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D 3.4 Report on Assistive Technologies Trends Impacts and Related Policies

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Reviewers	TUE (Elvia Vasconcelos); TRI (Tally Hatzakis)
Abstract	The document starts revising relevant digital trends already identified in 3.2, outlining their relevance for people with disabilities, going to analyse the trends in the framework of Assistive Technologies and their application w.r.t TRIPS scopes.
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Executive Summary

This document explores the trends and state of the art in Digital Assistive Technologies - the mobility options and ease of use for people with disabilities- in order to identify their potential impact on future mobility solutions. Assistive Technologies (AT) are those technologies that enable access for people with disabilities, they pervade across all aspects of daily life and are the subject of significant research and development efforts.

The pervasive nature of assistive technologies creates potential impact on all aspects of the life of users. In planning and promoting access to transport systems through AT those charged with implementation should seek to understand the broader impact of AT to ensure an equitable and consistent approach across domains. The present document seeks to guide the reader in understanding the potential impact of emerging technologies as experienced by people with disabilities in using current and emerging transportation for personal mobility.

To do so we have firstly explored some of the underlying social and technological influences that are driving trends in assistive technologies, including both user expectations and their behaviours, together with the underlying economic and demographic trends that are influencing the design of assistive technologies. These influences inform a review of the broad and mainstream technology trends that are most impacting on the design and development of assistive and accessible technologies that affect how people with disabilities engage and interact with mobility systems. The report further examines the impact of such innovation on the lives of people with disabilities, including increased opportunities for mobility and access to transport, examining each stage of the user "journey" and considering how innovation is reducing potential and actual barriers at each step, drawing from the findings of D3.2, and considering the outputs of D3.1 and D3.3.

The review established two key findings:

(1) Increasingly emerging technologies are moving from the provision of specialist devices designed solely for those with a specific need towards an increasing blend with mainstream technology that promotes benefits for all users. This reflects an increased interest in universal design principles and the pervasive nature of technology which requires access in less than optimal settings. As mainstream technologies increasingly embrace redundancy of input methods, integrating touch, sound and vision, there is greater flexibility for the user to determine the format in which information is received and the levels of control established. This blurs even further the boundaries between assistive and mainstream technologies.

Emerging trends in digital and assistive technologies demonstrate capacity to address many of the pain points experienced during travel by persons with disabilities. Such technologies need to be integrated and implemented across all stages of the travel experience and have clear benefits not only to those with disabilities but for all those challenged in making a journey, who

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might experience situational disability in a new setting, where language and services are not familiar. In addition, action needs to be taken to implement technology in ways that maximises their beneficial impacts for users. These would include addressing the need for trained and confident personnel, the creation of an accessible infrastructure through inclusive design, and the modular integration of interfaces to respond to a variety of needs

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List of acronyms/abbreviations

Abbreviation	Explanation
AAATE	Association for Advancement of Assistive Technology in Europe
ACPC	Always Connected PC
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
ASR	Automated Speech Recognition
AT	Assistive Technology
ATIA	Assistive Technology Industry Association
DBLP	Digital Bibliography & Library Project
DSI	Digital Social Innovation
ETA	Electronic Travel Aids
FLOSS	Free Libre Open Source Software
HCI	Human Computer Interface
HMI	Human Machine Interface
ICCHP STS	International Conference on Computers Helping People with Special Needs Special Thematic Sessions

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Abbreviation	Explanation
ICF	International Classification of Functioning, Disability and Health (WHO)
IIT	Istituto Italiano di Tecnologia – Italian Technology Institute
IOT	Internet Of Things
IPR	Intellectual Property Rights
MaaS	Mobility as a Service
ML	Machine Learning
NLP	Natural Language Processing
OS	Operating System
pwd/PWD/PwD	Person with disability
RPA	Robotic Process Automation
SI	Social Innovation
UD	Universal Design
UI	User Interface
VR	Virtual Reality
WHO	World Health Organisation

Table 1: List of acronyms/abbreviations

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Glossary of terms

Term	Explanation
Edge computing	Computing outside the cloud, happening at the edge of the network, and more specifically in applications where real-time processing of data is required. Edge computing operates on "instant data" that is real-time data generated by sensors or users, generally delivering low latency nearer to the requests.
GDPR - General Data Protection Regulation	The General Data Protection Regulation (EU) 2016/679 (GDPR) is a regulation in EU law on data protection and privacy in the European Union (EU) and the European Economic Area (EEA). It also addresses the transfer of personal data outside the EU and EEA areas
Google Scholar	www.scholar.google.com freely accessible web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines
Human Augmentation	It is founded upon technologies that once implanted into a person, will enable them to execute tasks that were previously impossible
Kialo	www.kialo.com Online discussion tool used to collect opinions about uploaded topics
Print impairment	A Print impairment is a difficulty or inability to read printed material due to a perceptual, physical or visual disability.
Researchgate	www.researchgate.net European commercial social networking site for scientists and researchers to share papers
Uber	American multinational ride-hailing company offering services that include peer-to-peer ridesharing, ride service hailing, food delivery (Uber Eats), and a micromobility system with electric bikes and scooters

Table 2: Glossary of terms

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1 Introduction

The way we interact with technology is undergoing a radical transformation which has the capacity to significantly benefit those with disabilities. Smart systems, such as digital conversational platforms, augmented, virtual and mixed reality, aim to provide more natural and immersive interactions with the physical world. Such systems are dependent upon the ability to process and analyse large datasets and must be continuously sensing and adapting. The same applies to the security and risk infrastructure that supports it, which must focus on protecting privacy whilst enhancing personal safety and cybersecurity.

For the purpose of this study the definition of assistive technology is taken by AAATE statement: "In the XXIst century Assistive Technology (AT) should be defined as a scientific & technologic approach to the development of products and services oriented to support the elderly and people with disabilities in their daily activities, maximizing their personal autonomy, independence, health and quality of life"[1]. This means a number of services and devices aimed at addressing a wide extent of needs: from structure and function substitution (protheses) for handling and mobility, to accessibility tools that help people to operate through digital media, as well as specific and customised systems to support sensory and communication functions.

Assistive technologies can be characterized in many ways: high-tech or low-tech, specialist device or mainstream platform, human augmentation, or inclusive design. In this plurality some underlying trends can be identified.

As Assistive Technologies (AT) are those that enable access for people with disabilities, they pervade across all aspects of daily life and are the subject of significant research and development efforts. The pervasive nature of assistive technologies creates potential impact on all aspects of the life of users. In planning and promoting access to transport systems through AT those charged with implementation should seek to understand the broader impact of AT to ensure an equitable and consistent approach across domains. The present document seeks to guide the reader in understanding the potential impact of emerging technologies as experienced by people with disabilities in using current and emerging transportation for personal mobility.

Hence, this document explores the potential impact of Digital Assistive Technologies trends on future mobility options for people with disabilities. Without an understanding of the drivers shaping the development of assistive technology, and if the pervasive nature of assistive technologies is ignored, those charged with planning and implementing modern integrated transport infrastructure are likely to fail to take advantage of new opportunities, whilst ignoring current barriers to free and independent movement, thus maintaining the status quo of social

[1] **Challenges for Assistive Technology** in Assistive Technology Research Series, Vol.20-2007, Gorka Eizmendi, José Miguel Azkoitia, Gerald Craddock

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and economic isolation of disabled people. Equity in personal mobility enables full access to education, employment and daily life. The collective experience during the Covid19 pandemic in Europe might suggest that when access to these aspects of life is inequitable, then society as a whole suffers.

2 Methodology

The deliverable and report has been created through a process of detailed desk research, validated by expert interviews and advice. The research was undertaken using an iterative approach examining both the academic and grey literature related to assistive technologies, access and inclusion of disabled people.

2.1 Stage 1 – Emerging Digital Technologies

In seeking to identify key emerging technologies with potential impact on assistive products and the lives of people with disabilities, the researchers built and elaborated upon the activity undertaken in T3.2 through three interconnected activities undertaken following the initial exploratory workshop on emerging technologies and assistive products delivered at ATIA 2020 (January 2020).

- Social Listening

Social listening is the process of tracking mentions of certain words, phrases, or even complex queries across social media and the web, followed by an analysis of the data.[2] Whilst originating from the field of marketing it has been utilised more broadly to identify industry trends and political or public opinion. People with disabilities and the professionals that engage with them use a wide range of social media tools, so social listening was not limited to one platform but included LinkedIn, Twitter, Facebook (pages and groups) and Pinterest. Throughout February posts from over 30 sources across platforms were tagged according to the technology discussed and the strength of endorsement by users. The emerging technologies outlined below were initially shaped by those most referenced with the greatest number of likes and positive comments.

The impressions from social listening were further refined through online discussion facilitated through Kialo; an online discussion tool which allows self-selecting stakeholders to express both a preference and a rationale for their opinion and choices

The semi structured approach to social listening was an important first step in refining the research questions to be considered and determining search terms for the desk research.

[2] https://marketingland.com/social-listening-267175

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- Desk research

Internet searches were undertaken using Google Scholar, ResearchGate, DBLP and other online repositories, to seek out data on current trends in digital technologies. These included both academic publications, market research reports and summaries within blogs and popular press. Key search terms used combinations of "technology" "emerging" "disruptive" "innovation" "trends" "digital" to identify those technologies with the greatest influence. Additionally, during this research stage, trends in demographics and economic constraints were identified.

2.2 Stage 2 - Trends in AT – Impact of emerging technologies on AT

At this stage, the Interplay between emerging and disruptive trends with assistive and accessible technologies was examined through the desk research and interviews conducted, aiming to identify the technologies with the greatest potential to be applied within the transport domain. Christensen (2005) distinguishes between two types of innovations: incremental innovation and disruptive innovation. In the model, incremental innovation has relatively minor impact upon the market and does not change conditions of use radically. It usually builds upon existing knowledge and products. Whereas disruptive innovation often seeks to "wipe the slate clean" with unanticipated consequences and impact that the market does not expect. It usually brings about or is developed from radical technical or technological change.

The many possible forms of assistive technologies that could be subject to rapid innovation can be illustrated through the table below, adapted from Margetis et al (2012).

Category	AT Examples
Visual Layout adapatations	UI adaptation to user need Desktop adaptation UI Plasticity for usability Design for all and unified design
Voice Technologies	Screen readers Text to speech Voice Commands for device control Speech based dictation Voice Browsers Voice portals Voice based mobility aids Speech based cursor control Document to speech
Scanning	Applications with embedded sanning

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	Scanning tools Visual keyboards with scanning
Touch	Single Touch Multitouch Multitouch and multiuser Hand positions and shape recognition Gestures recognition
Haptics	Haptic devices Embedded vibration Tactile screen
Handwriting	OS with handwriting recognition
Eye Tracking	Gaze gestures Mobile and wearabkle Trackers
Gestures	Vision based gestures Gesture based on sensorimotor actuators Mouse and multitouch gestures

Figure 1 –adapted from Assistive technology categories[3]

The desk research undertaken sought to identify the most widely used form of HCI underpinning assistive technologies. These would included "Touch" "Voice recognition" "Haptics" etc. Once an initial list was identified a second stage of desk research explored correlations between each of the emerging technologies and the assistive technologies e.g. searching for research related to "AI + Screenreader" "VR + Gestures". These included the increased use of natural interfaces with an analysis of potential barriers and the concept of sharing interfaces across groups to enable access. The desk research thus began to identify the relationship between emerging technologies and the development of assistive and accessible technologies.

- Digital Expert Interviews

Expert interviews were added to the data set to seek input on research and development that has not yet been fully published or is not publicly available. Such experts included both AT experts and those working on specific projects. Over 30 experts were approached and asked to respond to an online interview in the form of a questionnaire. A semi structured approach to the design of the interview was taken, using open questions related to forms of emerging technologies with prompts related to impact upon people with disabilities and the likelihood of implementation.

[3] Margetis, G., Antona, M., Ntoa, S., & Stephanidis, C. (2012, November). Towards accessibility in ambient intelligence environments. In *International Joint Conference on Ambient Intelligence* (pp. 328-337). Springer, Berlin, Heidelberg.

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The 30 experts approached met identified criteria and were drawn from a diverse set of related fields, including academia, private sector and not for profits including organisations led by disabled people. The interviews were scheduled during March and April 2020 at the height of the Covid pandemic in Europe with a transition to home working taking place. This had some impact on the availability and willingness of experts to contribute.

- ICCHP STS/workshop on Digital trends and access to transport

The relationship between trends and AT will be reviewed at the ICCHP STS conference taking place in September 2020 on "Innovation and Implementation in the area of independent mobility through digital technologies". This is an additional activity to extend the results of this Task. The Deliverable will be supplemented for this purpose during the remaining duration of WP3.

2.3 Stage 3 – Emerging Access and Mobility

At this stage, the researchers investigated in greater detail the current state of development of assistive and accessible products, technologies, and services to highlight those with the greatest potential impact in the transport and mobility domain. The examples and information gathered were further analysed to generate specific case studies. This data was gathered through ongoing desk research which sought to map relevant projects and initiatives in the TRIPS domain to identify those that are drawing upon cutting edge assistive and accessible technologies. Examples of projects related to each stage of the user journey. from initial decision and planning to arrival at destination, were reviewed to identify innovations that could be built into a delivery chain by TRIPS.

2.4 Stage 4 – Implications for guidance

During this stage the researcher teams developed D3.1, D3.2 and D3.3 with the aims to evaluate the extent to which current policy and practice enables the implementation of the innovative solutions identified, and where they do not appear to adequately support such action what actions might be required to address this. Throughout the research regular meetings to discuss findings were held using conferencing tools and draft documents were stored for comments and analysis in a shared workspace. The interactions informed the scope of thinking on the forms of transport that were likely to be available for people with a variety of needs and impairments, and moreover the complexity of related standards and policy that impinged on the development of assistive tools. As increasingly assistive tools were defined as being integrated with consumer technologies, not identified as medical devices, there were significant areas of standards and policy that were subject to review.

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2.5 Conclusion

The methodology presented demonstrates how the desk research was initially shaped and refined through a broad model of social listening and initial workshop. The impressions gathered at this early stage helped to refine and revise the desk research throughout the work package. The analysis of the desk research was then further validated not only by the authors and colleagues within AAATE and working on other work packages, but also by an experienced and relevant team of AT experts with a special interest in research, development and emerging trends for assistive technologies

This process has ensured that the technologies described below are relevant to the mission of TRIPS whilst fully understanding that the interplay of AT and forms of transport is not separated from other forms of integration and interaction across the daily life of users.

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3 Influences driving Digital Trends

Digital trends have a complex relationship with the development of assistive technologies. The technologies that are emerging are having a significant impact on user habits and behaviours, not only for people with disabilities, but also for non-disabled consumers and citizens. But those trends are also shaped by user behaviour which influence the development technologies and applications that are relevant for the TRIPS project. Technological development must be viewed within the broader context of social trends as they are part of a wider co-evolutionary scheme[4] involving value, policies, and technology interactions. In building an inclusive infrastructure for accessible transport, there is a need to not only respond to new products and services as they appear on the market, but also to anticipate future development to ensure that services are prepared for integration of new opportunities as and when they become available. This understanding of influences, trends, products and services is essential in seeking to enable transport provision to be fertile ground for inclusive innovation in the future

The availability of support services emerging coming from the application of underlying technologies (as defined in D3.2) facilitates the implementation of the opportunity within new domains as well as the rapid development of well-established and known areas of daily life.

3.1 Social Background to Innovation

Advancement in assistive technologies (AT) is driven by both disruptive and incremental innovation, (Christensen 2005) and frequently emerge from converging “incremental innovations” in related fields. The complexity of such advancement is integrated with social evolution addressing concepts of “product”, “service”, “ownership”, and “sustainability”.

Definitions of “hardware” and “software” are linked to a perspective of products where the parts are considered as separated and so evaluated accordingly. Increasingly we now see these as integrated. In the case of ACPC (Always Connected PC), performance is dependent on the mix of hardware, Operating System (OS), local applications and networked services or remote apps. Any evaluation of the product depends on access and quality of the services available and required by users.

Concepts such as sustainability incorporate not only an awareness of the environmental footprint of the product or service, but must be enlarged to consider other dimensions, incorporating usability and accessibility as they are defined by Universal Design (UD) and being cognizant of a population that is diverse with varying functional profiles and different cultural

[4] Gual, Miguel A., and Richard B. Norgaard. "Bridging ecological and social systems coevolution: A review and proposal." Ecological economics 69.4 (2010): 707-717

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origins and language influences. This issue of the impact of language and culture is highlighted in D3.3.

In seeking to understand the impact of emerging technologies we pay attention to customer and stakeholder needs within a pervading industrial economy model (typical of 2.0 and 3.0 Industry era) that was built upon mass production leading to the design and provision of "standard" products proposing a "one size fits all" approach.

Social Innovation (SI)[5] and Digital Social Innovation (DSI) offers evidence of a paradigm shift toward stakeholder or customer communities centred innovation: they are the protagonist of need identification (user requirements) but more frequently are involved also into development of suitable solutions. SI and DSI overlap with two trends typical of recent years: democratization of technology and inclusive design.

3.1.1 Democratization of Technology

Democratization is concerned with equality of access with associated rights and responsibilities. Equality of access may demand equal access to products and services regardless of status or location. Such equality has implications for design of future products as increasingly there is a need to ensure that users from across the spectrum of age and ability are actively involved in the end to end design process. The underlying trend towards democratisation in the design of assistive technologies is a key factor in introducing a Universal design approach and allows transport providers to have increased confidence that emerging products and services have been developed to address needs and therefore have a high likelihood of successful use by the intended market segment.

Panetta (2019) asserts four key areas of impact from the democratization of technology that will be most influential in the coming years:

- Application development
- Design
- Knowledge
- Data and analytics

This trend is encouraged by the availability of resources at low-cost/no-cost which are typical of digital applications. "Instructables"[6] channels are explaining "how to" fabricate and build applications that can be built by non-technical people. Years ago, Arduino[7] modules opened the opportunity to build specific hardware for diverse applications, including those for specific needs, with nearly the same power of commercially available systems. Spakfun[8] and similar online communities, are able to provide the functional parts such as microprocessors, sensors,

[5] Ref.: https://ec.europa.eu/growth/industry/policy/innovation/social_en
[6] https://www.instructables.com/
[7] https://www.arduino.cc/
[8] https://www.sparkfun.com/

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actuators etc. to manufacture a design and to experiment it with specific solutions. In terms of low-cost mechanical components, additive manufacturing, offered by 3D printers, is increasingly within everyone's reach and there is a flourishing community around design repositories such as Thingiverse[9] and Yeggi[10], which are collecting object files covering many needs. Equally, block programming and software development has pivoted from an educational context toward real world applications: MIT App Inventor[11] allows the creation of apps with limited digital programming literacy.

Hacking has become a common way to adapt standard products to address individual specific needs and is no longer conceived of as a hobby "just for nerds". Hacking, because of technology democratisation, is ready to be applied to further technological domains exploiting each option and feature. Despite regulatory concerns, we are forced to rethink IPR (Intellectual Property Rights) and ownership concepts as they have been thus far conceived as static concepts in products and services.

Some developments often related to open source applications are already providing the opportunity to customise and "re-build" code. This has been also referred to as the "*forever beta*" phenomenon, in which users knowingly accept to using a product that will constantly evolve.

3.1.2 Inclusive design

Such democratisation includes the increased recognition of the value of Inclusive and universal design as an important approach to address the needs of a broad community by consideration of all of its members. Designers are encouraged to think about all potential users of the products and services that they are designing. As a result, data used to shape those designs needs to reflect all potential users and avoid datasets that are too narrow or non-inclusive and which ignore those that could be defined as outliers. In a 2019 interview Daniel Sun, vice president analyst at Gartner said "Designers should work with data and analytics professionals to ensure that the data reflects the needs, values and behaviours of all segments of targeted customers."[12]

3.1.3 Quadruple Helix Innovation process

All these changes are modifying some "postulates" on which the value chain in innovation process was based. The "Triple Helix"[13] development model describes innovation as a recurrent process where the tracks (interest and mutual influences) of the key drivers are tied together around the timeline. The recognised drivers are academia (universities, research centres) as places of invention, industry as places where the invention could be placed on the ground and made replicable, and the governmental authorities, financing part of the innovation process

9 https://www.thingiverse.com/
10 https://www.yeggi.com/
11 https://appinventor.mit.edu/
12 https://businesstech.co.za/news/trending/362156/top-5-digital-technology-trends-for-2020/
13 "The Triple Helix Concept". Stanford University Triple Helix Research Group. 11 July 2011

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and regulating innovation deployment in societal framework. This model seemed to recognise the players of the innovation development so that it could be replicated with different weights in worldwide societies (from high-income to low-income countries).

Nowadays, concepts describing the innovation model (both incremental and disruptive) are moving from the Triple-helix model to a Quadruple-helix model[14] (which includes stakeholders and civil society). It takes note of the new role of clients in the process, not only as an object of study (from market analysis to Living Labs) but also as drivers of the innovation itself. This new role involves financing (bottom-up models through crowdfunding) requirements definition, and sometimes to be part of technological development process: for instance the Italian association of deaf persons (ENS – Ente Nazionale Sordi) has become a producer of innovative apps for deaf assistance/orientation[15].

All these aspects are part of a co-evolutionary scenario with mutual influences through digital technology. They constitute a promising scenario (ecosystem) for disabled people in general. The International Classification of Functioning (ICF) suggests a description of human behaviour as related to "functional profile" (momentary or permanent) which is part of the person. "Disability" is produced by the degree of adaptation of that functional profile to the social and physical environment where the person is operating.

The concept, that a person is either disabled or "not disabled", is rejected by disability activists in favour of a social model of disability, where context and environment dictate the extent to which an impairment becomes a disability. This merges with Universal Design (UD) concepts in use cases and their prevalence in thinking of design adaptations. Sharing the knowledge about technology is giving power to people with different needs to see their needs addressed not as an afterthought but as part of the general curve diffusion of innovation[16] and so introduces adaptations and suitable strategies or modifications, throughout innovation conception, as part of user requirements and specification.

The social model can be extended to a human rights model and perspective of disability. From this perspective technology and accessibility become human rights as well as tools for exercising human rights, and hence universal design is not simply concerned with removing barriers as expressed in the social model, but instead is concerned with building for equality and the participation of all citizens.

Stigma related to such different functional profile has also changed in recent years. This change was pushed by success story of those with disabilities in several fields. For example, elite athelets with disabilities participate using prostheses that allow them to perform better than runners without prostheses introducing debate and discussion of human augmentation into the public arena.

[14] https://vb.northsearegion.eu/public/files/repository/20180924154616_QuadrupleHelixguide.pdf

[15] https://ens.it/servizi/82-aci-sordi/8290-e-online-l-app-aci-sordi-per-sistemi-ios-e-android

[16] Rogers, Everett M. (1983). *Diffusion of innovations* (3rd ed.). New York: Free Press of Glencoe

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3.1.4 Human Augmentation and wearable technology

In understanding the growth and development of assistive technologies, it is crucial to understand that increasingly assistive products are both portable and used in multiple scenarios and contexts. This trend is accelerated by the growth of wearable technology that is widely available and is likely to pave the way for new forms of human augmentation. Human augmentation is controversial and has been defined as the process by which a person's physical and cognitive ability and capacity is strengthened or enhanced. It is founded upon technologies that once implanted into a person, will enable them to execute tasks that were previously impossible. This has implications for both the non-disabled population and for those experiencing a disabling condition. It is perhaps controversial as it draws upon a medical model of need where the accommodation is provided by enhancing the person, rather than addressing the social and physical environment. In practice both are like to be necessary and desirable in the future.

Human augmentation may enhance physical capability but may also enhance a person's ability to think and make decisions. Technologies such as 3D printing are influencing advanced prosthetics as universities expand research into 3D printing of body parts e.g. Princeton University has developed 3D printed "ears" that can perceive frequencies far beyond the range of normal human capability. Human augmentation (cyborging, trans-human) constitutes an application frontier that will interest all: experiences about an over-numeral finger and added parallel hand are already in place in IIT (Istituto Italiano di Tecnologia) – Genova (IT)17. They are proposing "protheses" aimed to supply additional and competitive advantage and not simply as functional remedial solution18.

In seeking to plan for the integration and interoperability of assistive technologies with transport systems and infrastructure, appreciation that the AT will be available to the user regardless of setting is crucial to establishing an equitable solution that is consistent with access in other parts of the user's life.

Taking into account the complexity of the scenario summarised above, in the following we seek to specify impact and connections of selected digital trends as identified in TRIPS D3.2.

[17] https://www.iit.it/it/ricerca/linee-di-ricerca/2d-materials-engineering

[18] Introduced, in some way, by wearable technologies (in general), this concept of transformation is not completely new. We have also to take into account how we are all already experiencing

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3.2 Internet of Things (IOT)

The Internet of things is having a significant impact upon people with disabilities, facilitating control over their environment, whilst gathering data to allow currently challenging tasks easier.

Holdowsky et al (2015) note that the importance of IoT lies in the underlying technologies that make it effective. Technologies such as Artificial Intelligence (AI) driven analytics, network speed, sensor technologies and edge computing, are at the heart of the next generation of devices. As data is amassed from smart devices, the need for analytics systems, built on AI and machine learning are necessary to make sense out of it all and creating actionable insights from it. Dahlqvist (2019) highlight the growth of IoT connected devices and that many “things” or devices are being designed with Wi-Fi capacity, connecting to both Internet, and each other. Consumers, including those with disabilities are already using and benefitting from IoT connected devices. Users can lock doors remotely, preheat our ovens on our way home, track our fitness on wearables or hail a taxi with Uber.

IoT supports greater safety, efficiency, and decision making through the collection and analysis of data. Such analysis offers a diverse set of benefits including areas such as mobility, health care or customer service.

As we look towards transport systems, it is important to recognise the variety of “things” that a user will engage with during a journey. By connecting these “things” during the journey we provide both active real time data upon which user decisions can be based, and facilitate personal control over parts of the transport system that addresses barriers.

3.3 5G, WiFi 6 and connectivity speed

To ensure that the control and analysis referenced above is realistic, there is a need for the transmission of data between objects, technologies, and users to be fast, consistent and reliable. This is especially true for those with disabilities who are reliant on the data for use of their AT and its interoperability with transport systems

Hoffman (2019) suggests that 5G Networks are defined as cellular networks capable of high throughput and data download, that can be divided into small geographical areas connected to the Internet and telephone network through a local antenna in the cell. The main advantage of these networks is that they will implement private/local services to support specific communication purposes.

Speed of connectivity is enhanced by improvements to the efficiency and response rate of systems through which data analysis is made. Edge computing brings enhanced data storage and computation to services reducing response times and saving bandwidth. This is especially

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valid when exploring the implementation of the Internet of Things (IoT). The capacity to store, retrieve and process data, issuing commands to IoT connected devices has considerable value for technologies such as drones and robotics and autonomous vehicles.

Hirscher (2020) suggests that Wi-Fi 6 will also be bringing faster processing and connectivity speeds when integrated with 5G and represents an opportunity for ultra-fast connectivity across both home and office. The real value of Wi-Fi 6 will be its ability to extend faster data speeds to far more devices than previously possible, facilitating the growth of connected devices on Wi-Fi networks requiring faster, more efficient, and smarter Wi-Fi capabilities. As the quality and volume of data consumed through networks increases Wi-Fi 6 will eliminate data blockages. For those people with disabilities, such consistent speed and connectivity will encourage still further the uptake of emerging technologies as accommodations to support access.

As transport systems are dynamic and open to disruption because of sudden changes to conditions, the ability to connect and communicate with objects and information is critical to the design of accessible and assistive technologies. Increased speed and reliability of connectivity leads to greater confidence on the part of disabled users.

3.4 Virtual Reality (VR) Augmented Reality (AR) and Mixed Reality (MR)

Enhanced realities offer people with disabilities the opportunity to augment their perceptions of reality to assist in making decisions and in rehearsing journeys, thus contributing to reducing anxiety. The more confident travellers with disabilities are in the transport system, the more included they are likely to be.

A technology that is emerging and gaining traction amongst the population is those of Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) applications. Explanations of the technology such as Gupton 2017[19] highlight the differences between each technology. VR immerses the user within a digital environment, replacing the physical world, whilst AR enhances the physical environment with additional digital information. VR has become popular as a gaming and entertainment platform to date, but has also been used for training, through simulation software such as that used to train U.S. Navy, Army and Coast Guard ship captains. One of the most widely known implementations AR was the popular Pokémon Go game for mobile phones. More recently AR has been used to provide augmented wayfinding and orientation through products such as Google maps creating augmented overlays giving local information and directions. Mixed Reality combines physical and virtual worlds to create new environments and visualizations, where physical and digital objects integrate and interact with the other in real time. All these technologies have potential in the fields of training, cultural and

[19]https://www.fi.edu/difference-between-ar-vr-and-mr#:~:text=Augmented%20reality%20(AR)%20adds%20digital,the%20camera%20on%20a%20smartphone.&text=Virtual%20reality%20(VR)%20implies%20a,shuts%20out%20the%20physical%20world.

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social activities, entertainment, education, marketing, and rehabilitation. They could be used to train doctors, offer museum goers an in-depth experience, enhance theme parks, or enhance marketing.

Whilst such digitally enhanced presentations of reality are in their infancy, the capacity of the tools to ensure that travellers are well prepared and informed for and throughout their journey can contribute to the reduction of perceived barriers and dependency on staff at locations to be available to assist and advise at short notice.

3.5 AI – Automated Speech Recognition (ASR) and Natural Language Processing (NLP) including virtual assistants

Increasingly, control and interaction systems as exemplified by AT, are moving from coded systems such as keyboards towards natural systems such as voice and gesture. These interfaces represent a shift in human-computer interaction and have implications that influence how consumers interact with providers of goods and services. Conversational UIs (or chatbots) are good examples. In these circumstances the steps required to access information or complete a transaction are reduced to a conversation. Using Artificial Intelligence (AI), such transactions are based on the technology predicting what users intend to do or require using data from past interactions, and those of other users.

Such technologies based upon natural systems, when integrated with AI offers opportunities for the development of interfaceless technologies, as described by Gartner[20], with minimal or no physical controls in favour of control being delegated to apps that run on user mobile devices. The availability of larger screens on mobile devices, high resolution and rich device APIs allow for a complexity of device control experiences far beyond what can be achieved with on-machine interfaces. Digital assistants are evolving rapidly, and voice interface with the environment and information will become increasingly central to user experience. The artificial intelligence behind such systems learn rapidly and can help users to engage with products and services throughout the desired interaction or journey.

The growth of natural interfaces offers people with disabilities a vastly increased range of ways that assistive technologies operate. At different times an individual could use touch, voice, and automated interfaces. This diversity will need to be accommodated by transport providers based on a principle of redundancy of input.

[20] https://www.gartner.com/smarterwithgartner/5-digital-technology-trends-for-2020/

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3.6 AI - Machine Learning and rule-based systems (ML)

AI and Machine learning have significant implications for the efficiency of assistive technologies. By making use of AT faster and more accurate, more people with disabilities will be able to engage with transport systems at the same pace and with the same expectations as the non-disabled population.

Companies and suppliers are increasingly investing in AI capacity to enhance user experience and personalize service, reduce human bias, and increase productivity. However, the value of AI and machine is dependent upon the data supplied. AI has been shown to offer a powerful tool for personalizing customer experiences, automating tasks and anticipating needs.

MuleSoft's Connectivity Benchmark survey (2019)[21] identified Machine Learning (ML), basic task automation and virtual agents/chatbots as the most common use cases of AI. The survey further suggested that twenty-five percent of customer service operations will be using virtual customer assistants by 2020. The impact of AI on daily lives is still uncertain as systems are built to reflect human intelligence and to perform tasks such as recognition of images, speech or patterns, and decision making. In many cases AI can do these tasks faster and more accurately than humans. Duggal (2020) reports that five out of six Americans are reported to use AI services in one form or another every day. This includes apps for navigation, streaming services, smartphone personal assistants, ride-sharing apps, home personal assistants, and smart home devices. Increasingly AI is also used to schedule trains, assess risk, predict needs, and suggest efficiencies, helping to reduce costs and maximise usage.

Concerns have been expressed at the challenges of gathering data from people with disabilities to ensure that algorithms reflect a diversity of users (Marzin 2018). The need for data sets that acknowledge and integrate those who fall outside the non-disabled persona is essential if AI is ever to deliver inclusive products and services (Treviranus 2018). Digital integration into people's lives is now so deep that data analytics has more information than it could ever be utilised, and this has turned the focus to how consumers interact with the available technology. This understanding is used to create profiles that can be used for AI analysis and include usage of social media apps, curation of personal profiles online, pictures posted, and places visited. As profiles are generated through AI, consumer consent is neglected and the tolerance of people with disabilities may be quite different to others if they perceive different costs/benefits. This need is highlighted in deliverable 3.3 and discussed further below.

The use of AI and Machine learning in the design of assistive products links closely with the use and application of data, together with related analytics as expanded below.

[21] https://www.mulesoft.com/press-center/technology-trends-2019-connectivity-benchmark

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3.7 Big Data Analytics

People with disabilities are seeking a seamless experience when travelling and engaging with the transport infrastructure. The assistive technologies that they use are the interface to that experience and to the tools supplied by transport providers to facilitate each stage of the journey. Underlying this front end there will be a need to effective use of data.

Using and applying data

To provide such a connected consumer experience, providers are seeking to gather, analyse and apply data to deliver the digital experience desired. Customer and supplier data are being integrated into products and services to improve customer service, streamline operations and to innovate. Data is gathered from the interactions and behaviour of customers and product users to identify preferred options and accelerate decision making. An understanding of individual actions and preferences shapes the desired personalised experience of users. However, the misuse of such data has been highlighted in WP 3.3 as a risk to providers and a concern for consumers.

Data Privacy and Security

WP 3.3 summarised some of the actions taken to address widespread public concern following privacy and security failures from technology companies and service providers. We have seen the establishment of the General Data Protection Regulation (GDPR) within the EU and further calls elsewhere to impose controls indicate that the need to address data security and privacy issues is likely to continue to grow. Privacy and transparency are increasingly required by consumers, including those with disabilities to build brand confidence. Any digital innovation for mobility will need to allow users to opt in or out of data collection schemes with greater ease and awareness than in the past.

Innovative technologies including voice assistants and social media are increasingly the subject of such concerns which are of special relevance to people with disabilities who have been identified as vulnerable and who have experienced historic levels of increased abuse, including financial abuse and fraud. The potential of such risks in other fields such as e-health and telecare further suggests concerns related to data privacy, and is relevant to the experience of people with disabilities

The risks and potential mitigations for people with disabilities require coherent action that recognises the various ways in which the tools and data are accessed by assistive technologies, both current and emerging.

3.8 Robotics and Automation

The experience of travel can be challenging for many people with disabilities, and we examine some of the additional challenges in the analysis of the end to end experience later in this

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report. The growth of robotics and automation is a significant contribution to addressing some of these additional barriers.

Automation seeks to reduce strain on people by augmenting processes through a combination of sensor driven data, machine learning, and automation to complete tasks. Such trends have seen changes to businesses in retail using sophisticated automation to compete with cashier-less stores. Such businesses as the Amazon Go stores can be found in many parts of the US, and according to reports the number will increase to 3,000 by 2021. It may be that such automation will be accelerated by the fears and response to social distancing measures resulting from Covid-19.
According to a PWC (Price Waterhouse Coopers) report in 2017[22], automation will go through three waves of automation:

- Algorithmic displacing around 3% to 30% of jobs from the early 2020s to mid-2020s.
- Augmentation increasing these percentages higher as technology improves itself.
- Autonomy wave that is predicted to surface in the mid-2030s.

Alongside AI and Machine Learning, Robotic Process Automation (RPA) is a technology that is automating jobs. RPA automates processes such as reviewing applications, processing transactions, compiling data, or replying to emails. RPA automates repetitive tasks, not only physical tasks of low skilled and low-paid workers but could include up to 45 percent of the activities carried out by professionals. (Chui et al 2016)

Forrester Research reported by CIO.com[23] estimates that RPA automation will threaten the jobs of approximately 9 percent of the global workforce, although in 2015 McKinsey[24] reported that whilst less than 5 percent of occupations can be fully automated, some 60 percent can be partially automated.

3.9 Conclusion

The influences and digital trends described are impacting upon our society, communities and individual lives at many levels. The technologies impact significantly upon every industry including those involved in mobility and transport. New business models are emerging that are relevant to those with disabilities, and the trends support key activities such as customer engagement, digital production, smart cities, self-driving cars, risk management, computer vision and speech recognition. Many of our existing processes and "things" are increasingly digitalized, and we anticipate seeing a dual track of engagement across physical and digital engagement. However, over time, it seems likely that the digital track will increasingly take

[22] PWC (2017) Sizing the prize https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf
[23] https://www.cio.com/article/3124638/why-bots-are-poised-to-disrupt-the-enterprise.html
[24] https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/four-fundamentals-of-workplace-automation

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precedence as the desire for personal experience and on demand services dominates planning. This is likely to fuel new business processes and digitally enabled business models and ecosystems.

The way we interact with technology is undergoing a radical transformation which has the capacity to significantly benefit those with disabilities. Conversational platforms, augmented, virtual and mixed reality will provide more natural and immersive interactions with the digital world, but all are dependent upon the ability to process and analyse large datasets, and systems must be continuously sensing and adapting. The same applies to the security and risk infrastructure that supports it, which must focus on protecting privacy whilst enhancing personal safety and security online.

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4 Trends in Assistive Technologies

4.1 Background

There are many terms used to describe technologies that enable and empower disabled users to act independently. We note that there is no clear and simple definition that encompasses all of them. The term “assistive technologies”, for example, includes an increasing and diverse portfolio of technologies, but terms such as rehabilitation technologies and accessible technologies add further to the scope and are at times used specifically and others, interchangeably.

Despite this challenge, developers of assistive technologies have recognised the trends described above and some underlying assumptions underpin that development, forming the basis of requirements and specifications for use. For instance:

- The pervasiveness of digital technologies
- Disabled people often have on-demand access to personal devices
- Personal devices are connected to high-speed internet (minimum 3G)
- Personal devices can interact and connect to devices within the environment using local networks (kiosks etc.).

The implementation of innovative technologies does not always consider the need for a receptive ecosystem in which the users have the capacity and capability to utilize the opportunities. These might include digital literacy, economic restrictions related to the cost of services or products and any additional support required from family or community, and the level of disability and the user’s ability to use and adopt digital innovations. In addition, new technologies have an impact upon organizations supporting those with disabilities and require a series of standards and requirements to be met before they approve their release to the market. These may include specification of systems, security and data privacy. As assistive technology options expand, both industries and decision-makers are faced with challenges as to how they integrate technologies and services into existing provision and how to take advantages of innovation to offer alternatives to support inclusion.

Desmond et al (2018) observe that as specialized and mainstream design of goods and services increasingly overlap, new ways must be sought to embed people within AT design. A deep respect for the intrapersonal and socio-cultural meaning of AT use, as well as for human diversity, demands a lifelong learning approach in AT practitioners. A position of mutual exchange with people, as experts in their own needs and experiences, represents the most authentic way to elicit individual goals and to respect individual meaning and potential. This holds for the AT service sector (service providers, AT practitioners) as well as mainstream designers, technologists and innovators. As already mentioned, introducing SI a co-production

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approach to the inclusion of people to work on infrastructure, sustainability, research, policy and development can ensure that the voice of people with disabilities is integral to design.

They continue, stating that for many with disabilities, the growth of options can be both exciting and overwhelming. The historical lack of access to assistive technologies is changing with the confluence of technological development, human rights progress, and progressive public policy. Recent interest in the potential of assistive technology to meet the twin goals of universal health coverage and sustainable development has uncovered a range of assistive technology system gaps.

Systems thinking enables the systematic evaluation of AT and has identified at least five key perspectives: including people, products, personnel, policy, and provision. Bodies of evidence regarding technology abandonment or non-use, consumer dissatisfaction and supply chain complexities suggest that the potential of assistive technology is not yet fully realized, and they point to the importance of matching person and technology and the complexities of matching person, environment, and technology.

Buchanan and Layton (2019) observe that there are a series of underlying trends that have and will influence the design and implementation of assistive and accessible technologies. These include:

- AT is being located and chosen differently, as users have more access to peer support but require products that have high levels of reliability and consistency
- Increasingly ATs that effectively integrate with each other and the environment are sought
- AT is more mainstream than ever before and is being used in new and imaginative ways, repurposing features on mainstream products to create access
- There is evidence that people with disabilities are increasingly seeking to make their own decisions about which AT they wish to use with less reliance on the direct intervention of professionals. However, increased use of professional jargon and terminology is making access to information challenging
- The growth of self-determination in AT is offering new ways in which that technology is funded and a much broader base of potential purchasers. However, with a more direct relationship between users and vendors comes the need to ensure that users have an opportunity to trial and evaluate products suitability for their needs.

These trends and influences are acting as drivers towards innovation in the AT ecosystem. Each element of the ecosystem is related and coordinated, and concurrent actions are required to improve ease of access and use of products. As the expertise of people with disabilities in choosing assistive products is recognized, they will define for themselves the success criteria for use and what they believe is fit for purpose.

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Buchanan and Layton (2019) comment further that "Really good assistive technology is life-changing. Assistive technology systems where each piece of technology is appropriate, and all the pieces work together effectively can be profoundly enabling. I hope that, if the assistive technology production chain can take on board some of the things I have written about, we can increase the chances of more people being able to obtain an optimal outcome from their assistive technology system."

In conclusion, we should recognise that the emerging forms of AT are based upon a different set of assumptions than some of the traditional tools. Recognising that developers are making assumptions about the context and infrastructure available to facilitate use of the AT is important when planning inclusive transport systems that can be accessed with a range of AT.

4.2 What is driving innovation in Assistive Technology?

Recent years have seen a significant growth in the diversity and availability of assistive technologies. Some of this growth is driven by factors that are influencing all technologies, but others are specific to the disability sector. As the market grows and matures the number of developers of assistive technologies is likely to increase with a corresponding increase in the range of products. Whilst there may be some periods of consolidation in the market, and the market shape may vary over time, the underlying drivers of innovation are consistent.

4.2.1 Increased Demand

People have always had disabilities and faced barriers due to those disabilities or other factors. There have been many attempts to design products to make overcoming those barriers possible and there have been many attempts to design products to make those disabilities easier to live with. Hearing aids have a long history demonstrating that innovation is not new, but AT seems to be more pervasive and in demand than we have ever seen. Morrissey (2019) 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. There are also more resources, both free and paid for, available now.

4.2.2 Mainstreaming of Technology

A trend that has been observed for the past decade is the increased integration of assistive features into products to support ease of use not only for people with disabilities but to potentially assist all non-disabled users (Layton and Steele 2019). Accessible technology includes mainstream technology that is designed to address the needs of a diversity of users incorporating AT features and functions.

Companies such as Apple, Microsoft, Amazon, and Google are increasingly designing products and services with built-in integrated features that allow people with disabilities to personalize

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usage. Businesses are incorporating accessible technology to support the needs of employees with disabilities, highlighting features such as narrator, magnifier, word prediction and voice recognition in Microsoft's Windows 10 or Google's ChromeVox screen reader, their magnification and contrast settings aid, and keyboard shortcuts. Apple's features for smartphones and tablets include features such as Switch Control, Voice Over, and Live Listen that are integrated into all of their devices. Similar features are available on Android devices also. Ultimately, while many of these customizations were developed to benefit people with disabilities, their universal designs can benefit anyone. [25]

Innovation such as eBook readers, fitness trackers and Smart Home technologies have all provided evidence that mainstream consumer technologies can be harnessed to benefit people with disabilities by offering different ways of interacting with content, data and the built environment. These trends are significant to incorporate into our thinking around AT as they are both forms of assistive technologies and reflect the growth of natural interfaces available and used by a wider population.

Assistive technology continues to evolve, incorporating specialized products for specific needs to simple customisations and modifications of everyday devices. As products become more available the impact grows accordingly.

Morrissey (2019) further adds that Voice-activated home technology, such as the Amazon Alexa and Google Home, can help people who have limited mobility or a visual impairment via the use of voice commands to: turn smart lights off or on; control music and media playback, including volume and play/pause; read out news headlines and weather updates.

Apart from the multitude of apps available for people with disabilities, new smartphones have many features built into the operating systems that make them accessible.[26] Noteworthy features include vibration alerts instead of a ringtone, ability to make the text size larger, speech-to-text communication, and the facial recognition software on the newest iPhone. As more models are released, expect to see more features designed with accessibility in mind.

4.2.3 Portability

A second trend in the design of AT is characterized by solutions that are pervasive and always connected (Thorpe, 2016). The widespread availability of high-speed internet connectivity and location-aware services have facilitated the use of technologies that are available to users regardless of context or location. This is best exemplified by technologies that are integrated into portable devices such as phones, tablets, and wearables, the wide range of designs and form factors reflect the growing preference and requirement for on-demand technology.

[25] https://www.vercida.com/uk/articles/assistive-technology-moving-towards-mainstream
[26] https://medium.com/swlh/smartphones-and-accessibility-ccc1cd6ad4de

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User expectations are increasing, expectations of customer service and value for money are changing, and both are being influenced by the experience of on-demand services for entertainment and services where content is driven by ease of use and an on-demand approach (Banes 2018). The integration of technology into daily life is more pervasive than ever before, and as the functionality used by people with disabilities is more fully integrated into and onto portable and mobile devices so the solutions will be less apparent and more widely available to all.

The use of such mobile devices is driven by the widespread availability of social media platforms where connecting with other people who have similar needs is easy, regardless of location. This brings about greater peer and professional support for AT when and where needed.

4.2.4 Local fabrication, manufacture, and customization.

Challenges of access to AT have seen a greater interest in models of creation and distribution that are based on local fabrication, both at home or through a local workshop using local materials or supported by 3D printing based on shared designs and the availability of a local printer. As a direct effect of the democratisation of technology mentioned in the previous chapter, the growth of local fabrication allows for rapid customization, maintenance and repair of simple assistive products and can draw upon the distribution of design and instructions curated into online repositories. Web resources such as Instructables[27] and Thingiverse[28] already have such resources available and community-driven organizations such as Atmakers.org are at the forefront of teaching users and facilitators how to manufacture simple products and aids.

For businesses and other stakeholders, the approach offers opportunities to reduce the cost of providing simple aids by increasing the use of local industry to produce aids that are required without the cost of shipping or customs inflating pricing. Local fabrication is reflected in the growth of hackathons across the globe who target designing products for social benefit.

4.2.5 Artificial Intelligence, automation, anticipation, and analysis.

Increasingly AI is driving the design of assistive technologies employing user data to offer a personalized experience and the automation of essential functions. This is in keeping with the broader application of AI into consumer and enterprise products available widely. Users do expect personalized experiences but remain concerned about the security of their data and their personal privacy. Salesforce in their 2nd edition of the State of the Connected Customer[29], considered the importance of trust when it comes to handling a customer's data, but also offer that "79% of customers are willing to share relevant information about themselves in exchange

[27] https://www.instructables.com/
[28] https://www.thingiverse.com/
[29] https://www.salesforce.com/eu/blog/2020/01/state-of-the-connected-customers-report.html

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for contextualized interactions in which they are immediately known and understood."[30]. If AT companies are to retain the trust of their users, they will need to be increasingly transparent about the collection and use of data, as well as being able to demonstrate the benefits. Such data can be of great value to a range of businesses and service providers, not merely from a marketing perspective but in seeking to respond to the behaviour of disabled people and to build more inclusive experiences.

4.2.6 Conclusion

Understanding the factors that are driving and shaping the AT market and its innovations, are highly relevant to those providing transport products and services.The likely impact of the factors driving innovation in AT (described above) is that more people with disabilities will aspire to travel and will use an increasingly diverse range of technologies to engage with transportation services and businesses using diverse technologies and in a variety of ways .

4.3 AT trends by application/function

To understand the full impact of AT across the wider life of people with disabilities, it is useful to examine the areas of activity in which emerging AT are having an impact. This provides a context for the functional use of the technologies discussed above. In understanding the range of aspects of daily life that emerging AT are impacting, we can start to determine which are most likely to be brought to market earliest. The diversity of use would suggest a wider market and grater utility for the consumer and places an expectation upon providers of transport services to ensure that they offer an equitable and compatible infrastructure.

4.3.1 ATs for Daily Life

These include devices and tools that support daily and independent living. They range from aids for essential functions such as bathing, feeding, dressing, and sleeping, to more complex digital tools such as environmental control systems, smart homes, alerts and alarms. These devices and tools support those with disabilities in interacting with their surroundings through remote-control devices, electronic doors, alternate controls, light switches, door answering or opening systems.

4.3.2 ATs for Mobility

These tools and devices support personal mobility challenges by facilitating movement and navigation in indoor and outdoor environments. They include personal mobility aids such as walking aids, stairlifts, and tools to support the transfer from one position to another and incorporate wheelchairs, exoskeletons, and walking canes.

[30] https://www.salesforce.com/content/dam/web/en_us/www/documents/e-books/state-of-the-connected-customer-report-second-edition2018.pdf

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They also include technologies that support wayfinding and orientation as well as providing information about the accessibility of the built environment to guide decision making by users. Such technologies are increasingly built upon smartphones and tablets as consumer devices.

4.3.3 ATs for Communication including speech and language impairments

A range of technologies are available to stimulate and facilitate social interaction, processing visual and auditory information, and production of communicative utterances. Some have been available for many years and would include low tech solutions such as digital recorders, speech synthesizers, voice output communication aids, low-vision aids, magnifying glass, hearing aids, telephone amplifiers, Braille display and writer, and visual notifications as replacements for alarms. The critical trend related to these technologies is that they are increasingly based on everyday devices using integrated sensors and displays to gather and convey information in a range of formats.

4.3.4 AT's for Sport and Leisure

There are many tools and devices that are designed to enable persons with disabilities to take part in sport and leisure activities — these range from adapted wheelchairs and other tools that allow participation in sports. However, the growth of virtual sports, initially exemplified by the Nintendo Wii console has encouraged new ways of taking part in sports and leisure, both for entertainment and as part of a healthy lifestyle.

4.3.5 AT for Access to Information

In an information society and economy, access to information is essential for daily life, employment and education. In some cases such access is provided within an environment (accessible signage or tactile maps etc) but its access may also be ensured through the use of individual solutions e.g. software, and might include symbolization, mind/concept mapping, writing aids or word predictions etc. Such tools are available for use on phones and mobile devices to "read" information in the immediate environment and present it in a form that is suitable for the individual.

4.4 Applying Digital Technology Trends as AT to Access and Inclusion

The function and application of the digital technologies described above are subject to ongoing evolution and disruptive design. Drawing upon those technologies outlined in D3.2, we can identify some of the specific uses of technologies that are shaping the design and implementation of assistive technologies for use by people with disabilities. In considering the application of these innovations we have drawn upon the observations and experience of our interviewees, who reflect upon the impact of the innovations.

4.4.1 Speech Interfaces

Speech interfaces are systems that use speech, either as digitized vocalizations or synthesized speech to communicate and interact with users (Weinschenk and Barker, 2000). Speech can be

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used as a primary input or output or in an interaction. Where speech is used to facilitate input, it Is based upon automatic speech recognition (ASR) and natural language processing (NLP) to identify user requests and commands. Increasingly there is wide use of spoken dialogue systems (SDSs), where the system and user can interact through spoken natural language. Such interfaces are growing in popularity and are offering new ways for people with disabilities to engage with information and devices. In addition to long-established telephony-based or interactive voice response systems (IVRSs), voice-enabled intelligent personal assistants (IPAs) like Amazon Alexa, Apple Siri, Google Assistant and Microsoft Cortana are widely available on consumer devices. The market for IPAs is projected to reach between $4.61 billion (Kamitis, 2016) and $9 billion (BusinessWire, 2018) by the early 2020s.

Research into such systems has explored how the interface can reach those who have traditionally been excluded from digital access. These include rural communities, novice users, or people with low levels of literacy, as well as those with disabilities. The intuitive nature of the use of speech for many users was highlighted by Medhi et al. (2009) who compared mobile speech-based, text-based and rich multimedia interfaces with users who were non-literate or had low levels of literacy. They found that while rich multimedia interfaces provided better task completion, speech-based interfaces afforded greater speed and required less assistance.

Although voice assistants can be classified as a form of artificial intelligence, the widespread use of the technology is worthy of note. Devices including the Amazon Echo or Google Home, and those with built-in functionality such as Apple's Siri, Samsung's Bixby, Microsoft Cortana, Google Assistant and Amazon Alexa, offer options to make an environment accessible. Voice responses simulate conversations, and the technology facilitates a range of activities from making calls or appointments to controlling electric devices such as heating or lighting.

Speech was identified by interviewees as one form of natural interface facilitating use of technology by people with disabilities. The use of such interfaces was widely welcomed. One interviewee stated

"One of the more significant barriers to accessing smart services and products is the requirement to use specific terminology, which would be significantly improved through the use of natural language."

Natural Interfaces were defined as a user interface that is effectively invisible and remains invisible as the user continuously learns increasingly complex interactions. The word natural is used because most computer interfaces use artificial control devices whose operation has to be learned.[31] For the user such interfaces provide interactions with technology that come naturally.

The capacity of such interfaces was identified as beneficial to all users by interviewees:

[31] Natural user interface - Wikipedia. https://en.wikipedia.org/wiki/Natural_user_interface

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"Natural Interfaces are the end goal of many of the previously mentioned technologies (AI, IoT, Context Awareness). Operating systems and menus disappear leaving only the choice, actions based on previous actions (triggers) or pure automation when appropriate."

"Current app/service options like IFTTT and Tasker allow the creation of natural interfaces to a certain extent. Use IFTTT to raise the blind in your bedroom when your alarm goes off or lower them based on the outside light."

4.4.2 Internet of Things (IoT)

Digital voice assistants interact with connected devices through the internet of things. This is reshaping society by changing aspects of the daily life of users (Bandyopadhyay and Sen, 2011). Smart health, assisted living, smart homes, and enhanced learning are examples of possible application scenarios in which this will play a role for people with disabilities (Atzori, Iera, and Morabito, 2010). IoT for people with disabilities has become increasingly personalized to meet individual needs and user requirements.

IoT is enhancing AT by adding capabilities that support independence in communication, self-care, independent living, health care, mobility and transportation, education and learning (Lee, 2017). Also, the technology is increasingly used in rehabilitation through the integration of medical devices with software, through networks that support health care needs by monitoring patients, sharing information, analysing data and supporting health professionals in improving the quality of health care and reducing the burden upon services.

In interviews the use of IoT was identified as one of the areas in technology trends that is driving innovation in assistive technologies and is already having a significant impact upon the lives of people with disabilities. One interviewee commented:

"The availability of IoT devices are having a great impact on those with disabilities living independently within the community. Smart home devices could be considered a luxury for many but if access and mobility is a difficulty, they can be a life enhancing technology. Seeing who is at the front door, checking you have unplugged the iron, control of appliances using voice or another alternative input method. There are so many benefits to connected technology in the home. IoT also allows carers to give someone living independently space and privacy while having peace of mind knowing that if their living pattern deviates from the norm they will be immediately alerted (AI crossover) Telecare."

The use of IoT to augment health monitoring and care was also highlighted by those interviewed:

"telehealth: monitoring of seizure activity enabling better pre-emptive response for those with epilepsy, resulting in reduced hospital admissions and greater autonomy. In an age of Covid,

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self-monitoring of temperature is likely to play a big role in determining who can/cannot work, for the foreseeable future. Smart home tech is developing at a pace and is likely to offer even more options that are affordable and accessible."

It may be that the data gathered from such monitoring could become part of approval for visas and entry to countries as locations seek to respond to the Covid crisis by reducing the potential of infection from high risk countries.

Such developments led to some commentators expressing concern about the need for clear guidelines and standards to protect the privacy and security of users. The broader the area of application for IoT solutions the greater the risk is to individuals. As one commentator reflected:

"Remote assistance can be helpful, remote surveillance can be a problem. Voice activation can be practical, loss of privacy an issue."

4.4.3 Artificial Intelligence

Deep Learning and Neural Networks are helping health professionals make faster, more accurate diagnoses, providing feedback on rehabilitation activities and progress made. However, artificial intelligence is leading innovation in many aspects of life for people with disabilities. Starting with developments in predictive text, visual recognition, and speech-to-text transcription, AI now stimulates other products and features that are expanding opportunities for those with disabilities.

Interviewees identified the importance of this area for people with disabilities. One expert noted that:
"The potential for AI to personalize the experience of individuals with disabilities in how they interact with the world (built and digital environments) is immense: rendering education, employment, travel, communication and leisure more accessible than previously."

Others noted that:
"For anybody with access difficulties AI offers incredible potential as through data analysis it can facilitate automation and provide contextually relevant tools and features. AI is driving advances in speech and object recognition with both now essential assistive tools for daily living, employment, and education. In the near future, AI developments will facilitate cost effective support for people living independently and autonomous vehicles."

One expert voiced a degree of caution in examining the potential impact of AI on assistive technologies noting that:
"In terms of anticipation and adaptability of support AI could be a fabulous tool that supports independent living and employment opportunities. However, that needs to be balanced with the application and development of the AI. For example, AI used to conduct remote initial

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employment interviews could be biased against those with a speech impediment, facial paralysis or autism if the AI is not correctly developed."

Areas of potential application were very wide, amongst others interviewees identified:
"Speech recognition, Captioning speech and sounds, Sign Language Synthesis & Recognition, Intelligent personalized interfaces, Artificial Assistance, Symbol communication, Simplification of text, Describing images, Recommendations of AT solutions, Autonomous mobility guides - navigation inside and out. Multilingual and multicultural symbol linking" as areas of interest and development.

AI is being implemented at many levels. These range from ATvisor[32], which helps people with disabilities to select the aids and appliances which would have greatest impact on their daily lives, through to a range of applications which address a specific need that a disabled person might have.

Applications such as Microsoft's Seeing AI describe people, text, and objects aloud for people with low vision. Livox[33] is a customizable Augmentative and Alternative Communication (AAC) app that allows people without speech to communicate using symbols easily. Tobii[34] systems offer solutions that allow people with profound physical disabilities, to operate their computers using eye control, such systems would benefit from the potential use of AI to make such systems easier to use and less tiring for users.

Increasingly it is recognised that AI advancements prove beneficial for people with disabilities and communities overall (Marzin 2018). As a result, corporations are investing in further innovation. In 2018, Microsoft launched the AI for Accessibility program to provide technology-focused seed grants to developers, universities, non-governmental organizations, and inventors that aim to focus on AI and in the same year the UNICEF innovation fund supported open development that built upon AI and other emerging technologies.[35]

4.4.4 Location based services

Location based services are a crucial component in the implementation of several of the other technologies discussed. For example, many of the applications based on AI, IoT or wearable technologies utilize location-based services to gather and share information.

Such services are defined as software services which utilize geographic data and information to provide services or information to users. This can be used in a variety of contexts, such as health, indoor object search, entertainment, work, personal life, etc.

[32] www.atvisor.ai
[33] http://www.livoxarabia.com/en/
[34] https://www.tobii.com/
[35] https://www.unicef.org/innovation/innovation-fund-ottaa-project

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One expert commented that:
"When a technology has some awareness of contextual information like location it makes access much easier by being able to skip over the first few and often most complex stages of the user interaction. A simple example would be if an AAC user has a location aware communication device it will provide appropriate vocabulary when they need it. The tools you need when you need them."

At one level such services inform and refine information upon which decisions can be made, as one expert noted that the technology enabled:
"Internet searches for goods and services yielding results that are geographically specific: e.g. accessible local cafe/library/parking spaces/public transport; voice assistants to guide individuals with cognitive impairments to the desired space in their homes; simplification of route finding and audio cueing; reminders/cues when out int the community to avail of a local service listed in user's personal phone/device.".

Practical applications of location-based services were described by many of those interviewed. Amongst other applications identified experts noted widespread use of applications such as the "Lookout" Android app for those who are blind and "Soundscape" by Microsoft, "LookAround" GPS from Sendero and the "Ariadne" GPS. In addition, mobile applications such as "Be My Eyes." UK Train Times, "BlindSquare" "Wheelmap" and "Route4U" in the UK were all referenced.

4.4.5 Virtual and Augmented Reality

Augmented Reality (AR) is having a significant impact on the rehabilitation of people who have acquired a disability by using virtual objects and overlays to enhance interaction with exercises and activities (Escalona et al 2019). AR can make training exercises more readily understandable, helping users to understand the devices and technologies that they have available. Similarly, Virtual Reality (VR) offers the integration of treatment and entertainment through artificial environments in a gamified setting (Held et al 2020). VR increases motivation and commitment to rehabilitation and other activities that are challenging.

Interviewees recognise the potential of AR/VR although practical implementation for persons with disabilities was more limited. One respondent noted:
"VR offers potential to allow people with disabilities to participate in some experiences that might be impossible in the real world due to their disability. It also offers a safe space for neurodiverse people to practice dealing with environments and situations they find challenging in the real world through exposure therapy. It also has a lot of educational potential. AR has probably more potential as an assistive technology in areas like literacy, cognitive and memory support. AR also offers a great deal of potential supporting remote AT assessments."

Social participation through AR was suggested as one area of future implementation "Virtual Voting, Meetings, Concerts, Festivals, Touristic Routes, etc." But in the more immediate future

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travel and navigation were highlighted as being well advanced in use "Navigation support by augmenting with line to follow." The capacity of the technology to be used to prepare people for travel was also highlighted as being useful:

"Familiarisation with new environments such as new home, new work environment, social spaces, for people with disabilities such as autism, anxiety disorders, dementia, etc. Ability to access experiences previously unavailable: virtual travel, clearer demonstration of concepts in education rendering them more understandable (resulting in greater educational attainment)"

4.4.6 Wearables

Wearable Technologies are defined in Wikipedia as smart electronic devices that are worn close to and/or on the surface of the skin, where they display, detect, analyze, and transmit information concerning to and from the wearer.[36]

Wearable technologies are delivering assistive and accessible features in a variety of ways (de Oliveira et al 2019). They can form the basis of sensors to gather data e.g. smartwatches or fitness trackers, but can also provide a source for displaying information in a non-obtrusive manner. Such wearable technologies have a long history, both hearing aids and Bluetooth headsets are forms of wearable technology, and smartwatches such as the Apple Watch have grown in popularity and functionality during recent years. A variety of forms of assistive technologies are making use of the form factor to support control of other devices such as music players, alerts and notifications and improvements to health and safety.

One significant area of wearable technology development is in heads-up displays designed for use with virtual and augmented reality applications. While these are usually currently used when connected to a PC or gaming console, technologies such as Microsoft "HoloLens" offer an independent display that is both wearable and portable. The implementation of new products onto the platform could include wayfinding, facial recognition, and real-time translation and captioning.

More advanced research includes the development of applications that promise to enhance specific parts of a person's vision, increasing image contrast or highlighting specific features of an image, using AR on a wearable display (Zolyomi and Snyder 2020).

Interviewees noted that wearable technologies are already readily available and used in a variety of ways by people with disabilities. Ease of access to information, gathering of biometric data and control over digital devices were all suggested as practical implementations:
"Wearable Technologies can give biometric data that can provide key contextual information which along with AI and IoT will inform more natural interfaces." The interviewee continues by noting that wearables are also a key technology in telecare.

[36] https://en.wikipedia.org/wiki/Wearable_technology

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Current use of wearables identified by interviewees included:
"Fitbits, smart watches with person-centered apps such as time/location diary reminders, audio directions, temperature monitors, smart fabrics that wick moisture from body".

4.4.7 Robotics and Automation

A robot is a machine designed to execute one or more tasks automatically with speed and precision[37]. Drones are an implementation of robotics that are mobile and are guided by remote control or onboard computers.

The adoption and implementation of robotic solutions is an emerging trend. The availability of robotics-based systems started in work with the field of rehabilitation including solutions for lower limb and upper limb loss. These have demonstrated their validity for a range of needs and tasks. Recently, the availability of modular/adaptable and easy to wear robotics such as exoskeletons offers an opportunity for use as aids for daily living. Flexible soft robotics will enhance the range of application supporting locomotion and upper limb functions for persons with disabilities and the elderly. One outstanding issue is battery duration and the potential limited time of operation. Product development will benefit from research into extended capacity battery technology being undertaken by the automotive sector.

Not all solutions will be based upon complex systems, some of them will focus in precise functions: such as to enhance gripping force, to facilitate transfer through different postures, to help and secure stand-up. One example is HERO – (Hand Extension Robotic Orthosis) developed at Toronto Rehabilitation Institute. Taking the form of a glove with integrated robotic tendons. The glove's grasping movements are activated manually by pressing a button or automatically through a movement sensor.[38]

Some of these solutions will be integrated or interfaced (mechanically and electronically) by means of standardised "hooks" to AT already in use by the person with disabilities for example a R-Net Bluetooth extension on an electrical wheelchair can communicate activations to add on devices. These could incorporate IOT sensors to an output that is integrated by AI (on cloud or edge computing) that enhances safety and comfort during use.

Interviewees noted that many persons with disabilities were already beginning to make use of simple robotic devices:
"Single task robots like vacuums and lawn mowers are well established. Considered luxury consumer tech by most and not even on the radar of most people with disabilities. However, devices like these should be funded for people with disabilities as many of these mundane

[37] What is robot ? - Definition from WhatIs.com. https://searchenterpriseai.techtarget.com/definition/robot
[38] http://www.uhnresearch.ca/news/robotic-glove-improves-function

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household tasks take up valuable personal assistance time that could be better spent. Drones are starting to be used for delivery and could be used for telepresence in the future"

"Robotic cleaning appliances, robotic arms for transfers. Robotic wheelchairs to navigate obstacles/inaccessible environments"

"Drones for looking at the things you cannot reach outside and you can then get help with exact instructions to the person who can solve the problem. Robot to make a cup of tea in the morning if you physically cannot do it. Also for company but a bit limiting."

4.4.8 Autonomous Vehicles

Autonomous vehicles are defined by their capability of sensing its environment and moving safely with little or no human input. Self-driving cars combine a variety of sensors to perceive their surroundings, such as radar, lidar, sonar, GPS, odometry and inertial measurement units. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage were identified as an accessible technology that could have significant benefits to people with disabilities (Reddy P 2019).

One interviewee noted that such technologies facilitated:
"Travelling independently, removing reliance on specialist transport or timetables that don't suit an individual; more affordable: use only on an as needed basis. Level the playing pitch between car owners and non-owners. Reduce health risks associated with infection due to reduced exposure to general public on public transport; environmental benefits of reduced single car ownership leading to reduced emissions and greater health status for all."

Many interviewees were conscious that such technology could be used in ways that are beyond autonomous cars. Examples of autonomous wheelchairs and grocery carts were identified as making use of the same technologies to the benefit of persons with disabilities.

4.4.9 Conclusion

This section of the report clearly demonstrates how the application of digital trends in the form of accessible and assistive technologies are currently having and will continue to have a significant impact upon the lives of disabled people. The capacity to move from location to location is an integral part of the rights of persons with disabilities and we have outlined many of the implementations of such technologies to enhance people's lives, including the right to travel through accessible transport and infrastructure.

4.5 Assistive Technology Trends to address specific needs

Many forms of assistive technology impact across a diverse range of needs and impairments. In many cases, technologies such as text to speech or speech recognition cannot be viewed as

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restricted in application to one field of need rather than another. For instance the same text to speech engine is used to assist a person who is blind to read a newspaper, to help a person with cerebral palsy to use AAC, and to help a person with dyslexia to check and review their writing.

Despite this caveat, there are some technologies that are currently under development, which are designed to address a specific real-world problem encountered by a defined group of people with an impairment. Whilst universal design and shared applications address many barriers, others need a more focussed and incisive approach such as those described here.

Many of these technologies have implications for a range of transport and mobility scenarios. Later in the report we examine the phases of a journey and seek to demonstrate how implementation reduces barriers to travel.

4.5.1 Visual Impairment

In recent years there has been a growth of research and development into wearable electronic travel aids (ETAs), smart canes, wearable technologies, smartphone-based devices and apps, tactile displays and interfaces, cortical and retinal implants etc. These reflect both the underlying trends in assistive technologies described above but also some potential areas of human augmentation.

It should also be recognized that not all forms of AT are designed for use by individuals. Embedded technologies, such as tactile or audible signage systems, make the setting easier to navigate and may be integrated with information held online and carefully integrated and timed to synchronize with a smartphone as the user transits through a building. The Disney device[39] offered a unique vision of such integration on many rides. For instance, the "Pirates of the Caribbean" ride combines embedded information in the environment including sounds, smells and vibrations which are continually changing as the user moves with the ride, but the handheld device augments this with audio description of characters and action.

An example of such development is the "ultracane" combining a long mobility cane with ultrasonic sensors. While advanced handheld, wearable, and embedded assistive devices have been developed, a comprehensive solution remains elusive. Increasingly innovation has led to smaller designs of solutions that are both pervasive and portable and would include wearable ETAs such as those with the potential to be worn on a shirt as a badge or brooch; for example the clear-path indicator for the blind people by Jameson and Manduchi (2010).

Similarly, innovations such as ARIANNA[40] which seek to offer both indoor and outdoor navigation through a 3D smartphone-based aerial obstacle detection system, is both discreet and favours social integration. These support those with a visual impairment to navigate in both known or unknown, indoor or outdoor settings by providing rich environmental information,

[39] https://www.disneyworld.co.uk/guest-services/hearing-disabilities-services/
[40] http://in.sight.srl/arianna/

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obstacle avoidance, object recognition, and navigation through the combination of sensors including ultrasonic, GPS, cameras, infrared, laser, built upon mobile phone technology.

Increasing integration of mobile technologies, smartphones and computer vision has led to research and development across independent living, accessible design, access to print, and social interactions. Smartphone-based AT have been developed that enhance daily living activities. An example would be the Trinetra project[41] which scans product barcodes to aid in grocery-shopping or StopInfo[42] that offers detailed information about transport stops tailored to the needs of those who are blind. Widely used products for smartphones are SeeingAI[43] which can verbally represent text, barcodes or describe people and Be My Eyes[44] app which connects blind users with volunteers to describe an object event or environment in real-time. Such smartphone technologies have current utility but have the potential for still further implementation as heads up display and augmented reality headsets become available.

Bhowmick and Hazarika (2017) identify SmartTouch[45] as a notable example of a tactile interface that uses electrodes to activate sensory nerves under the skin (electro cutaneous display systems). These have been developed to work on areas of the skin such as Optacon for fingertips and the tongue display unit (TDU) that creates real-time tactile images using the tongue as an HMI. Brainport V100 is a recent, non-surgical visual prosthetic which uses tactile tongue stimulation to translate information. HamsaTouch is a smartphone based TVSS evincing the advances of current technology.

One theme in sensory substitution research is cortical visual prosthesis, sometimes referred to as brain implants. These provide a degree of visual sense directly to the brain via electrodes connected to the primary visual cortex. Brindley and Lewin (1968) produced a functional cortical implant of 80 electrodes allowing a user to experience sensations of light. Similarly, retinal implant technology that offers visual perception via stimulation of the retina through implantable microelectrodes have also emerged (Tong et al 2019). While such human augmentation is under development, the growth of augmented reality glasses or headsets offer more concrete examples of potential benefits. AR projects include real-time magnification of images, adjustment to colour and contrast, to object and facial recognition.

Such computer vision-based assistive technologies enhanced with AI have had a considerable impact on the market in recent years. From the OCR based system for scanning text available in the last decade, we see such functionality on smartphones and tablets, including automated image description. Kesavan and Giudice (2012) note that automatic and meaningful natural language (NL) image description provided through a smartphone or mobile device would

[41] https://research.ece.cmu.edu/trinetra/docs/trinetra-cmu-cylab-06-006.pdf
[42] https://www.washington.edu/news/2014/08/18/stopinfo-for-onebusaway-app-makes-buses-more-usable-for-blind-riders/
[43] https://www.microsoft.com/en-us/ai/seeing-ai
[44] https://www.bemyeyes.com/
[45] https://tachilab.org/content/files/publication/ic/kajimoto200307SIGGRAPH.pdf

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benefit users to know the contents of a scene and then support navigation through that space. Convolutional Neural Networks based software can accurately describe scenes shown in photos in natural language based upon deep machine learning (Jishan et al 2019) and this has the potential for a broader range of tasks and activities such as describing activities, emotions, and people.

Navigation and wayfinding have also been an area of considerable research and development, both navigating from location to location outdoors and further effort applied to unfamiliar indoor settings. In many public settings such as stations and shopping malls, evidence suggests that people with little or no vision often lack awareness of where emergency exits are and safe routes for leaving a building. Wearable indoor wayfinding systems built on personal devices such as the Roshni project[46] offer the potential to download floor plans, orientate the user and track movement while providing step by step directions through audible and haptic cues.
ARIANNA offers an alternate approach but requires considerable effort to install cues into the building itself. Such systems were deployed at Walt Disney World through the loan of dedicate navigation devices, but more recently such approaches are being supplanted by smartphone-based technology to reduce cost and make provision scalable and meet the needs for such devices to be unobtrusive, light, discreet and effective if they are to be successful.

Head-height obstacles offer particular challenges to safe mobility. Saez et al.[47] tackled the problem with 3D smartphones through the Tango Project, but such devices remain expensive and are only beginning to influence consumer devices.

Traditional low-tech devices such as white canes and Braille texts, as well as embossed or tactile maps and textured surfaces, have long been available to support navigation. However, increasingly such functions are being assimilated and enhanced through digital technologies. Such technologies can facilitate independent actions such as travel and navigation and are a complete solution in themselves while others offer a partial solution and need to be used alongside other devices or act as access to human guidance and aid.

The advancement of technology is evident, but only a limited number of assistive technology solutions have emerged to make a social or economic impact and improve quality of life. The ability for those with a visual impairment to orientate themselves in an unfamiliar setting, engage other people they encounter and consume information in real-time remains a challenge. Development of AT for blind and visually impaired users is increasingly founded upon mainstream technology developments. User-led design and fabrication of aids are made feasible by the availability of 3D printer and increased portability. Pervasiveness is driven by miniaturization and efficient power sources alongside innovative displays and natural interfaces including voice, touch and gesture.

Example – Innovation in Travel

[46] https://www.theroshniproject.com/
[47] https://core.ac.uk/download/pdf/32318969.pdf

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Seeing AI by Microsoft has introduced a new feature for the iOS based app. Scenes, allows the user to take a photograph of the environment around them and the application will seek to describe that photograph to them. This has been demonstrated as working at bus stops and stations to narrate the location of where busses are parked for passengers, or to advise that there are steps ahead that lead to entry onto a train. Such technologies reduce the need for a user to rely upon a human guide, but could be further enhanced with services such as "Be my eyes" where a human guide remotely narrates the scene around the person with disabilities.

4.5.2 Deaf and hearing impaired

Current AT for the deaf and hearing-impaired fall into three broad categories: hearing, alerting and communicating. Some forms of AT seek to enhance hearing ability through volume and other sound adjustments such as noise reduction. These include hearing aids, assistive listening devices, personal sound amplification products and Cochlear implants. The implants are surgically implanted sensors that convert sounds into electrical signals directed to the auditory nerve. Other solutions for the deaf and hearing-impaired include systems that alert the user to specific events in the environment through light, vibration or a combination of the two. The third group are communication technologies which seek to facilitate a flow of communication and translation through speech, text and sign language in both face-to-face and remote contexts.

Analysis on behalf of the European Parliament (2018) [48]noted that advanced versions of these are in development, including advanced auditory brainstem implants that can bypass the inner ear and acoustic nerve to stimulate brainstem neurons directly. There have been improvements and combinations of current technologies, such as support for sign language translation, which are likely to be combined with emerging technologies such as augmented reality in the future. One example of such translation tools is KinTrans[49], which seeks to translate sign language into voice and text, and vice versa. This is based upon a 3D camera to track both hands and body of the signer while they sign. Based upon AI and machine learning the project plans to build a crowd-sourced, 3D database for American Sign Language to compliment the future development of new, sign-accessible technology solutions

Increased availability of automated high-quality captions is the focus of considerable development time. This has included the automated captioning of videos on social media platforms such as YouTube, but also real-time captioning of speech, with the capacity for real-time translation as offered by-products such as interact streamer

Example - Innovation in Travel

"Chatable" is an application for mobile phones which reduces background noise when a deaf or hard of hearing person is attempting to listen. Originally designed for use when watching TV,

[48] Assistive technologies for people with disabilities.
https://www.itas.kit.edu/downloads/projekt/projekt_nier16_asstech_EPRS_IDA_2018_603218_EN.PDF
[49] www.kintrans.com

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where background noise may be a problem when attempting to follow dialogue, the same technology can be used by placing a mobile phone between the user and staff prior to boarding transport or during a journey, the technology isolates the voice from extraneous noise and streams the signal to a digital hearing aid or wireless earphones. The technology has the capacity to reduce confusion and anxiety amongst users of public transport system where hearing is an issue.

4.5.3 Physical Disability

Research into assistive technologies for persons with physical disabilities has tended to be divided into improving the functionality of mobility aids, including prosthetics to enhance the capability of the individual, and those that seek to address environmental barriers to access. The need for advanced wheelchair designs has arisen to support mobility and access to the built environment. Reinkensmeyer, 2012 notes that amongst other areas research and development has investigated:

- Assistive robotics and intelligent systems to enable wheelchairs to overcome obstacles and self-adjust, assist in navigation, and to facilitate aid from caregivers, including transfers.
- Innovations in interface design may advance control of mobility devices and robots through BCI, eye-tracking, gestures and other consistent movements.
- The further development of smart devices and smart buildings offers control of the environment, promoting independence, monitoring activity, and encouraging activity and exercise.

Advanced wheelchair design has sought to address the need for alternative power sources for wheelchairs and the need for technology that improves activity, participation, and safety, especially during travel. The demand for alternatives to conventional batteries is consistent with research showing that batteries and electrical components are the most common components of powered mobility devices to fail and need replacement. Advanced mobility research also draws upon the implementation of robotics and intelligent systems into designs. These include obstacle avoidance, self-adjustment based on data from sensors, navigation assistance, and autonomous chairs. Research suggests that navigation, sensing and control systems, facilitating mobility aids that adapt to client needs and behaviour, are priorities for advanced wheelchair designs.

The increased use of technology innovation is reflected in the growing expectations around significant potential of robotics to support independence in daily life, especially in areas of self-care and mobility. Dependence on such devices needs to be cautious until efficacy, safety and reliability are proven. Robotic aids for transfers is especially valued in making transitions from wheelchairs to bed and toilet, facilitating personal choice and reducing both dependency upon and physical strain of caregivers.

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Such advanced designs and robotic innovation are enhanced by innovation in human-machine interfaces for control. The steady growth of interfaces that interact with connected devices allows greater control of mobility devices and robots through natural actions. Such trends are consistent with those in digital technologies and other implementations of AT.

The growth of smart devices and IoT has seen a steady increase in technology that facilitates control at home and in other settings, alongside technology for telecare or telehealth, and wearable devices that can be used to monitor activity and control other devices. Such technologies still require effective support and training to build user confidence and reliability, but significantly reduce reliance on daily human interventions. Training and support programs as part of the implementation of such technology is an essential factor in its success and impact.

Technology to reduce the need for caregiver assistance includes the growth of assistive robots and robotic tools that address both mobility and manipulation of objects for daily living. Research suggests that people with disabilities prefer the opportunity to perform a task independently through technology; even this takes more time or effort. Smart home technology, combined with voice-control, has been widely promoted and implemented, reflecting the underlying digital trends into natural interfaces and automation.

Further developments to powered mobility devices have also been undertaken. Understanding the likely direction and form factor of such innovation is valuable in considering how the design would be accommodated in public spaces, including transport. Four key technologies have been suggested as being influential: powered wheelchairs, prosthetics, functional electrical stimulation, and robotic exoskeletons. For the purposes of transport, powered wheelchairs and exoskeletons are the most relevant (Reinkensmeyer 2012).

Powered wheelchairs

Not all persons who could benefit from the use of a powered wheelchair can maintain control and navigate through a given setting using traditional controls. As a result, a “shared” control approach and alternative interfaces have been developed. In this scenario, routes are programmed by an aide. The user then controls speed, starts, and stops, as well as any actions required to avoid obstacles. The wheelchair returns to the path once the obstacle is avoided. Alternate interfaces to support this scenario include:

- Brain-computer interfaces (BCI)
- Prosthetic limb control
- Computer-vision enhanced control

Such smart chairs have also been developed to accommodate some barriers within the built environment. Prototypes of chairs that can navigate stairs, adjust seating for different heights

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of tables and remain stable on slopes and uneven ground have all been made available for testing by researchers and mobility companies.[50]

Robotic exoskeletons

Beyond the further development of powered wheelchairs, there has been a steady development of technologies based upon robotic exoskeletons. Early research focused on rehabilitation and therapeutic use of exoskeletons, such as the Lokomat[51] gait training robot. More recently, attention has shifted to access, activities and mobility in the home and the community.

Pons (2010) identified four characteristics of robotic exoskeletons that are required if the technology is to have an impact:
1) A need for robust human-robot multimodal cognitive interaction
2) Interactions must be safe and dependable
3) Solutions must be wearable and portable
4) Development must embrace user-centred approaches including acceptance and usability

Much of the research to support people with physical disabilities is evolutionary rather than revolutionary, with increased ease and flexibility of use a priority - increasingly there is an expectation that the interface should be intuitive, seamless, and non-obtrusive. Enhanced systems and technologies decrease the burden upon both users and carers, support more sensitive control of prosthetics and enable autonomous mobility for those who have been denied such opportunity in the past.

Example – Innovation in Travel

Many people with physical disabilities face significant frustrations when checking in, passing through security, getting to gates or platforms on time. People with physical disabilities often spend long periods waiting for an employee to bring them a wheelchair, to be taken to the gate, reducing their independence while traveling. Autonomous wheelchairs have been tested at airports and have been used by passengers to be transferred to key locations within a terminal in a timely and independent fashion. Whilst such technologies are currently available within a location, and loaned to the user, it is feasible that the solution will increasingly become available on mainstream powered chairs with maps and routes downloaded by passengers to drive their own chair.

4.5.4 Intellectual Disability

People with cognitive and intellectual impairments, including those with dementia, encounter many challenges, including reasoning, memory and judgments. As a result, a wide range of aids and resources have been developed to assist (Alkadri and Jutai, 2016). One example is the availability of reminders, often delivered on a smartphone which reminds users of the daily

[50] https://www.designboom.com/technology/scewo-electric-wheelchair-climb-stairs-independently-03-28-2017/
[51] https://www.hocoma.com/solutions/lokomat/

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activities they need to undertake at a given time and in order. These might include medication, mealtimes, travel times or appointments.

Similar technologies provide the basis for telecare and telehealth technologies which can be used to monitor health conditions and personal safety using a range of sensors for biometric or movement data. Such intervention can be valuable in promoting self-management for people with intellectual disabilities.

AT have also been used to support people with intellectual impairments by reducing social isolation. Technologies used by the general population including icon-based instant messaging easy use phones, and video calls have all been well received (Barbareschi 2019). Development in easy interfaces have been widespread, and an example is the interface developed by Project Ray[52]. Such replacement front ends for smartphones have been more widespread for Android than for other platforms due to the open nature of the operating system. In practice some interfaces can be applied to support different needs, project-ray is a good example of an options that is widely used by both those with a visual impairment and those with intellectual needs.

Similarly, independent travelling for people with intellectual impairments has built upon consumer technologies. Programs such as Life360, Find my…, Waze and Google maps use location-aware services including networks and GPS to aid in navigation and orientation, as well as helping carers to locate an individual if they are lost or confused. Further development of technologies that can create and track travel plans and activities automatically are beneficial and can build upon tourism applications for the non-disabled population.

Example – Innovation in Travel
Google Maps was designed to help people navigate and explore the world, providing directions, to those traveling by car, bicycle or on foot. For those in urban settings public transport is often the preferred option. People who use wheelchairs or with other mobility needs require information about which stations and routes are wheelchair friendly and recent versions of the app have incorporated 'wheelchair accessible" routes in transit navigation to make getting around easier for those with mobility needs. When selected, Google Maps shows a list of possible routes that take mobility needs into consideration, and availability is being expanded to new locations in cities across the world.

4.5.5 Autism and Communication

AT for those on the autistic spectrum tend to focus upon communication, interaction, and independent living. AT for communication is based upon principles of augmentative and alternative communication and are designed to help those with autism to interact with other

[52] https://project-ray.com/

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people.[53] Smartphones and tablets[54] are often a platform for speech-generating devices using text or symbols to create sentences that can be spoken aloud. Similar technologies offer opportunities for those on the spectrum to rehearse social interactions, including eye contact and interpreting expressions and emotions.

Research and development into AT for people with autism and other communication needs is wide-ranging. Development includes 'social robots' (Cabibahan et al 2013) that interact with users and simulate human interactions and emotional states to help develop social skills and to reduce nonverbal signals that a user finds overwhelming. A similar approach has been taken in the use of smart glasses or other devices to provide information about the context while reducing sensory, cognitive and emotional overload.

It is potentially problematic to separate the needs of those on the autistic spectrum from other needs and impairments. In this case we have done so to ensure that the experience of autistic and neurodiverse people is recognised and addressed. Many of the technologies and approaches for self-management of autism have equal relevance for some people with cognitive needs such as Alzheimer's disease or those experiencing poor mental health.

Example – Innovation in Travel

A range of wearable technologies including watches and pendants are available to provide rapid access to word and phrases required by people with a communication disability. Vocabulary available on the wearable can be preloaded to support travel, including question such as requests for fare details, directions, or further assistance. Such technologies can be easily used for rapid communication in time critical interactions with transport providers such as when boarding transport or purchasing tickets.

4.6 Implementation Scenarios

As a result of the analysis above, it is possible to outline a series of user scenarios related to the use and implementation of assistive products. In our next stage, we will explore these in relation specifically to mobility and transport, but there is value in considering other scenarios in which the technologies are being used. As suggested previously, the provision of equitable access to transport and travel requires the consistent use of accessible and assistive technologies designed to meet needs in a variety of settings, and the infrastructure to support those solutions will need to be compatible with other contexts.

4.6.1 Smarthomes and environmental interactions

Alex who is blind uses his tablet to control many of the features of his home which allows him to have control over heating, lighting and his home entertainment features just by

[53] https://aacinstitute.org/introduction-to-aac/
[54] https://www.callscotland.org.uk/blog/ipad-or-windows-tablet-for-aac/

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pressing the button on his tablet and swiping to change settings. His home control app is fully accessible using the built-in screen reader which speaks out the controls and settings. He has recently added additional controls to allow him to close his curtains, and a wireless door control, where he can speak to someone at the front door, confirm their identity, and unlock the door remotely to let them in. This increases his sense of security when at home. An additional feature unlocks the door when he is walking home and is within 10m of the front door, this allows him to get straight into the house and not need to try to find housekeys to enter the house.

Implications for Travel

The transition from transport to door can be challenging for people with disabilities and may contribute to a sense of disorientation. The use of location aware technologies that automate opening doors and turning on lights as the person approaches their door can reduce any feelings of vulnerability and allow the user to focus on one step at a time to safely enter a building once the journey is complete.

4.6.2 Communication and Interaction

Muneera, who is profoundly deaf uses a video call system on her phone to speak to customer services to make appointments for engineers to visit her home. The speech from the customer service representative is automatically transcribed for her using an AI driven application, so that she does not miss any important information. If the representative finds any of her speech difficult to follow, she can type explanations into a chat window to avoid confusion.

Implications for Travel

Reliable interactions with customer service staff for people with disabilities, throughout a journey is essential to travelling with confidence. Live transcription technologies such as Otter.AI can transcribe conversations in person, or held remotely, to ensure that people with hearing loss can understand and anticipate all parts of a journey and any requirements. The ability to save and recall a transcription can be valuable for people with cognitive needs who find it useful to recall any advice during the journey itself.

4.6.3 Financial and Purchasing

Andrea who has cerebral palsy uses Bpay[55] a wearable developed by her bank, for contactless payments at kiosks and paygates. She pays for entrance, or products from a kiosk, including payment for tickets, snacks and topping up her phone and energy bills simply by placing her wrist close to the contactless pad to authorize payments. This reduces her need to handle debit and credit cards, or to type in a PIN code into a small

[55] https://www.bpay.co.uk/

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keypad. Purchase and actions are easily completed without the need for any specialized system on the kiosk.

Implications for Travel

Contactless and remote payments methods are highly effective for many people with disabilities. Technology can be used to automate payment, with biometrics such as fingerprint being used to authorise the payments to increase security and a sense of safety. Increasing the availability of methods of payment will help ensure that purchasing to travel is more inclusive.

These scenarios indicate that assistive and accessible technologies have widespread application in the lives of people with disabilities. In the next section we examine these specifically when considering mobility and personal transport.

4.7 Conclusion

Assistive technologies can be characterized in many ways, high-tech or low-tech, specialist device or mainstream platform, human augmentation, or inclusive design. In this diversity some underlying trends can be identified:
Increasingly emerging technologies are moving from the provision of specialist devices designed solely for those with a specific need towards an increasing blend with mainstream technology that has a benefit to all users. This reflects increased interest in universal design principles and the pervasive nature of technology which requires access in less than optimal settings. As mainstream technologies increasingly embrace redundancy of input methods, integrating touch, sound and vision, there is greater flexibility for the user to determine the format in which information is received and control established. This further blur the boundaries between assistive and mainstream technologies.

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5 Travel

5.1 Applying digital trends in assistive technologies to travel and transportation

The growth of mobility and accessible environments research actively pursues topics such as human-computer interaction (HCI), electronic travel aids, rehabilitation robotics, obstacle detection and avoidance, indoor and outdoor navigation, wayfinding, cognitive psychology, and augmented reality (AR).
Methods include pattern recognition and machine learning, computer vision methods, ultrasonic audio feedbacks or echolocations, sensor-based techniques, global positioning system (GPS)-based navigation, spatial cognitive mapping and orientation.
Applications include (wearable) electronic travel aids, mobility aids, smartphone apps, accessible public transport, navigation technologies, accessible airports and accessible offices (as proposed by the ARIANNA navigation system when GPS information is unavailable) and augmented reality systems.

Other research has explored sensory substitution, visual prostheses, visual neuro-prostheses, brain plasticity, brain-computer interfaces (BCI), artificial vision, tactile human-machine interfaces (HMI), accessible computing, and human factors research.

Deliverable 3.1 defines a series of mobility scenarios which might bring benefits to people with disabilities. These scenarios include:

- Ride Pooling
- E-Scooter Rental (Sharing)
- Urban Ropeway
- Bike Rapid Lane
- Mobility Hub
- Moped Taxi/ Scooter Taxi
- Car Sharing/Automative Car Sharing
- Micro Transit
- Bike Sharing (includes electric bikes)
- MaaS
- Conventional public transport

In each of these scenarios a user journey comprised of a set of steps, is to be undertaken.
This user journey is critical to understanding ease of access to mobility. The Whole Journey Guide developed by the Australian Government[56] stresses the importance of this.

[56] https://www.infrastructure.gov.au/transport/disabilities/whole-journey/guide/index.aspx

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"People with disability are more likely to experience social and economic disadvantage because of more limited opportunities to earn income and the high cost (in proportion to their income) of their housing, travel, medical and other needs. In many cases disability restricts people from driving a private vehicle, either through physical or cognitive ability or the lack of economic resources to own and operate a car. For many people, the perceived or real inaccessibility of public transport leaves them reliant on family or friends, or particular types of public transport such as the taxi system and the increasingly popular ride-share. This reliance on others to drive them where they want to go affects their ability to participate independently in many social, economic or cultural aspects of the community.

Access to public transport opens up opportunities for personal empowerment, social inclusion and community participation. People can choose to travel to see friends and family and participate in social and cultural activities or other initiatives such as training or education. Accessible public transport allows individuals to travel based on their requirements (such as cost, time of day, urgency of travel, length of the journey, interchanges etc.) rather than having to rely on private transport options.

Public transport is cost effective for individuals and the economy. Improving the accessibility of public transport can promote more efficient transport decisions by individuals and increase the customer base as more people are able to travel for work, business or study. This improves productivity and supports a stronger economy."

In the Australian model that whole journey is made of the the following parts:

- Pre-journey planning: these are the decisions about using transportation that are made based on available information.
- Journey start and end: these usually occur outside the transport system. For example, travelling from home to the stop, station, or terminal along a footpath, and then from the stop, station or terminal to the final destination.
- Transport stop/station: the dedicated or identified locations where transport services operate to and from.
- Transport service: the conveyance that enables the journey, the 'on board experience', as well as the scheduling/routing of services
- Interchange: places where service or mode transfers take place.
- Return journey planning: reversing the journey for the return to origin or an onward journey to another place.
- Disruption to business-as-usual: this includes planned and unplanned disruption to transport services or along the journey start and end sections.
- Supporting infrastructure: this supports the journey and includes mid and end of trip infrastructure such as toilets, drinking fountains, wayfinding and seating

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At each stage of this journey we can explore where the emerging assistive technologies described above will impact and promote ease of access. We will also seek to apply the emerging mobility systems as examples within the stages of the journey.

In D3.1 the journey was defined as:

- pre-trip activities (planning and information gathering),
- on-trip activities (getting from point to point in the chosen means of transport) and
- additional activities (cancelling, re-booking, handling complaints, passenger rights, etc.).

In the details below these broad groupings have been divided according to the Australian model so that:

- pre-trip activities include
  - Pre-journey planning
  - Journey start
- on-trip activities encompass
  - Transport stop/station
  - Transport service
  - Interchange
  - Return journey planning
- additional activities include
  - Disruption to business-as-usual
  - Supporting infrastructure

5.1.1 Pre-journey planning

Decisions about using a mode of transport based on available information

Scenario

Pre-journey planning generally takes place before someone leaves an initial location to start their journey. This stage involves accessing information about options, routes, service timetables and any required connections and conditions at the destination. Sources of information may include:

- online sources
- telephone services
- printed materials, or
- asking someone (friends, family, customer service staff or others) to help provide this information.

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Persons with disabilities may need to expend time and effort at this stage to feel confident that they can efficiently and safely complete their journey. This contrasts with other customers who can often make more spontaneous public transport travel decisions.

Digital payment methods also allow travellers to pay, or authorise payment at this stage, reducing the need to pay at kiosks or counters at stations, or to find cash or debit cards when boarding or departing a taxi or shared ride. Services such as **Uber** offer the ability to have payment preauthorised and made automatically when the journey is complete.

During this phase, users are seeking information to confirm the accessibility of all parts of the journey. Their decision making during this phase is influenced by their lived experiences and the experience of friends and family. Building confidence around the accessibility of the entire journey is key to enabling and encouraging more people to use a form of transport to meet their travel needs.

Increased ease of access to this phase would be demonstrated by:

- More people are able to make informed decisions about transport
- Reduced time taken to plan journeys
- Increased confidence of users that the journey will be seamless and safe

Potential Impact of emerging AT

Natural Interfaces offer more diverse and accessible ways for people with disabilities to interact with information. Voice interfaces such as Amazon's Alexa allow natural language to be used for enquiries, which are then spoken out supporting people with a visual or other form of print impairment. An example might be: "Alexa what time is the next bus to the airport"; the system is **location aware** and can understand the likelihood that you are searching for a route to the nearest airport. Such systems may then prompt with further information such as "do you want to know about later buses?"

AI can help us in planning journeys by suggesting and recommending the best options for a journey. For instance, if we needed to get to the airport, we might enquire, what the best way to the airport is, we might get asked whether we mean the fastest, most direct or cheapest journey and then recommend a solution based on refining the query. Over time the system has the capacity to learn from our choices, how we personally define "best" and retains that when responding to similar future enquiries.

The **Internet of Things**, when integrated with AI or machine learning allows us to plan our journey based on the real-time experience of others with similar needs. For instance the technology could inform that user that "people using a wheelchair near you, travelling to the airport by taxi take on average 22 minutes to reach the destination or 36 minutes by bus" Such systems could automatically then prompt users with a questions such as "would you like us to book a taxi for you?"

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VR can support users with a realistic simulation of the crucial phases of journey planning, so that user can choose best options and/or prepare to the journey itself, anticipating views and operations (access, drive and use means of transportation).

5.1.2 Journey start and end

Including entry and exit from transport systems

These might include travelling from home to transport entry, and then from the transport drop off point to the destination.

Scenario

To enter the transport system, people need to move from their current location to a transport point of access, or to leave the system to enter a destination. This might require the user to walk, use a wheelchair, use an elevator, or drive to and from the relevant point. People with disabilities face challenges because of a lack of information about the environment they are entering. This is also a challenging part of the journey for providers and operators as they may have little or no control over conditions around the entrance and exit points and links to destinations.

Increased ease of access to this phase would be demonstrated by:

- Travel to and from transport access points is easy and efficient for people with disabilities both for those requiring assistance and those who are fully independent.
- Those involved in managing the environment around destinations, receive support and guidance to consider the impact their actions have on users and work cooperatively to resolve issues and explore opportunities.

Potential Impact of emerging AT

The Internet of Things allows for Real-time tracking of transport which can be communicated to a person with disabilities to aid them in leaving their location to reach the access point for the transport. These can include both outdoor navigation, based upon GPS systems, and indoor systems utilising beacons. Ideally these systems are integrated and seamless. Wearable technology and machine learning can record the maximum time taken by the user to reach that point and warn the person well in advance that they need to be leaving to reach the access point on time. For people with disabilities this reduces the risk of missing crucial transportation which may incur costs and add to frustration.

Augmented Reality can indicate specific access points for both the passenger and the provider of the service. Meeting points can be displayed in AR, and can be used to indicate locations of bus stops or platforms which are permanent access points, but also both points of access and routes to temporary access points including ride sharing collection points for services such as UBER or the direct route to temporary transport such as eScooters or other shared vehicles.

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Such AR systems can also take into account the need for accessible routing to an access point avoiding both fixed and temporary barriers to the desired location and reducing the risks of missing a transport connection.

Wearable and location-based technologies can support ticketless access and keyless unlocking of rental vehicles when the user is in proximity. The automation of such services can be of value to those with intellectual disabilities who may find codes complex to repeat into a keypad, and the provider can be assured that the vehicle will be automatically locked when the user is more than 10m from the vehicle.

5.1.3 Transport access point

The locations where the user accesses the transport service

Scenario

This stage is concerned with the person's experience at the access point, from their arrival until they board the vehicle or conveyance. During this stage they:

- arrive and enter any agreed access point
- access information about their journey
- access ticketing, retail, or other facilities
- navigate their way to their transport
- wait for their service
- board the transport vehicle

Transport access points may be as simple as a sign or stop marker, or as complex as a multi-modal interchange where different services converge.
People with disability have highlighted issues at this point of the journey, including:

- lack of shade and shelter
- sufficient space for mobility devices
- visual and audio 'clutter' associated with advertising or general street/road signage
- issues around identifying and hailing their service
- late changes to departure points
- difficulty in boarding a vehicle

In larger transport settings such as bus, air or rail terminals, movement between drop-off points and access points for the next stage can be challenging.

Increased ease of access to this phase would be demonstrated by:

- The access point is easy to identify through tactile, visual or audio messaging, easy to access, provides information about services in a variety of formats, and offers a safe, suitable boarding point
- Users can easily locate boarding points from drop-off points and surrounding infrastructure

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- Users are safe and comfortable while waiting at the access point for their service
- Boarding itself is easy, safe and occurs without drawing undue attention to the individuals needs or condition.

Potential Impact of emerging AT

Location based services will allow the virtual access point to be shared with the provider and the precise details to be agreed. This allows a point of access to be confirmed that has the facilities required by the passenger for their comfort and convenience. Choosing a virtual access point can also be eased with the addition of local data around the point indicating potential places with shade and shelter or other facilities for personal care.

5G offers opportunities for information on services to be delivered in a range of formats in real time. The speed of 5G connections allows multiple data sources to be integrated including the location of the vehicle, the likely journey time and any immediate changes that are needed.

For many passengers, the ability to automate the booking and payment system using **wearable or portable technologies,** reducing the risk of errors in payment, or booking. The move towards **cashless facilities** makes payment both safer and easier for disabled passengers.

Robotics applications as they could ease the boarding phase for passengers with mobility impairments: it includes the chance to have adaptable and safe robotic automation as part of access features to means of transport, as well as the evolution of specific mechanical interfaces for those are already using AT for mobility, such as electrical wheelchairs, exoskeletons for locomotion, special postures…

5.1.4 Transport service:

The vehicle that enables the journey, the 'on board experience', and the scheduling/routing of services

Scenario

This phase involves the user's interaction with the vehicle and potentially a driver or other users of the vehicle. During this stage, the customer boards the vehicle, travels to their destination, and exits the vehicles. Ideally, independently, quickly, and effectively with:

- a safe, secure and comfortable experience on board the vehicle: including chance to exploit means of transportation services onboard
- access to information during the journey: in case of self-driving, the chance to be guided, receiving accessible information, to reach the destination
- Exits the vehicle easily at their desired stop/station.

People may need assistance with boarding and exiting in the form of ramp deployment or other aid, on board communication should help build the confidence of the passenger that such services are prepared for arrival. Requirements of the in-vehicle stage may be different depending on the mode of travel and length of the journey.

Increased ease of access to this phase would be demonstrated by:

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- Persons with disabilities using public transport feel confident, safe, and secure knowing they can board, travel and exit the service
- Requests for assistance from persons with disabilties are responded to appropriately

Potential Impact of emerging AT

5G and **location-based services** allow users to receive and share real time ongoing travel data. The ability to share real time travel locations can be especially valuable to some of the most vulnerable in society who can be monitored for safe arrival and for any additional support required.

For those with communication impairments **AI** supports access to real time communication with the transport provider including real time transcriptions of speech, word prediction and text to speech for communication. It could be of help also for all passengers with a cultural disadvantage, considering language barriers in international contexts. Text can be augmented by symbols to aid understanding for those with literacy impairments or other form of communication need.

Increased **personalisation of services** can be established from the actual records of transport use. Hence if a passenger has always required a wheelchair accessible vehicle than that is what is automatically ordered, if the passenger requires help or support to board a vehicle and a chair stored, this is instantly communicated to the provider when the journey is booked. Equally the accessibility of onboard services, including washrooms or restaurants could benefit from the application of **modular automations/robotics** helping passengers to reach and use services. Such services are especially important for persons with disabilties in planning longer journeys.

5.1.5 Interchange:

Places where transport systems converge and transfers take place

Scenario

People with disabilities may need to transfer to another transport system, mode or route at a point during their journey. To do this, they exit the service, navigate their way through an interchange to the next service, and then board. Changing services or modes occurs at an interchange. Changing may occur in a purpose-built location, while other changes require travellers to exit one service and travel to the point of access. Transfers need to be efficient and easy to use to maintain confidence and reduce stress.

People with disabilities are less likely to embark on public transport journeys that involve interchanges as it adds complexity and uncertainty to their trip.

Increased ease of access to this phase would be demonstrated by:

- People are not deterred from a journey because it involves an interchange
- The transfer is as easy, convenient and efficient for a person with disabilities as it is for non-disabled users.

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Potential Impact of emerging AT

AR and location-based services offer the opportunity for real time navigation through an interchange, with live updated directions based on the movements of others. As with other such services the ability to track the movements of users, including those with specific needs, helps users to be confident that they have the time and the most optimal route to reach the next stage of their journey.

AI applied to analysis of other user movement can inform in real time the passenger with disabilities whether the planned transfer time is realistic or if they should make alternate plans. Such systems can alert the provider of a service that a passenger with additional needs is en-route and to request a delay or any other accommodations to facilitate their transfer.

5.1.6 Return/Next journey planning:

Reversing the journey to return to the origin or for an onward journey to another place

Scenario

Once people have reached a destination, they may need to return to their origin, or know they will need to undertake an onward journey to a second destination. Users should be able to easily find the start of their return journey by re-tracing their travel path to locate an access point and board services.

Persons with disabilities may arrange further or return journeys as part of their pre-journey planning. Travel plans may be fixed on returning on a service at a particular time. If their circumstances change, or if changes are made by service operators, it can be difficult to re-plan their return journey.

Increased ease of access to this phase would be demonstrated by:

- People being able to easily re-trace their steps to find the public transport node that takes them to their origin or further destination
- Journey planning should be flexible, so people don't have to work to a rigid schedule if they prefer not to

Potential Impact of emerging AT

AI and location-based services can support the tracking of movements and help to plan a return or onward journey. One of the challenges experienced by those with disabilities at this stage is the uncertainty of departure times from the new location. The technologies can be used to maintain a live update on options for the next stage of the journey as the day progresses and this can be communicated on an ongoing basis with the use of high speed **5G** connectivity.

Similarly, **AI and location-based services** can offer real time updates to plans taking account of data from other passengers planning to use similar routes and forms of transport. Sensors held with mobile and portable devices and **wearable technologies** can track ease of movement and update planning options for the next stage of the journey.

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For those with intellectual impairments the capacity to have a journey replayed in reverse with **VR** and **AR** will add clear contextual information in unfamiliar contexts. Equally where an onward or return journey requires the person with disabilities to make the journey using a different route or form of transport, then it is helpful for them to review a simulation of the journey prior to starting the next steps.

5.1.7 Disruption

Including planned and unplanned disruption to services or the journey

Scenario

This stage addresses any disruptions to the usual operation of the transport system. These might include cancellations, closure of a service, weather related disruptions, vehicle breakdown, vehicle and transport replacements, or evacuation of a vehicle or station due to an emergency.

Disruptions can be planned or unplanned. A planned disruption is generally well managed with advance notice, and alternate arrangements can be put in place to minimise the effects of disruption on planning a journey. Many of the lessons learned from emergency evacuation planning can inform other responses to disruption and the mainstreaming of such information into everyday use may help prepare people with disabilities to cope when a crisis does arise.

Unplanned disruptions are more difficult to manage as information about the nature of the disruption and alternate arrangements can be difficult to source and communicate.

When disruption occurs, people should be made aware of the situation, how they should respond, and whether there are alternative arrangements in place for them to complete their journey.

People with disability say that disruptions are highly stressful and the possibility of disruption is a significant barrier to their participation in public transport journeys. For those experiencing mental health needs such disruptions may have significant impact and the need for on demand assistance in these situations may be critical to continued well being.

Increased ease of access to this phase would be demonstrated by:

- People with disability are no more impacted by a disruption than their fellow non-disabled travellers
- People with accessibility needs know where to go or who to ask for information and assistance if there is a disruption

Potential Impact of emerging AT

AI can interpret live data to predict and anticipate disruptions based on real time data. Unlike non-disabled users, persons with disabilities need to understand options that are both available and accessible. The sharing of information on real time disruption and arrival times can help ensure that destinations are aware of arrival times and can support those who are vulnerable.

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Information gleaned from potential services linked through **IoT** can suggest the locations of alternate travel options through a mobile or portable device including the availability of rentable and usable vehicles in nearby locations.

5.1.8 Supporting infrastructure for the journey

Includes mid and end infrastructure such as toilets, drinking fountains, wayfinding on board services and seating

Scenario

People interact with a supporting infrastructure throughout their journey. This may include physical infrastructure such as bathroom facilities, drinking fountains, signage, seating, shelter, lighting, maps, and timetables. It also includes the service provision infrastructure such as customer service, other operator staff and those involved in their journey. Both are critical to the experience of people with disabilities whilst travelling. Interactions with service staff, drivers and other support people often define the success of a journey.

Increased ease of access to this phase would be demonstrated by:

- A supporting infrastructure that allows people to travel safely, informed and comfortably
- Where assistance is required, there are people available, trained, and willing to help

Potential Impact of emerging AT

Location based services offer real time information about surrounding and nearby facilities that are accessible and usable for a person with a specific need. Such information can also be used as part of planning a journey access point, destination, or interchange where users are aware that they may need such facilities.

Such information can be presented through **AR** to offer instant redirection information to appropriate facilities on demand.

Accessibility to information should be assured in a variable way in order to have the chance to personalize the access to those with disabilities: **5G** technologies will bring all the information on a mobile terminal of the user. Physical accessibility to specific services could benefit from **Robotics and Automation** applied per se as AT solution or directly interfaced to AT already in use by the passenger.

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6 Implications

In seeking to implement the emerging technologies outlined above, to facilitate the benefits described for people with disabilities, there will be a need for agencies to determine the extent to which current regulations, policy and standards are sufficient to protect individual rights, including privacy and safety, without creating undue impediments to the potential of innovation.

Many of the technologies outlined demonstrate a means by which some of the barriers to full social inclusion and access to mobility can be removed or reduced. The UN Convention on the Rights of Persons with Disabilities (United Nations 2006) is the international binding human rights treaty addressing the rights of all persons with disabilities. Member states have to take action to ensure they uphold the rights of persons with disabilities.

Article 3 of the Convention sets out general principles, including full and effective participation and inclusion in society and accessibility, whilst Article 4 sets out general obligations, including an obligation to undertake or promote research and development of universally designed goods, services, equipment and facilities and to promote universal design in the development of standards and guidelines. There is also an obligation to undertake or promote research and development, availability and use of new technologies, including information and communication technologies, mobility aids, devices and assistive technologies, suitable for persons with disabilities, giving priority to technologies at an affordable cost, as well as to provide accessible information to persons with disabilities about these products and services.

Article 9 of the Convention gives persons with disabilities the right to access, on an equal basis, the physical environment, transportation, information and communication, including information and communication technologies and systems. Whilst Article 21 of the Convention states that all measures should be taken to ensure that persons with disabilities can exercise their right to freedom of expression and opinion, including the freedom to seek, receive and impart information and ideas on an equal basis with others and through all forms of communication of their choice.

Viewed together these articles provide a strong basis for stakeholders to ensure that the regulations and policy related to emerging technologies are enabling, and not unduly impeding successful implementation to bring about increased access.

Similarly, the 2030 Agenda for Sustainable Development (UNDESA 2016) and the Sustainable Development Goals committed to a plan of action to end poverty, protect the planet and ensure global prosperity. The 2030 Agenda promotes universal respect of human rights, human dignity, the rule of law, justice, equality and non-discrimination. Its motto is to “leave no one behind”, with the pledge to recognise the dignity in every person and to reach the “furthest behind first”. The goals are universal and provide a policy framework for regulatory actions. In 2017 the Stakeholder Group of Persons with Disabilities (IDA/IDDC 2017) presented a paper

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with a clear set of recommendations in relation to emerging technology. Emerging technologies can support the achievement of SDGs.

European policy and regulatory framework

The EU Charter of Fundamental Rights (European Union 2007), brings together all the personal, civic, political, economic, and social rights enjoyed by people within the EU. As technologies emerge current EU directives are directly relevant and are referenced in section 3.3 on standardisation. The EU directive on accessibility of public sector bodies websites and applications[57] and the European Accessibility Act[58] cover a broad range of ICT products and services and lays down a set of accessibility requirements, including a list of functional performance criteria.

Such policy and regulation which supports the implementation of the rights of persons with disabilities, must be carefully considered within a context of broader regulation to protect citizens rights. For instance, the EU General Data Protection Regulation[59] came into force in May 2018 and provides a high standard of personal data protection, including the principles of data protection 'by design and by default'. The EU has high standards in terms of safety and product liability, but it is not yet clear whether these are sufficiently robust for emerging technologies. It is essential for citizens and businesses alike to be able to trust the technology they interact with, to have a predictable legal environment and rely on effective safeguards protecting their fundamental rights and freedoms.

The European Commission published a Communication on Artificial Intelligence in April 2018,[60] stating that "Growth in computing power, availability of data and progress in algorithms have turned AI into one of the most strategic technologies of the 21st century. The stakes could not be higher. The way we approach AI will define the world we live in. Amid fierce global competition, a solid European framework is needed."

The European Commission seeks for the EU to "be the champion of an approach to AI that benefits people and society as a whole." The Communication states that "Europe should strive to increase the number of people trained in AI and encourages diversity. More women and people of diverse backgrounds, including people with disabilities, need to be involved in the development of AI, starting from inclusive AI education and training, to ensure that AI is non-discriminatory and inclusive."

Some consumer organisations (BEUC 2019) have raised concerns that the communication does not include a commitment to update relevant consumer protection laws to ensure these are fit for the AI era.

57 https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32016L2102
58 https://ec.europa.eu/social/main.jsp?catId=1202
59 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016R0679
60 https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe

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In a survey undertaken by Marzin (2018) on behalf of EDF, people with disabilities were asked to suggest their concerns about emerging technologies. Many of these concerns will need to be addressed in the policy, regulations and standards that guide the use of emerging technologies in the development of AT.

The concerns expressed included

- 88% were concerned about lack of accessibility
- 60% were concerned about lack of standardisation
- 56% were concerned about interoperability with the assistive technology they already use
- 50% were concerned about emerging technologies leading to discrimination
- 40% were concerned about emerging technologies affecting their privacy
- 42% were concerned about ET affecting their security
- 20% had other concerns, including concerns about usability, affordability and lack of digital skills

The report considers each in turn and suggests how policy needs to respond to the concerns expressed. Those considerations are summarised below.

Accessibility

Treviranus (2018) has expressed concerns about the risk of data-driven design, notably for smart cities. Her concern rests upon these techniques to be founded upon 'norms'. She notes that better cities are likely to be designed through consideration of the needs of those that are excluded by current designs, creating an alternative that is both more welcoming and humane. Equally, applications based on IoT services may be inaccessible because the app that controls connected devices is unusable by people with disabilities. One can suggest that the application of universal design principles, in the end to end design process, would help to ensure that such goods and services can be used by all. Compliance with existing digital accessibility standards and guidelines, as outlined in section 3.3 might address this barrier.

The design of both AT and technology interfaces based upon emerging technologies will need to be user-friendly and guarantee adequate support for users. Many users may need help in installing and using new products and services. For this the ready availability of support teams with staff equipped with knowledge about accessibility features will be invaluable.

Interoperability and standardisation

Concerns over the lack of standardisation and interoperability of emerging technologies with assistive technologies reflect the experience of many disabled people who have encountered inaccessible technologies in the past. Both in the case of current and emerging assistive products there is a need for reliable interoperability to maintain and progress access. The need for standards has been expressed by Abou Zahra et al (2017) seeking standards to support an accessible and inclusive IoT. They suggest that any lack of interoperability would prevent

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assistive technologies integrating with IoT systems. New standards could resolve such issues, although as with the web, standards alone will have limited impact.

Deliverable 3.3 highlights recent developments in accessibility standards, which when fully implemented will address this challenge. Initiatives such as international standardisation work on AI offer an opportunity for collaboration towards inclusive AI standards that benefit all users.

Discrimination

AI driven automated decision-making has the potential to discriminate against some parts of the population. For instance, an algorithm estimating the price of travel insurance could lead to those with disabilities being charged more or denied cover where data falls outside the standard responses. Such discrimination may be unintentional, but there remains a risk that emerging technologies reinforce the exclusion of persons with disabilities. Such bias is an issue to be addressed. If biased data is interpreted by an algorithm, biased results will be the outcome (Hacker P 2018). For this reason, grounding recommendations for travel upon historic data of journeys undertaken by persons with disabilities is likely to offer biased results as the historic limitations of user decision making will not have been considered. If AI is to be integrated to support the access needs of those with disabilities, then the dataset must include appropriate and relevant data based upon an inclusive ethical and legal framework (Jobin et al 2019).

Privacy and security

Many emerging technologies require access to personal or sensitive information, therefore need to ensure privacy and security is critical (Naeini et al 2017) . Emerging authentication methods, such as better biometrics, could address these risks for persons with disabilities and the non-disabled population (Rui and Yan 2018). The data collected by such technologies could unwittingly disclose the nature of a disability which could be used to justify further exclusion from goods and services

The EDF report suggests that there is a lack of understanding about the implications of sharing data, including sensitive personal data. The misuse of such data could become widespread and it is important for persons with disabilities to be conscious of the risks and of steps they should take to protect themselves.

In the European Union, citizens have significant rights for protection of their personal data, because of General Data Protection Regulation (GDPR) although it is not yet clear how emerging technologies will be impacted by this. GDPR, requires consent to collect data on user behaviour and there remains a risk that a refusal to allow such collection could lead to the denial of a service provision. Initiatives such as the European Consumer Consultative Group put forward policy recommendations for a 'safe and secure use of artificial intelligence,

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automated decision making, robotics and connected devices in a modern consumer world'[61]. BEUC[62], the European consumer organisation are also requiring policy makers to ensure that products are safe and that risks including discrimination, loss of privacy, autonomy and lack of transparency are avoided, with associated enforcement and redress.

Affordability

Cost can be a significant barrier to assistive and accessible technologies (Rohwerder B 2018). In seeking to implement the emerging technologies to support access as outlined above there will be a need to consider how any additional costs will be met. The role of the state in subsidising access and inclusion may need to be explored in making such decisions, to avoid any additional costs needing to be borne by the person with disabilities.

Lack of digital skills

Whilst many persons with disabilities have been early adopters of new technology, others are less able to do so as they do not have the skills required (Mavrou et al 2017). Policy and implementation of emerging technologies will need to ensure that all persons with disabilities can take advantage of the opportunity.

Implications for Providers of Mobility Services

The EDF report suggests a series of policy issues that service providers should consider in planning the design of services for the future. Such considerations should be recognised as a crucial element of CSR (Corporate Social Responsibility) not only in terms of declarative adhesion, but also as part of a general attitude that will produce (on an annual basis) continuous improvement in the accessibility of transportation. They suggest that:

- Accessibility is integrated as a process that is constantly looking at societal and ethical aspects, technology trends, assistive technology, as well as to requirements, guidelines and all issues related to standardization pathways (RPIS 2020)
- The inclusion of persons with disabilities should be considered as part of a general understanding of human diversity. As a result the principle of "accessible by design" will save providers from needing to retrofit or modify designs whilst recognising the principle of dignity to all customers. In this sense, designing services offers an opportunity to provide alternative and adapted solutions to be accessed by persons with different functional, linguistic and cultural characteristics
- Human Resources are an integral part of the solution, any technology-based innovation requires adequate infrastructure to work, training for team members should aim to assure a better understanding of purposely applied technologies, but also to ensure a positive attitude towards people with disabilities as the product of a "cultural" step forward.

[61] https://ec.europa.eu/info/sites/info/files/eccg-recommendation-on-ai_may2018_en.pdf
[62] https://www.beuc.eu/publications/beuc-x-2018-058_automated_decision_making_and_artificial_intelligence.pdf

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- In more complex organisations specific expertise in accessibility and access should be part of the team. These team members have responsibility for supervising implementation of any plans, educational programmes, counselling about policy evolution and evaluating outcomes
- In planning for access, care should be taken to consider all the phases of the journey, so it is framed with an integrated design including ICT and the physical accessibility of the built environment
- AI and RPA when applied to service functions such as travel planning, booking, or navigation could help to increase levels of accessibility and may be based upon the development of an API drawing upon standards for data and communication exchange across cloud based services
- Interoperability will be assured by the harmonization (RPIS 2020) of standards and user requirements, assuring secure and reliable ICT services are designed for accessibility
- Interoperability should be anticipated not only for ICT systems and services, but also for what is emerging in the field of AT based on robotics
- End user involvement in conceiving and testing accessible solutions, mentioned in general terms for stakeholders, should become a common practice: starting from iterative process as provided in ISO 9241-210 (Ergonomics of human–system interaction)
- Personal and wearable technologies are preferred in most cases as part of AT solution for those with disabilities and referenced in D3.3. Standards organisations are operating within the EU to assure interoperability between agents, allowing accessibility of customised interfaces, as part of requirements and standards applicable to new products or solutions
- The two-channel principle (or principle of alternative use), referred to in D3.1, could be an option to address specific accessibility needs. The reduction of stigma and increased in the dignity of customers should be taken into account in conceiving alternative approaches to access (either physical or virtual)

"Plug and Pray" (Marzin 2018) makes a series of recommendations to support the full implementation of emerging technologies to benefit the lives of persons with disabilities. Many of these are highly relevant within the context of TRIPS. Some of the key, relevant recommendations can be summarised as:

- Stakeholders should adopt a human-rights approach as set out in the UNCRPD and UN Agenda 2030 and its Sustainable Development Goals. Accessibility standards should include minimum key performance indicators to ensure persons with disabilities are provided with functional equivalency
- Technology should not be primarily seen as an opportunity to cut costs and as a convenient excuse to close other routes to access services
- Stakeholders should actively engage persons with disabilities and representative organisations in the end to end development process

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- Stakeholders should seek to establish diverse teams through inclusive recruitment and training policies. Teams should seek to reflect the diversity of the general population, including persons with disabilities
- Use universal design principles, and relevant standards to ensure research and development leads to emerging technology products and services that are accessible to all consumers
- Products and services should be tested in a range of scenarios including challenging cases to ensure your product meets functional equivalence
- Set up free and accessible customer support services so that all your customers, including those with disabilities, can access the advice they need on demand
- Customers should have the support to set up, configure, use and update purchased and provided products and service, with user-friendly guidance
- Include full and jargon-free information about accessibility features in product description. This should be available in accessible formats, such as large print or braille, but also on accessible websites
- Team members should receive disability-awareness training
- Stakeholders should promote and support digital skills training for persons with disabilities of all ages, to ensure that all citizens can safely use emerging technology products and services
- Policy should seek to make compliance with UNCRPD obligations on accessibility and universal design a pre-requisite when public funds are used to develop technology, so that resulting technology solutions are accessible for persons with disabilities
- Ensure all emerging technologies used in e-government services including public transport are built with a requirement to apply universal design from the outset
- Ensure all emerging technologies used in public services are able to provide functional equivalency
- Develop a legal framework that delivers a good level of accessibility for emerging technologies, but also supports the human rights of persons with disabilities using them and addresses any concerns
- Researchers should promote and communicate research on emerging technologies to people with disabilities and other stakeholders, with easy to understand language and practical examples of benefits and risks
- Researchers should actively engage with disabled persons organisations to consider how emerging technologies are impacting on disabled people
- The growth of multidisciplinary networks including computer science, social science and law should be encouraged to promote understanding of how any research impacts on other domains
- Opportunities to undertake research into how emerging technologies are impacting disability rights should be encouraged
- Universities should seek to Include accessibility and the principles of Universal Design into relevant curricula and courses

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7 Conclusion

Emerging trends in digital and assistive technologies demonstrate capacity to address many of the pain points during travel experienced by persons with disabilities. Such technologies need to be integrated and implemented across all stages of the travel experience and have clear benefits not only to those with disabilities but for all those challenged in making a journey, who experience situational disability in a new setting, where language and services are not familiar. In addition, actions need to be taken to implement the technologies to have the greatest beneficial impact. These would include addressing the need for trained and confident personnel, the creation of an accessible infrastructure through inclusive design and the modular integration of interfaces to respond to a variety of needs.

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9 Annex 1 Methodological Framwork

With reference to chapter 2 (Methodology),this appendix offers greater detail to describe the steps that have been carried out in following a unique methodological scheme.

9.1 Desk Analysis

Desk reserach has been carried out collecting articles and reports using Google Scholar, ResearchGate, DBLP and other online repositories following the next assumptions:

- search keywords as referred to the specific topic (Emerging Technologies, Trends in AT and Emerging Access and Mobility)
- material published in the last 5 years, discarding older ones with the exceptions of top and reference works (for instance WHO ICF Classification).

Each publication has been classified on the basis of:
- key findings outlined in text and conclusions
- foreseeing impacts privileging those describing a timeframe of next 5 years.

A short list of collected material has been discussed among AAATE team members, discarding similar publications produced by the same working group or insisting in the same framework. In case of conference presentations (i.e. SlideShare presentation published in Internet), related proceeding/journal publication has been searched in order to include original work.

Some trend reports have been analysed: a matching between key findings has been discussed to evaluate recurrent foreseen solutions, to be considered in the research. At the end of this process, a total of 48 reports and articles in academic journals, with a further 47 reports and reviews in the grey literature including reports and news published on the internet were considered and key information incorporated.

9.2 Interviews

Main reference to this work is constituted by its relationship with Delphi Method[63]: even if the availability for a second round (video call) has been asked to participants, the iteration process has been avoided at end of the first submission, on the basis of satisfactory results of the analysis of first round of responses.

Recruitment of interviewee

The panel has been selected on the basis of AAATE team advice: a list of 37 international experts in digital technologies and AT was compiled comprising:

- Research institution (public or private): 9

[63] https://en.wikipedia.org/wiki/Delphi_method

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- SME and self-employment (consultant): 11
- Associations (profit or not profit): 15
- Industry (>SME): 2

Most of them are working in within the EU whilst 9 are living elsewhere.

Interview

The interview questions were centred mostly on what is emerging from desk research: in particular, in consideration of selected panel, the main point was the impact of some of reported trends as expected for people with disabilities, asking for a descriptive text (example of field of application) and for the value of importance in the everyday life of persons with disabilities.

The questions are reported next:

Q1	*Artificial Intelligence defined as a branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence.*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

Q2	*Internet of Things defined as the interconnection through the Internet of technology devices embedded in everyday objects, enabling them to send and receive data.*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

Q3	*Location Based Services defined as software services which utilize geographic data and information to provide services or information to users. This can be used in a variety of contexts, such as health, indoor object search, entertainment, work, personal life, etc.*	
Please describe the potential Impact on People with	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

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disabilities of this technology		

Q4	*Augmented and Virtual Reality are defined as the bridge between the digital and physical worlds. They allow you to take in information and content visually, in the same way you take in the world. AR adds digital data to our view of the physical world, while VR creates a digital representation of physical environments ad objects.*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

Q5	*5G Networks are defined as cellular networks capable of high throughput and data download, that can divided into small geographical areas connected to the Internet and telephone network through a local antenna in the cell. The main advantage of these networks is that they will implement private/local services to support specific communication purposes.*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

Q6	*Autonomous Vehicles are defined as s a vehicle that is capable of sensing its environment and moving safely with little or no human input. Self-driving cars combine a variety of sensors to perceive their surroundings, such as radar, lidar, sonar, GPS, odometry and inertial measurement units . Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

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Q7	*Natural Interfaces are defined as a user interface that is effectively invisible, and remains invisible as the user continuously learns increasingly complex interactions. The word natural is used because most computer interfaces use artificial control devices whose operation has to be learned. For the user such interfaces provide interactions with technology that come naturally.*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

Q8	*Digital Payments are defined as as any payments made using digital instruments. In digital payment, the payer and the payee, both use electronic modes to send and receive money. No hard cash is used.*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

Q9	*Wearable Technologies are defined as smart electronic devices that are worn close to and/or on the surface of the skin, where they display, detect, analyze, and transmit information concerning to and from the wearer.*	
Please describe the potential Impact on People with disabilities of this technology	Can you give examples of applications, products or services based on this technology	Ranking of importance on the lives of people with disabilities 1 = low / 10 = High

Q10	*Robotics and Drones. A robot is a machine designed to execute one or more tasks automatically with speed and precision, drones are an implementation of robotics that are mobile and are guided by remote control or onboard computers*	
Please describe the potential	Can you give examples of applications, products or	Ranking of importance on the lives of people

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Impact on People with disabilities of this technology	services based on this technology	with disabilities 1 = low / 10 = High

Interview submission

As a result of the Covid19 crisis, which included the closure of universities, we undertook to automate data collection, questions were submitted by means of a fully accessible electronic survey system (SurveyMonkey[64]), asking for mandatory fields (respondent name and emails) in order to have the chance to classify responses.

Data analysis

The total respondents were 14: (one was interviewed verbally) data gathered were analysed checking for recurrences and specific points proposed. They were downloaded and processed on a spreadsheet to re-classify the responses on basis of belonging to defined frameworks, taking into account the ranking value (from higher to lower) the potential impact described and the example given by each respondent. As an example the responses for AI were mapped onto three categories, personalisation, health and safety and accessibility.

At the end of analysis, relevant outcomes have been compared with results coming from desk analysis to reach a uniform description to be reflected in the document sections. References and insight from individual interviewees are cited in chapters 4.3 and 4.4.

[64] www.surveymonkey.com

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