4.2. Direct payments

In a direct payment model, the money required for assistive technologies is given directly to the person with a disability to purchase and procure the products and services they require. Some direct payment schemes are based on a set amount for any eligible person. Others are more closely related to the needs of the person and the accommodations, products, and services they require. The latter model is most common in most cases related to assistive technology.

State funding for AT is mostly now made in Australia through the National Disability Insurance Scheme (NDIS). Different forms of support budgets under the NDIS help meet short, medium and long-term goals. Funding is based on what is 'reasonable' and 'necessary' to achieve goals. They state that this is in addition to the support provided by family, friends, and other community and government services.

A capital support budget relates to supports such as assistive technology or home modifications. Funds within this budget can only be used for their specific purpose and cannot fund other items. Whilst no reference to particular consumer technologies is made, they can be discussed and agreed upon if a person wants such technology in their plan. This may require reports from specialists with a rationale explaining why the AT is necessary to achieve stated goals, and providers can offer quotations for any planning meeting so a budget can be included in the plan. However, such information does not guarantee that assistive technology will be included in the plan as the NDIA makes the final decision.

The capital support AT ranges from Level 1 (Basic Assistive Technology), such as non-slip bathmats, to Level 4 (Complex Assistive Technology) for custom-made wheelchairs and hearing aids. The price difference between these levels can differ dramatically, so certain AT requires users to undertake an assessment and provide multiple quotes before purchasing.

More recently, the NDIA has recognised the more central role that smart technologies might play due to public policy in the light of Covid 19. These have changed how some supports are delivered, with technology enabling support continuity through tele health, video conferencing, and other technologies. For example, a more flexible approach was introduced during the pandemic that allowed participants to spend up to $1,500 on low-cost AT items, such as smart devices and fitness equipment, in consultation with their existing support providers. However, it is recommended that participants should not spend more than $750 on electronic devices needed to maintain existing services. For instance, it is suggested that if a standard tablet computer or iPad is required to participate in online video classes, these should generally cost no more than $600.

Some potential assistive products are excluded from the policy that established such flexibility. These include items unrelated to the participant's disability, items with extra specifications above the basic model, and smartphones, tablets, or iPads with mobile-only 3G, 4G or 5G connections.

3.4.3. Public and private insurance schemes

The third model of provision is a combination of private and public health insurance schemes. In both cases, eligibility depends on contributions made to a shared fund. These are either made by the individual, either in a levy upon their income or to a specific carrier or are done on their behalf by the state or employer. While there are some similarities to the direct payment (NDIS) referred to above, there are distinct differences in scope and inclusion. Probably the best-known model, and one of the most widely discussed, is used in the United States. Insurance schemes such as Medicare, Medicaid, private health or disability insurance, and worker's compensation may pay for some assistive technology. In most cases, a demonstration of medical necessity for the product or equipment and a prescription from a doctor or other professional will be required.

Similarly, electronic AT is funded mainly by mandatory health insurance in Germany. This has been estimated as being as high as 90% of that required. If AT is necessary

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for the workplace, it is federally funded or by accident insurance and, in most cases, is supported by almost 100%. However, such technology funding appears to be predominantly related to computer access, AAC, and environmental controls. The relevant law guiding this funding suggests that products used by most people in daily life are not eligible (Sozialgesetzbuch, 2021).

As a result, whilst the list of technical aids funded by the insurance held on the GKV website has over 50 categories of aids and devices that are supported, there is a reference to electronic aids. It is unclear whether this would be extended to personal digital or consumer technologies as such solutions are unlikely to meet the requirements of medical devices. The medical perspective of this provision appears to exclude the recommendation of phones. Moreover, such devices are expressly excluded in the case of those with hearing impairment.

3.4.4. Not-for-profit and charitable funding

Not-for-profit organisations often distribute assistive technology as a service or charitable activity. In the USA, these can include regional disability organisations. State and local disability organisations sometimes offer assistive technology for a nominal fee. For example, the Texas Centre for the Physically Impaired (TCPI) provides refurbished desktop computers to blind and visually impaired people for a $100 donation. It is unclear whether such a scheme would be extended to mobile technologies.

Similarly, the Association of Blind Citizens (ACB) operates the Assistive Technology Fund (ATF) to help blind and visually impaired persons access technology. The grants cover half the software or equipment cost between $200 and $6,000 for blind US residents with an annual income below $50,000 and cash assets under $20,000. Fraternal organisations such as chapters of Lions Clubs International or United Way may purchase assistive technology on request.

In many countries reviewed, charitable funding for assistive technology has declined. Organisations such as the AIDIS Trust in the UK no longer appear to fund the acquisition of such technology directly. Such provision by philanthropic organisations is firmly based upon providing a final funding source for equipment if all other funding sources have been unsuccessful. Other charitable sources may be closely linked to a specific disability, such as the Multiple Sclerosis Society in the UK, which offers grants for support dependent on the financial status of people with MS or may be related to specific parts of the country or the age of the individual. The Family fund in the UK will also fund computers and tablets for children with some disabilities, but their model is very specific and states that: "We work with Stone to provide our computers and tablets grant and can consider helping with computers, laptops, iPads and various tablets. This supplier can only provide these awards, and we cannot consider a cash alternative."

In some cases, the role of an NGO as part of the funding network can be significant. For example, in Spain, the ONCE Foundation is a substantial funder of solutions, especially in employment for people who are blind or with some other disabilities. ONCE operates the Spanish Natural Lottery, which provides sustainable funding to achieve this.

3.4.5. Private funding

Stakeholders identified private sources as a funding model widespread in purchasing phones and tablet devices. Such funding relies upon the individual having sufficient funds to pay for the needed or desired technology but is distinct from the more structured direct funding mechanisms. In some cases, including parts of the Middle East, this model predominates because the very low levels of personal taxation mean that government policy seeks to ensure that individuals have the funds they need to pay for such devices. Such models ensure that people with a disability have the disposable income to make sure a purchase is also related to the concepts and trends towards self-determination of technology needs.

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Including gifts from family and friends to support purchases is not unusual. Many people with a disability also benefit from used and refurbished phones from friends and family, which is not uncommon in low-income cases.

However, some more structured approaches have been supportive in addition to this benevolent social model. For instance, Manufacturer Purchase and Lease Programs have been helpful in the US. Some manufacturers give customers with disabilities discounts or offer purchase plans. In the case of assistive technologies, one company which sells OCR, magnification, and braille products, lets qualified customers spread payments for $1,700+ solutions out over a 13- or 24-month period through a third-party leasing company. At the end of either contract, both carry a $250 document fee, the equipment is returned to the leasing company, or the individual can choose to own it.

Many states in the US offer Assistive Technology Loan Programs and low-interest loans under the Alternative Financing Technical Assistance Project (AFTAP). This program, run by the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA), helps states establish loan programs under Title III of the Assistive Technology Act of 1998. The RESNA website lists loan programs by state.

Similarly, models have been applied in some circumstances in some countries. For instance, in Kenya, Safaricom partnered with the government to offer 0% and favourable repayment terms to people with a disability. In Qatar, the telecommunications operators offered a 20% discount on handsets and 50% on tariffs for people with a disability who held a state disability registration card.

Employers may also be considered as a source of "private" funding. For instance, in the US, where a person with a disability requires technology to do a job, it may constitute a reasonable accommodation that an employer must provide. The Americans with Disabilities Act (ADA) mandates accessible workplaces.

3.4.6. Refurbished and reuse models

This model of provision is a further extension of a social or philanthropic model of provision. These can include both technology loan programs and refurbishment of donated devices.

In assistive technology's case, many US organisations demonstrate assistive devices and sometimes loan or sell products at a reduced cost. These loans can help an individual to identify the most cost-effective solution. For example, Assistive Technology in New Hampshire, at the University of New Hampshire's Institute on Disability, offers training, loaner equipment, and low-cost funding alternatives. Buying used or refurbished equipment is far less expensive than purchasing new equipment and still provides the necessary functionality. Often, the technology has been donated due to lack of use or abandonment, prompting donation of sale. Many second-hand products have a continued value.

The most common and unquantified approach is when a personal device is reset and given to a relative or friend by someone upgrading their equipment. In many cases, this extends the use of the handset or device and offers access to functions and apps for as long as the operating system is supported. It was acknowledged that this was widespread in every country where interviews took place.

Similarly, the use of mainstream second-hand resellers was also widespread. These could range from national chains to small market stalls. Again, quality was mixed with no guarantee that specific devices would be available. The availability of such sales online through marketplaces such as eBay also helped people with a disability to make choices.

The third option was centres that dealt with a wide range of used and refurbished disability equipment, often within a specific town or district. The equipment is donated or bought from families at a low cost. These have now included phones, tablets, and computers in some areas. However, these are sold to those with disabilities and the broader population to generate funds for other activities.

The final group of refurbishment services is similar to the "Pass It On" Centre from Georgia in the US. The Pass It On Centre creates national and state resources to foster the safe, effective, and appropriate reuse of assistive technology (AT), offering affordable AT

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needed to live, learn, work and play more independently. One aspect of this has traditionally been the reuse of computers and, more recently, phones and tablets.

3.5 Validation of key issues

Six key issues were derived from the 19 in-depth qualitative interviews of persons with disabilities conducted in Norway, the UK and Poland. There were seven interviews in Norway, five in the UK, and seven in Poland. The participants were diverse across gender, age, abilities, and disabilities. These offered validation of the findings of the desk research and interviews with professionals.

3.5.1. The funded ATs are not meeting the needs of people with disabilities

Barriers exist in the funding processes. Both the technology distributed and the procedures were not up to date. The list of funded devices available limit the choices and exclude technology that can effectively improve the independent living of persons with disabilities.

3.5.2. Mobile technology is essential in the lives of people with disabilities

It has the potential to bridge the gap by doing what AT equipment cannot do. In addition, mobile technology makes better use of AT equipment by enabling interoperability among specialised AT.

3.5.3. For people with disabilities, access to mainstream technologies greatly improves their lives

The technologies enable those with disabilities to participate in different areas of life. In addition, mainstream technologies help them better use the external technologies they own and get the most out of the available applications for mobile phones.

3.5.4. Ensuring access to consumer technologies is important

The participants supported the idea of ensuring access to mainstream AT for people with disabilities. Changes need to be made in buying and supplying AT devices, software, and equipment. A solution is for the government to step in and provide support or the training needed in an accessible format.

3.5.5. Cost is not the only barrier to access to assistive and accessible technology

Beyond cost, some of the most mentioned barriers to accessing AT were the lack of training, support, and digital competencies. Moreover, awareness of AT and its potential impact and problems of interoperability where phones and dedicated AT work poorly together

3.5.6. There is great potential impact through widening the scope of assistive devices to include consumer technologies

Expanding the list of funded AT devices to include mainstream devices would positively impact and increase the quality of life for people with disabilities, including the elderly, for whom it would reduce loneliness.

3.6. Towards a standard set of SRoI metrics and qualifiers for AT

The potential impact of addressing the expansion of funding for consumer technologies for people with a disability can be considered through any social return on investment (SRoI). SRoI provides a sound basis for creating measures to evaluate the non-financial benefits of interventions or policy changes (Arvidson, Lyon, McKay, & Moro, 2013) [15]. It allows researchers to consider the social and economic benefits that can provide new opportunities for participation and independent living for persons with disabilities. In considering this approach, we aimed to provide a set of factors that governments may consider when investing in purchasing or providing AT and mainstream technologies to support the independent living of persons with disabilities.

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Scholars have shown the challenge of quantifying social benefits (Arvidson, Lyon, McKay, & Moro, 2013) [15]. Therefore, the research focused on providing an initial set of metrics and qualifiers that governments may use to evaluate the social benefits of any potential investment in expanding the list of eligible devices or eligibility of existing devices. As national contexts and levels of investment vary, these metrics may be used as a basis for calculating SRoI in various social and economic contexts where regional, national, or international governments are considering investing in improving AT support and provision.

The results from this work revealed six key themes. The social benefits of each theme are articulated below to provide a clear and measurable standard on which authorities can draw to evaluate the existing AT provision systems and the SRoI of investing in new AT. While these metrics are meant to provide a broad range of criteria for assessing the provision and impact of AT, they are not comprehensive and require further validation.

The first metrics focus on the social impact of providing effective AT to meet users' needs.

3.7. Economic and Personal Benefits of Effectively Providing AT

Economic Benefits

- To what extent does the provision or expansion of AT increase competition among providers?
- To what extent are a variety of choices or options of AT available?
- To what extent has the provision of AT resulted in the reduced cost of AT?

Personal Benefits

- To what extent has the provision of AT contributed to increased exercise?
- To what extent does the provision of AT contribute to improving health outcomes?
- To what extent has the provision of AT contributed to an increase in quality of life?
- To what extent has the provision of AT led to an individual gaining or remaining in employment?
- To what extent has the provision of AT led to an individual entering or remaining in an educational program?
- To what extent has the provision of AT reduced loneliness or isolation?
- To what extent has AT provision improved an individual's perceived social support?
- To what extent has the provision of AT reduced the stigma of disability?
- To what extent has the provision of AT reduced the financial burden for the individual?
- To what extent has the provision of AT improved an individual's self-efficacy?

The second set of metrics focuses on evaluating AT provision to generate the greatest social benefit from investment.

3.8 Provision of AT

Technical Support and Provision

- The average length of time for repair.
- The average length of reimbursement time.
- The average time for new AT or consumer technology to be available for purchase or provision? (e.g., time from market availability to availability for purchase or provision)
- Are temporary replacements offered during repair?

- Are multiple channels (i.e., digital and non-digital) available for purchasing and supplying AT?
- Are support and training provided for using AT? Does this include training for using mobile technologies?
- To what extent is support and training for using AT accessible for persons with disabilities? To what extent is that support or training focused on highly specialised or complex AT?
- To what extent do online training platforms adhere to the latest Web Content Accessibility Guidelines or other international standards for web accessibility?
- Is information provided regarding compatibility between AT and consumer technologies?
- To what extent are awareness campaigns used to promote the applications, availability, purchase, and adoption of AT and consumer technologies?
- To what extent are broader stakeholders (e.g., family members, employers, teachers) considered in providing information and training and raising awareness?
- To what extent are all user groups (e.g., older adults, people with temporary disabilities, second language users) taken into consideration in AT provision and support?

Individual eligibility and needs assessment

- To what extent is employment a criterion for eligibility?
- To what extent is age a criterion for eligibility?
- To what extent is income a criterion for eligibility?
- To what extent are individual needs assessed?
- To what extent are concerns or fears about stigma and technophobia assessed?

Technology assessment

- To what extent is interoperability with the latest technology communication protocols and standards (e.g., Bluetooth) considered in eligibility criteria?
- Are there procedures for updating eligible technologies to align with the latest consumer technology?
- To what extent are mobile technologies available?
- To what extent are mainstream, non-specialised (i.e., consumer) technologies eligible to be included in AT provision?
- To what extent does this include mobile technologies (e.g., smartphones, wearables, smart home devices, independent living technology.)?
- To what extent are Disabled People's Organisations involved in decision-making concerning the assessment and eligibility of AT?
- To what extent are small- and medium-sized AT providers given support or priority in provision?
- Is training provided for decision-makers and sales agents on mobile technologies and AT?
- To what extent is affordability considered in eligibility criteria?
- To what extent are technologies produced outside of the domestic market eligible?

Other factors

- The average time to implement and adapt international standards to local languages.
- To what extent are government agencies that provide AT recognisable to the public?
- To what extent are international organisations (e.g., GARI) considered a reliable source of information?
- To what extent are the lists of AT available open access?

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4. Discussion

As consumer devices become increasingly accessible, more users with disabilities are identifying accessible consumer electronics as an effective way to address their needs. The devices provide a range of accessible and assistive functions rather than only addressing one specific function. For many people with a disability, there is greater enjoyment in using mainstream products that avoid the stigma of using dedicated devices.

Currently, most national funding systems are not designed to respond to this preference and opportunity. Systems effectively deny access to consumer technologies, ignore a means to bridge the significant gaps in AT provision with desirable technologies for users, and potentially fail to offer the available additional and unanticipated benefits.

Funding systems seem to be rooted in an approach based on equalising deficits instead of seeking to improve a person's quality of life and standard of living, as outlined in Gasper's analysis of Sen's capability approach and Nussbaum's capabilities ethic [2].

Investigation of the funding models from domain-specific such as education or employment, direct payments, and private and public insurance schemes, to not-for-profit and charitable funding, private funding, and the use of refurbished and reused models found that mainstream mobile technologies can be a cost-effective way of providing people with disabilities with the technology they want and need. Presently, in many cases, people with disabilities and their families are self-funding these technologies. As these technologies can provide people with disabilities with a capability set as defined by Sen [2], they offer an enhanced range of options and opportunities.

To take advantage of this opportunity, our systems for AT provision need to evolve. Furthermore, we need to reconsider the concept of assistive technology to reflect the trend toward digital solutions. This requires a paradigm shift from a simple functional but blurred definition of assistive technology toward a renewed focus on the impact and purpose of provision upon the lives of people with disabilities. In the review, the most effective approach to meeting users' needs was based on those systems that provide direct funding. In these models, people with disabilities can decide what they need and want for the available money.

The greater value of accessible mobile devices that provide integrated text-to-speech, voice recognition, word prediction, and screen readers alongside other accessibility features lies in being the core for comprehensive and personalised solutions upon which an ecosystem of features and functions can be built. These include fall detection, AAC (alternative and augmented communication), sound amplification, and wayfinding. They offer additional value as the preferred platform of users with disabilities, which is likely to reduce abandonment and reach into the widest parts of lives to include social, leisure and entertainment functions. The experience of the pandemic suggests that such devices and functions are central to the emotional well-being of users as an effective means of responding to social isolation and exclusion

Building on the conclusions of our research undertaken, we believe it is evident that accessible consumer electronics are complementary and expand AT in Technology and Environmental Intervention (TEI) as defined by the American Occupational Therapy Association in 2010 [1]. Their definition of TEI builds on the understanding that environmental interventions (EI) refer to modifications and adaptations of the environment in combination with AT to best serve and enable the person with a disability to live independently. With the emergence of the Internet of Things (IoT), smart home technologies, telecare, and telehealth services, the understanding evolved toward environmental interventions being an integral part of assistive technology.

This trend is reinforced through the continued technological progress towards ambient computing, where a combination of smart devices, data, artificial intelligence, and human activity enable computer actions alongside everyday life, without the need for direct human commands or intervention [16].

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5. Conclusions

Given the increasing accessibility and assistive functionality of mainstream mobile technologies, it becomes harder to justify many of the costs of AT. Equally, denying such technologies to people with disabilities due to a lack of AT provision can only reinforce social isolation and lack of self-determination. A balanced model of provision will always need to offer some dedicated assistive technologies, but many people with disabilities are well served with accessible technology. When we examine demographics and an ageing population, it will become increasingly essential to incorporate accessible mainstream technology into our thinking to enable the community to continue living independently for as long as possible.

Unanticipated benefits and the impact that the joy of using these technologies can have on people's lives require further investigation. Research studies at University College Cork have begun to consider how people with disabilities derive pleasure from the technology they are using and seek to understand what this would mean for well-being and quality of life Boyle et al (2022) [17]. We remain far from fully understanding the true impact of these technologies on a person's opportunities and functionings. However, the technology offers opportunities in keeping with Gaspers (1997) outline of Sen's capabilities approach as a combination of well-being and agency but moreover expands upon that in line with Gaspers' description of Nussbaum's capabilities ethic which stressed the importance of a "good life". This integration of thinking is perfectly in line with the potential of technology, despite being dated just as we were seeing the first shoots of the exponential growth of personal technology.

Ultimately, irrespective of the framework for categorising technologies as TEI, AT or accessible consumer devices, there is increasing evidence that these devices empower people with disabilities to live independently, gain employment, succeed in education, and facilitate broader participation in social and political life. Increasingly we see new forms of consumer technology for fitness, well-being, and mobility. To continue to reinforce barriers to provision through outdated distinctions, effectively denying access to available products will only serve to maintain the global failure to meet demand.

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The Global Accessibility Reporting Initiative (GARI) is run by the Mobile & Wireless Forum. It is a project designed to help consumers learn more about the accessibility features of mobile devices and to help them identify devices with the features that may assist them with their particular needs. In this research, the Mobile & Wireless Forum or GARI Initiative engaged Global Universal Design Commission Europe (GUDC-EU) and David Banes Access and Inclusion Services to conduct the work.

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