Open Research Online

Bennett, Roger and Vijaygopal, Rohini (2024). Exploring mobility and transportation technology futures for people with ambulatory disabilities: A science fiction prototype. Technovation, 133, article no. 103001.

Technovation 133 (2024) 103001

Contents lists available at ScienceDirect

Technovation

journal homepage: www.elsevier.com/locate/technovation

Exploring mobility and transportation technology futures for people with ambulatory disabilities: A science fiction prototype

Roger Bennett [a,*], Rohini Vijaygopal [b]

[a] *Kingston Business School, Kingston University, London, UK*
[b] *Open University, UK*

ARTICLE INFO

Keywords:
Science fiction prototype
Mobility
Transport
Transportation self-efficacy
Ambulatory disability
Technology interest
Imagination workshop

ABSTRACT

Although a number of studies have explored science fiction prototyping as a method for new product development, no study has ever used the method to examine the mobility and transportation technology needs of people with disabilities. The current research created a science fiction prototype, based on expert opinion expressed during an imagination workshop, which the authors then presented to a sample of people with ambulatory disabilities. Through a conjoint analysis, the sample members delineated the elements of the prototype they regarded as most important. The participants considered personal mobility assistive technology (either an automated wheelchair or an exoskeleton) the most important, followed by personal automation (autonomous [driverless] vehicle or personal robot) and thirdly by personal assistance technologies (real-time response versus augmented metaverse planning systems). Outputs to the conjoint analysis were clustered and three categories of individual emerged (i) more innovatively minded people who occupied the first cluster and preferred an exoskeleton, a personal robot and a subscription to the metaverse, (ii) people who appeared to be less technologically inclined and preferred an automated wheelchair, an autonomous vehicle and a subscription to a real-time assistive system, and (iii) a group with members favouring an AV but with few other predilections.

1. Introduction

A critical objective of technology foresighting is the assessment of the future technology needs and preferences of particular groups in society (Martino, 1980; Georghiou et al., 2009; Dourish and Bell, 2011; Kuosa, 2016) and, specifically, to ask “what futures would we like to have for these groups?“. The present research was based on science fiction as a foresighting method (Johnson, 2011; Graham et al., 2015). Science fiction has been defined in various ways. Dictionary definitions are, for example, that it comprises “fiction dealing principally with the impact of actual or imagined science on society or individuals or having a scientific factor as an essential orienting component” (Merriam-Webster); or that it comprises “a type of writing about imagined developments in science and their effect on life especially in the future” (Cambridge Dictionary). According to the Encyclopedia of Science Fiction, however, multiple definitions exist, and there is considerable debate about the meaning of the genre (see SFE Ltd, 2023). As well as including science, Asimov (1975) incorporated technology into his definition, characterising science fiction as a branch of literature that deals with the reaction of human beings to changes in science and technology. Michaud and Appio (2022) similarly described science fiction as narrative that deals with imaginative and futuristic concepts in the advanced science and technology field, in order to make realistic speculations about possible future events, albeit based on an imagined future world. Braun (2019) emphasized the importance of the role within science fiction of the interplay of technology and society as an alternative, speculative approach to thinking about the future. With science fiction, things are possible that have never been considered before, Braun (2019) continued, and with time horizons many years in the future. Forms of advanced technology can be pushed to the extreme.

The present study dealt with science fiction in relation to futuristic mobility and transportation technologies, and their potential for improving the quality of life across several areas of society of people with ambulatory disabilities. Numerous birth conditions, accidents, and other causes of ambulatory impairment can prevent or greatly impede walking yet not leave the person bedridden, including inter alia spinal cord paralysis, muscular and skeletal problems, multiple sclerosis, limblessness, industrial mishaps, motor vehicle collisions, and Parkinson’s disease (see Halsey, 2017). The current research examined the future technology requirements and preferences of this group vis-à-vis

---

* Corresponding author.
E-mail address: r.d.bennett@kingston.ac.uk (R. Bennett).

https://doi.org/10.1016/j.technovation.2024.103001
Received 4 November 2022; Received in revised form 15 March 2024; Accepted 25 March 2024

certain assistive technologies likely to be capable of improving their mobility and transportation. Braun (2019) suggested that "autonomous mobility" is a "prime candidate" for a rigorous interrogation in terms of futuristic imagination (p. 262), given the confluence of advances in technological concepts of automobility and its potential impacts on society. Braun's (2019) history of science fiction literature dealing with autonomous mobility noted how science fiction within the automobility domain involved complex social, spatial, and cultural interrelations, as well as creating "dreamscapes" (p. 264). Autonomous mobility was transformational in nature, having the capacity to "rearrange gendered motions, representations, and practices" (p.265).

1.1. *Science fiction prototyping*

The study employed a method founded on science fiction, i.e., science fiction prototyping (Johnson, 2011; Bell et al., 2013; Fletcher et al., 2016), to explore possible future technological situations for people with severe ambulatory disabilities. The method involves, according to Dourish and Bell (2011), "the creation of short works of fiction, grounded in scientific fact, crafted for the purpose of starting a conversation about the implications, effects, or ramifications of technology and the future" (p.14). Rather than simply forecasting the future (an activity for which an abundance of methods is available (e.g., Delphi, scenario analysis, mind mapping, trend analysis, various econometric methods [see Tseng et al., 2012; Potstada and Zybura, 2014]), science fiction prototyping presumes that, whilst long term futures are rarely predictable, they can be created (Georghiou et al., 2009; Dourish and Bell, 2011). Science fiction ideas are applied to explore the implications of futuristic technologies (Graham et al., 2015; Gordon, 2019), plus the social structures they require and enable (Johnson, 2011; Bennett and Johnson, 2016), and the challenges they offer. As well as *foreseeing* possible futures, science fiction prototyping seeks to *invent* and analyse potential future situations. Bell et al. (2013) distinguished between, on the one hand, a science fiction prototype, which the authors characterised as "an expression of hope and an approximation of the future resulting from inspiration", and on the other a specific set of predictions depicting a future that might happen. A prototype need not represent actual future reality, Bell et al. (2013) continued, but instead offers an outline of possible future realities. Thus, according to Johnson (2011), science fiction prototyping looks beyond what is currently technologically feasible, hence facilitating long range product development and "prepares the ground for entrepreneurial thinking and opportunity recognition" (p. 14).

Prototyping of this nature represents a "new lens through which new developments can be viewed differently and explored differently", and without constraint (Johnson, 2011, p. 44). Science fiction prototyping lies within the tradition of science fiction literature (Burnam-Fink, 2015). This was because, according to Burnam-Fink (2015), science fiction involves a mode of thought about the future and contains speculations about future science and technology so that a science fiction prototype comprises an "imaginary launch pad" for thinking about the future (p.52). A science fiction prototype uses narrative that explores boundaries and represents a tool for describing potential future technological trajectories (p.52), with the result that science fiction and science fiction prototype scenarios "are related futurological genres" (p.48).

1.2. *Aims of the research*

Transportation and mobility are among the most important challenges that confront people with ambulatory disabilities. The provision of transportation (and other urban services) is being revolutionised via the application of new technologies designed to improve city infrastructures (Sousa et al., 2022), which are increasingly characterised by the extensive application of information and communication technology (ICT) (Yigitcanlar et al., 2018; Ryan and Gregory, 2019) and by Artificial Intelligence, Big Data and the Internet of Things (Ryan and Gregory, 2019; Cugurullo, 2020). New assistive technologies arising from such developments have the potential to improve the quality of life of people with ambulatory disabilities, so it is essential to identify future transportation and mobility products and supportive environments that might help achieve this aim. Accordingly, the present research constructed a science fiction prototype detailing an ideal future transportation situation, 40–50 years hence, for ambulatory disabled people. Specific aims of the study were.

1. To establish which core elements of the constructed prototype were deemed the most important by a sample of ambulatory disabled people.
2. To segment into categories the members of the sample who deemed certain elements of the prototype to be the most important, and to define the characteristics of the people in each category; and
3. To determine the variables that significantly influenced sample members' preferences for particular core elements of the prototype.

1.3. *Transportation, disability, and new technology*

Transportation difficulties affect multiple aspects of the lives of people with ambulatory disabilities (Gorev et al., 2020). Chen and Silva (2021) observed how fresh transport and transportation technology initiatives are normally included in new urban developments but, Chen and Silva (2021) continued, these initiatives can be highly uncertain and many quite different future scenarios may arise. Most future transportation scenarios will have an impact on people with ambulatory disabilities; many of whom rely heavily on human and/or technological assistance for transportation and mobility (see Rocha et al., 2021). As several investigators have reported, however (e.g., Titchkosky, 2011; Engelbert et al., 2019; Sykes, 2019; Woyke, 2016), urban development projects routinely ignore the transportation comfort and convenience of people with disabilities. Research has demonstrated that *public* transport is particularly troublesome for people with disabilities (see Chiscano, 2020), resulting in their travelling considerably less often via public transport than the rest of the population (Bezyak et al., 2017).

These are important matters because transportation and mobility problems experienced by disabled people create difficulties in relation to, among other things, social isolation, employment, education, and access to recreational and health care facilities (see Asplund et al., 2012; Sykes, 2019). Bennett (2017) noted the dearth of assistive transportation technology products available for people with disabilities and, where they did exist, that the products were often "retrofitted in hindsight" and not regarded as "mainstream" (p. 87). Foley and Ferri (2012) similarly concluded that technologies conceptualised, designed, and promoted for the use of people with disabilities, often "follow a reactive and retrofit model rather than being considered from the beginning" (p. 198).

The prototype created for the present study comprised a fictional depiction of what a disability-friendly future transportation situation should look like, including assistive technologies not yet developed (cf. Johnson, 2011; Graham et al., 2015). Beginning from a consideration of "here and now" technologies, the process posed questions such as: what might the transportation world confronting people with disabilities involve in (say) 40 to 50-years' time; what transportation technologies will or might be present; what new transportation technologies (however fantastical) would radically improve the welfare of people with disabilities, how might society change, and what social/regulatory changes would be needed (cf. Fletcher et al., 2016)? Consideration of social factors was necessary because, as Dourish and Bell (2011) pointed out, social and technical systems are inseparable, and all technologies are embedded in the social systems they are intended to transform.

Although theoretical models of disability vary (see end note 1), this approach is compatible with the social model, which focuses on barriers that prevent people with disability from participating in society. This model argues that rather than disability involving an issue relating to a disabled person's body or mind, it is more of a problem with a society that denies people with disabilities accessibility and inclusivity. Disability is believed to result from a mismatch between the person with a disability and the environment (both physical and social). It is the environment that creates handicaps and barriers, not the individual's disability. Under the social model, society needs to be more accessible and inclusive to ensure that disabled people can participate to the same extent as everyone else. The model focuses on enabling people with disabilities to be independent and to exercise autonomy in their lives.

2. Assistive possibilities and people with disabilities

Recent and current literature concerning new assistive technologies for people with ambulatory disabilities usually relates to the Internet of Things (IoT) and to Radio Frequency Identification (RFID) devices, often providing tools to help individuals to move and travel (Zulqarnain et al., 2017). Systems have been developed whereby wheelchair or scooter users who cannot reach items placed beyond their arm's length when shopping can communicate with the items via RFID and the items will then call a robot to collect them (Faria et al., 2014). An extendable robotic arm allows users autonomously to collect a desired object from a shelf has been created (Tsui et al., 2011), as have stairclimbing motorised wheelchairs (Prajapat et al., 2020). Fully autonomous (driverless) vehicles (see Bennett et al., 2019; Kassens-Noor et al., 2021) will enable door-to-door transportation for disabled individuals (Bradshaw-Martin and Easton, 2014; Darcy and Burke, 2018). This includes people who cannot currently drive. (In the UK, restrictions apply to the driving capacities of people with many ambulatory conditions that impede normal physical functioning.)

Advances relating to motorised wheelchairs include systems whereby control can be executed via facial gestures presented to a console or to a mobile phone (Kuno et al., 2000), or by hand strength exerted on a wheelchair arm (Biswas and Langdon, 2012), by tongue movements (Kim et al., 2010), or eye movements (Chatterjee and Roy, 2021). Future traffic management systems will provide instant data for journey planning (Bubelíny and Kubina, 2021). Cheap, low-power sensors placed on people's clothing can allow the analysis of digital traces left by individuals as they travel, hence potentially improving the services available to ambulatory disabled residents (Zawieska and Pieriegud, 2018). Future generations of robots will be able physically to lift a wheelchair over obstacles and stairways (Cooper and Cooper, 2019). Hand-held controllers should enable robotic limbs fitted to ambulatory disabled individuals to lift and manipulate objects of any size, shape, and weight (Raisamo et al., 2019). Future exoskeletons (worn or implanted) could permit people with certain types of severe ambulatory disability to travel by bicycle relatively comfortably and to walk for significant distances (Ferris, Schlink and Young, 2019). In certain cases, powered exoskeleton devices can be placed over paralysed or weakened limbs to provide near-complete ambulation (Bertos and Papadopoulos, 2019; Ruiz-Olaya et al., 2019).

Developments in the metaverse will allow people with disabilities to use technologically advanced assistive devices via avatars of disabled (or if preferred non-disabled) people in virtual reality, and to practice engaging in helpful activities (Masachio, 2022). The metaverse can create high-fidelity digital twins of airports, highways, bus shelters, railway stations and other transportation venues (Liddell, 2021; Njoku et al., 2022). Thus, an ambulatory disabled person will be able to learn how to overcome obstacles and barriers to free movement (cf. Pamucar et al., 2022). Buhalis et al. (2019) observed how sensory perceptions associated with virtual reality experiences can be controlled from haptic devices and exoskeletons. Faller et al. (2012) reported the (experimental) construction of a helmet with electrodes which capture electronic signals generated by the brain that, inter alia, will control a wheelchair within a virtual reality environment. A phone-sized device is envisaged that will collect real-time information on transport networks and transport accessibility, will learn how fast a wearer is walking, locate the person via a GPS signal, and then adjust traffic lights to facilitate the individual's safe road crossing (Pallone, 2017; Dew-Veal, 2020).

The following sections detail how a prototype was created and incorporated into a conjoint analysis completed by a sample of 661 individuals with physical (but not intellectual or visual) disabilities. Two covariates posited to affect the results of the conjoint analysis, i.e., transportation self-efficacy and technology interest, are then examined. The results of a cluster analysis of the outcomes to the conjoint analysis are presented and matched against the personal characteristics of members of particular cluster segments favouring certain elements of the prototype. Next, outputs to a series of logistic regressions designed to assess the magnitudes and significance of causal influences on the sample members' preferences are given. The paper concludes with an overview of the results and their implications.

3. Materials and methods

An online imagination workshop (Wu, 2013) was convened to construct a prototype for an ideal future urban transportation situation for people with ambulatory disabilities. Sneath et al. (2009) observed how the stimulation of imagination creates perceptions of possible future realities and hence is an appropriate method for studying technologies which communities have yet to encounter. A group of experts from different backgrounds is assembled, a goal is specified for innovating some new types of technology, and brainstorming occurs vis-à-vis possible futures (Wu, 2013). "Disciplined imagination" is employed as the participants share their visions of future technologies and build scenarios of desired future environments (Chermack, 2007, p. 2). The workshop assembled for the present study involved four experts in urban planning with direct experience of transport-related issues (recruited during a previous study, four managers of fundraising charities that deal with ambulatory disability and who expressed interests in transportation (approached via emails to relevant charities), two senior members of an academic transport research centre, three hospital specialist disability health care workers, two representatives of manufacturers of mobility equipment for people with ambulatory disabilities, and two senior managers of associations representing people with particular types of ambulatory disability. One of the of the charity managers herself had an ambulatory disability, as had one of the health care workers, one association manager and one urban planner.

3.1. Organisation of the workshop

Following Kymalainen (2016), the workshop began with the authors describing the background to the project and specifying the aims of the exercise, i.e., for the participants to conduct a "mind simulation" of a future world envisioning an ideal transportation situation in 40–50 years' time for people with disabilities. Members were placed into two groups of eight and nine people respectively, each group containing participants with the same mix of functional backgrounds. Questions were asked regarding the participants' vision of ideal mobility, transport, and transportation situations within a future urban environment. The participants were told to proffer ideas, however fantastic, fanciful, or currently unrealistic they might initially appear (cf. Nygrén, 2019). Themes put forward for discussion included the factors that create problems and why? How difficulties might be overcome. What, in the opinions of the group members, would people with ambulatory disabilities like to see changed? What governmental interventions would be needed? What would the best possible mobility and transportation environment look like? Groups were invited to imagine new scientific discoveries that could remove mobility and/or transportation difficulties experienced by people with disabilities, no matter how futuristic and implausible they might seem (cf. Carbonell et al., 2017; Fergnani, 2021). The workshop lasted just over two and a half hours, ending with a plenary discussion. Supplementary email correspondence with additional comments was received after the event.

The workshop transcript was subjected to a semantic network analysis (see Doerfel, 1998) using the KH Coder package (khcoder.net/en), which examined word frequency, word co-occurrence and word proximity among the participants' comments and which identified major themes within the text. "Relevant" words and phrases (i.e., those conveying valuable content or information regarding the topic of the investigation) converged around three major themes, the first concerning the use of advanced technologies for personal transportation, notably computerised wheelchairs, scooter-like devices, driverless cars adapted to carry people with severe ambulatory disabilities, and exoskeletons. The second involved futuristic developments in robotics, building on, for example, the "robotic dogs" that in future might replace live guide dogs and humanistic robots currently under construction for patient care in hospitals (examples are shown in Exhibit 1). The application of these assistive devices offers many potentially attractive benefits to users, including, for example, the facilitation of independent living, reduced stresses associated with transport and mobility, more convenient socialisation, healthcare visits, shopping, etc., enhanced self-efficacy, and reduced isolation and sense of entrapment (see Bennett et al., 2019).

As regards the third theme, many workshop participants noted the probable future rise of real-time needs response systems that could be employed to help people with disabilities. Fresh real-time devices were being developed at an increasingly rapid pace and disability issues should always be considered by system designers. Also, several members of the workshop suggested, the metaverse was about to explode and would affect most aspects of life in coming decades. People with disabilities should be able to use virtual reality systems for journey planning, route selection, multi-modal transport choices, and decisions about where to stay. The most prominent elements of the three themes revealed by the semantic network analysis were woven into the science fiction protocol given below (see end note 2). Elements were identified independently by each of the researchers, who agreed about the designations in over 80% of all cases.

3.2. *The emerging prototype*

A narrative science fiction prototype containing the main points emerging from the workshop was constructed and is shown in Appendix 1. This prototype contains three main themes: automated wheelchair versus an exoskeleton; autonomous vehicle versus a personal robot; and subscription to either a real-time response system or the augmented metaverse. These were incorporated into a conjoint analysis designed to establish which components of the prototype were valued most highly by a sample of 661 people with ambulatory disabilities. Members of the sample were drawn from the database of the research company (Qualtrics) that collected the data. Table 1 presents information on the members of the sample, from which it can be seen that a majority of the participants had been disabled for less than five years (a third for more than eleven years), that 61% were in paid employment, 38% were in wheelchairs, with only 9.4 per cent using any form of exoskeleton. (The table also gives the results of a cluster analysis detailed in a later section.)

Table 1
Characteristics of the sample.

	All Sample	C1	C2	C3
Age (mean average number of years)	38.6	37	39	43[a]
Gender (% female)	52.6	49	55[a]	59**
Education (% with a university degree)	36.9	38	37	33**
Income:				
% self-defined as better off than most others	17.5	18	17	17
% self-defined as worse off than most others	35.5	35	37	34
General health other than disability (% self-defined as good)	57.9	57	59	58
How long the person has been disabled:				
% less than 5 years	58.2	58	59	56
% more than 11 years	34.3	34	33	38**
Employment (% working)	61.1	60	63	60
Live alone (%)	17.7	17	18	19
Drive a vehicle (%)	61	60	62	62
Mobility:				
Motorised wheelchair or scooter (%)	26.4	20[a]	32[a]	34[a]
Manual wheelchair (%)	11.5	11	12	12
Crutches (%)	12.4	12	13	12
Walking stick or walker (%)	32.2	33	31	32
Exoskeleton (%)	9.4	10	10	6[a]
Intensity of disability (mean average of 4 items)	3.4	3.6[a]	3.2	3.1[a]
Transportation self-efficacy (mean average of 6 items)	2.8	3.0[a]	2.6	2.3[a]
Technology interest (mean average of 5 items)	2.8	3.1[a]	2.6	2.2[a]

[a] Indicates significant difference with the all-sample weighted mean or proportion at the .05 level. **Indicates significant difference at the .01 level.

4. The conjoint analysis

The conjoint analysis was included in a questionnaire (see Appendix 2) that contained (i) the prototype, (ii) a conjoint preference question, (iii) items concerning a respondent's demographic and disability profile, and (iv) queries regarding two individual characteristics (see section 5) likely to affect preferences: transportation self-efficacy and technology interest (Appendix 2 gives the literature sources of the questionnaire items plus key diagnostics for the measures obtained from the participants' responses). Table 2 shows the prototype features presented to the sample and the outcome to the conjoint analysis. The conjoint design involved 2 × 2 × 2 = 8 possible combinations of elements (see Appendix 3). These were presented to the participants together with an instruction to rank the combinations in order of preference (via an easy to use "slide up or down" facility).

Thus, the respondents had to make trade-offs among the elements and to decide which combinations of elements were most and least attractive. Thereafter the (SPSS) conjoint software disentangled each respondent's preferences and established the individual's views on the utility (referred to as a "part worth") to that person of each of the elements within the combinations. The software ascribed the highest utility (part worth) to the element the individual deemed most important, the second highest part worth was allocated to the element regarded as second most important, and so on. Individual part worths were then

EXHIBIT 1. EXAMPLES of assistive technologies in development.

Table 2
Conjoint elements and solution

Theme	Relative Importance (%)	Part Worth
Intercept		6.44
Personal Mobility Assistive Technology:		
- Has an automated wheelchair of the type described in the protocol	44.1	−3.77
- Has an exoskeleton of the type described in the protocol		3.77
Personal Automation:		
- Has a personal robot of the type described	31.3	3.1
- Has an autonomous (driverless) vehicle		−3.1
Personal Assistance:		
- Has a metaverse subscription	24.6	2.7
- Has a real-time system subscription		−2.7
R-square between observed and estimated preferences		0.72
Kendall's tau		0.68

averaged across the total sample, and the "relative importance" to the entire sample of each of the themes was determined. Table 2 shows the averaged part worths for each element of the three themes of the protocol and the relative importance of each theme.

The table indicates that, on the average, the sample members considered personal mobility assistive technology the most important theme within the prototype (44.1%), followed by issues related to personal automation (AVs versus personal robots), with personal assistance technology (real-time response system versus augmented metaverse) in third place.

Higher part worths indicate greater preference. Accordingly, "having an exoskeleton" was generally preferred to having an automated wheelchair (in terms of the description of each option shown in Appendix 3). On average, possession of a personal robot was preferred to owning an autonomous vehicle. A subscription to the augmented metaverse was preferred to a subscription to a real-time system.

5. Possible influences on conjoint rankings

The next stage of the study involved an examination of the heterogeneity of the preference structure identified by the conjoint analysis in terms of the sample members' demographics and key traits (Endrizzi et al., 2011), undertaken via a cluster analysis (cf. Næs et al., 2010). Endrizzi et al. (2011) observed how the clustering of conjoint preferences is necessary both for improved understanding of the participants and for subsequent new product development. Two key individual traits were deemed relevant to the investigation: technology interest and transportation self-efficacy. The first was included in view of the results of a study of attitudes towards autonomous vehicles among people with ambulatory disabilities completed by Bennett et al. (2019), which found that technology interest exerted powerful influences on ambulatory disabled individuals' views on the importance of certain elements contained of the current science fiction prototype. The second was incorporated because several investigations have concluded that "self-efficacy" significantly affects attitudes and behaviour towards travel and various modes of transport of people with disabilities (see for example, Huang and Ford, 2012; Dicianno et al., 2021). A related personal construct with particular relevance for the present investigation is the trait "transportation self-efficacy". The two variables are discussed below.

5.1. *Transportation self-efficacy*

"Transportation self-efficacy" involves a person's level of confidence in the ability to plan and use transportation effectively (Cmar et al., 2018). It derives from general self-efficacy, i.e., "a person's belief in her/his capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997 p.7). Self-efficacy has been found to affect attitudes and behaviour vis-à-vis transport and transportation among people with many ambulatory disabling conditions (Block et al., 2010). In general, self-efficacy is associated with an individual's perceptions of being able to perform technology related tasks (Karavidas et al., 2005). According to Tihic et al. (2021), a person's level of self-efficacy determines the likelihood that the individual will select technological options connected with high rather than low personal control. Block et al. (2010) found that wheelchair users with spinal cord injuries or multiple sclerosis might refrain from using certain modes of transport and transportation because they believe that their mobility impairment prevents them from having the skills necessary to navigate these modes successfully, leading to the expectation that *any* attempt to use them will fail. Among high self-efficacy people, conversely, technology issues are regarded as challenges rather than obstacles or threats, and the individuals involved experience little stress when dealing with transport and transportation (see Crudden et al., 2016; Cserdi and Kenesei, 2020).

As regards transportation rather than general self-efficacy, research has established that people with disabilities high in transportation self-efficacy may be anticipated to respond positively to the task of finding and using new, improved, but unfamiliar transportation methods (Cmar et al., 2018). On the other hand, people with low transportation self-efficacy might see the task of coping with new transportation technology as insurmountable (Schreder et al., 2009). Empirically, studies have shown that transportation self-efficacy affects the adoption of new travel technologies by people with ambulatory disabilities, including their choice of transportation mode (see for example Carlson et al., 2012; Skarin et al., 2019).

5.2. *Technology interest*

Parasuraman (2000) defined technology interest as "people's propensity to embrace and use new technologies for accomplishing goals in home life and at work" (p. 308). It has been described as an enduring disposition to accept new technologies (Westjohn et al., 2009), resulting inter alia from experience, educational background, and/or social influences (Blut and Wang, 2020). Interest in new technology is typically associated with a liking for innovative ideas and with the early adoption of technologically advanced products (Egbue and Long, 2012; Coppola, 2017), including robotics (see Blut and Wang, 2020). Allegedly, people high in technology interest appreciate innovation for its own sake and often create mental associations with scientific know-how (Blut and Wang, 2020; Chatterjee and Roy, 2021). Research has established that interest in technology is (i) negatively and significantly related to technology anxiety, (i.e., the fear and apprehension experienced when some people consider the use of, or actually use, new technological devices), and (ii) a construct that differs from self-efficacy, as the latter only captures a person's beliefs in *ability to use* a technology, as opposed to *interest* in the technology (see Blut and Wang, 2020). It is suggested therefore that, in the present context, deep interest in technology could cause a person with an ambulatory disability to hold positive views of futuristic technological innovations.

5.3. *Effects of self-efficacy and technology interest on conjoint solutions*

A relevant question arising from the above is whether a person's preference for an exoskeleton as opposed to an automated wheelchair is influenced by the individual's transportation self-efficacy and/or technology interest? Exoskeletons are perhaps more technologically sophisticated than automated wheelchairs, require more training to operate, and allow more complex movements via jointed appendages (Gorgey, 2018). Thus, technology interest may be expected to induce a preference for exoskeletons. Automated wheelchairs require less effort to control, and the user does not have to spend substantial time periods each day in order to become mobile. Studies have confirmed, moreover, that many wheelchair users are unwilling to make the daily lifetime changes necessary to adapt to new technology (Federici et al., 2015). Hence, low technology interest might be associated with a preference for automated wheelchairs. Conversely, exoskeletons can provide better access to social events than wheelchairs (van Dijsseldonk, van Nes, Geurts and Keijsers, 2020). Moreover, the recovery of walking is frequently deemed a top priority of ambulatory rehabilitation (Sirlantzis et al., 2019). Such considerations could lead to preferences for exoskeletons.

A South American study of Alvarez-Risco, Del-Aguila-Arcentales, Rosen and Yáñez (2022) found a positive relationship between self-efficacy and intention to participate in the metaverse. A further possible influence on conjoint solutions is the intensity of a person's disability. High intensity of disability might be associated with preferences both for a personal robot and for a real-time system subscription, given the practical assistance it would provide to an intensely disabled person.

6. Cluster analysis

A post hoc cluster analysis (using Latent Gold 5.1 software) was applied to the part worths of the individual participants and the demographic and other features of the people within each cluster delineated. The Table 2 element with the highest part worth under each of the thematic headings was recorded as a person's preference in respect of that theme. For instance, one participant might exhibit part worth preferences for (i) using an exoskeleton, (ii) having an AV, and (iii) a future world with an augmented metaverse of the sort described. Someone else might have preferences for a quite different set of elements (see end note 3). Four cluster solutions were estimated, a three-cluster outcome generating the best fit to the data ($L^2 = 21.97$; $p = 0.18$; $Npar = 21$). Table 3 shows the conditional probabilities determining the response patterns within the clusters. Half the cases fell in cluster 1; just over a third in cluster 2; and the remaining 15.27% in cluster 3.

Table 3 indicates that the average member of cluster 1 (C1) had a higher probability of reporting preferences for an exoskeleton (of the type described in Appendix 3) and for having a personal robot rather than an AV. Also, they favoured a subscription to an augmented metaverse over a subscription to a real-time system. Table 1 above shows the participant profiles of the members in each cluster, from which it emerges that, on the average, people in C1 had high levels of intensity of disability, high transportation self-efficacy, and high technology interest. They tended to be a little younger and rather better educated than the all-sample average, although these differences were not statistically significant. Thus, members of C1 might be characterised as more "innovatively minded" than others.

Individuals in the second cluster were ambivalent regarding preference for an automated wheelchair or an exoskeleton but preferred having an AV to having a robot and favoured access to the metaverse. More females than males inhabited C2; otherwise, members of the cluster did not exhibit any outstanding attributes. Several significant differences from the all-sample averages applied to members of cluster 3, who tended to be older, female, less well-educated, to have been disabled for longer but to have a disability that was less intense, and to have low transportation self-efficacy and less interest in new technology. People in cluster 3 were likely (i) to prefer having an automated wheelchair (of the type described in Appendix 3), (ii) to want an AV, and (iii) to desire subscribing to a real-time system. Many members of this cluster currently used a motorised wheelchair or scooter or a manually operated wheelchair. These individuals might be described as "less technologically minded" in their views and behaviour.

6.1. *Determinants of preference structure*

The cluster analysis suggested the existence of associations between conjoint preferences and certain variables and segmented the sample, but without indicating causality. Thus, a series of logistic regressions was completed to determine the magnitudes of the significant influences of specific variables on the participants' preferences for each aspect of the prototype. Table 4 gives the results, which show the odds ratios of the sample members having expressed preferences for particular options (e.g., automatic wheelchair versus an exoskeleton). (Exp beta values less than 1 indicate negative influences.) Only those variables that exerted significant influences were retained in the final regressions. There was no evidence of damaging multicollinearity.

It can be seen from Table 4 that preference for an automated wheelchair tended to be more common among older members of the

Table 4
Logistic regressions[a].

	Personal Mobility Assistive Technology	Personal Automation	Personal Assistance
	Automated wheelchair or exoskeleton	AV or personal robot	Metaverse or real-time system
Transportation self-efficacy	0.88 (3.59)*	0.69 (4.88)*	1.10 (4.56)*
Technology interest	0.67 (6.96)**	0.72 (5.52)*	1.12 (4.29)*
Intensity of disability	0.82 (7.29)**	0.75 (5.00)*	0.87 (3.92)*
Age	1.38 (4.16)*	1.23 (3.99)*	0.89 (3.99)*
Female gender	1.01 (0.556)	1.17 (3.97)*	0.93 (4.01)*
Period disabled	0.92 (2.33)	0.90 (1.88)	0.83 (3.99)*
General health	1.07 (2.55)	1.11 (1.88)	0.83 (5.66)*
-2LL (653 df)	441.00	671.00	664.41
Nagelkerke Pseudo R^2	0.49	0.51	0.59

[a] Exp beta coefficients, Wald Chi-square values (1 df) in parentheses. *Indicates significance at the .05 level. **Indicates significance at the .01 level or below.

Table 3
Cluster conditional probabilities.

	C1 (N = 331) 50.07%	C2 (N = 229) 34.6%	C3 (N = 101) 15.27%	Wald Chi-square	P value (Ho: all influences are zero)	R-square (variance of theme explained by the 3-cluster solution)
Personal Mobility Assistive Technology:				27.42	0.000	0.464
- Prefers an automated wheelchair of the type described in the protocol	0.099	0.495	0.795			
- Prefers an exoskeleton of the type described in the protocol	0.901	0.505	0.205			
Personal Automation:				17.96	0.000	0.306
- Prefers a personal robot of the type described	0.876	0.100	0.217			
- Prefers an autonomous (driverless) vehicle	0.124	0.900	0.793			
Personal Assistance:				18.57	0.000	0.349
- Has a metaverse subscription	0.776	0.789	0.127			
- Has a real-time system subscription	0.224	0.221	0.873			

sample. Preference for an exoskeleton, conversely, was greatest for individuals (i) with high technology interest, (ii) who possessed high technology self-efficacy, and (iii) whose disabilities were more intense.

6.2. Discussion

Personal mobility assistive technology was deemed the most important issue within the cluster analysis possibly because personal mobility, whether by automated wheelchair or by using an exoskeleton, is an integral and indispensable part of everyday living for an ambulatory disabled individual. Arguably, the general preference for an exoskeleton over an automated wheelchair (see Table 2) was due to the greater flexibility of mobility afforded by exoskeletons, which offer the ability to stand upright and to walk in a manner essentially comparable to non-disabled people. These benefits might have an emotional value to individuals with ambulatory disabilities (Gorgey, 2018). The preference, on average, for a personal robot over an autonomous vehicle could reflect the large amount of publicity given to robots in contemporary news media, and perhaps a perception that a personal robot of the type described would make an immediate contribution to improving an ambulatory person's quality of life (Carnevale, 2015). It is relevant to note moreover that the current survey was undertaken in the UK, where people with disabilities travel fare-free on public transport buses and trains (except during the morning rush hour period), and this might reduce the appeal of an AV. Preference for a metaverse subscription was greatest among people who were perhaps more innovatively minded (high on both self-efficacy and technology interest [cf. Alvarez-Risco et al., 2022), male, and younger than those preferring a real-time subscription. (The findings concerning younger males match what is currently known about metaverse users [see Clement, 2022].) Younger individuals may perhaps have spent more time on social media, playing computer games, and generally engaging in screen-based activities than the older generation, so that the metaverse (with avatars, etc.) may be more appealing to them. People who were older, female, less technologically minded, and whose disability was more intense were more likely to favour a subscription to a real-time system, reflecting possibly the practical day-to-day benefits (extra time at traffic crossings for instance) that such a subscription would provide.

Table 4 confirms the importance of technology interest and self-efficacy as determinants of preferences. High values of these characteristics may have caused individuals to be less worried about the safety of exoskeletons and/or the risk of their failure while in use (Wolff et al., 2014). Manzoor and Vimarlund (2018) noted a number of studies which found that interest in technology often translates into interest in high-tech assistive devices for people with disabilities. The significance of high intensity of an ambulatory disability in Table 4 may result in part from perceptions that using an exoskeleton could make the individual appear similar to non-disabled people. Preference for a personal robot rather than an AV and for the metaverse similarly depended significantly on transportation self-efficacy and technology interest.

On average, females and older members of the sample were inclined to favour AVs and real-time assistive systems. To the extent that robots and the metaverse were perceived by the female participants as "more technical" than AVs, lower exposure to technology matters during females' schooling (UK females are known to have received less education and training in technology related subjects than males [Needle, 2021; DfE, 2021]) and life experience might help explain this finding (Marks, 2015). A study by Rahman et al. (2013) found a preference for real-time information systems among a sample of females using public transport. As regards the older people in the sample, these participants might have had less involvement with technology products than younger participants and hence might be more disposed to see new technology as arduous, time-consuming, and not particularly useful (see Knowles and Hanson, 2018).

7. Conclusion

This study contributes to innovation, foresighting, and new product development literatures by suggesting the use of an approach, science fiction prototyping, which can be employed to obtain valuable insights into technology development pathways that could and should be followed by assistive technology manufacturers and by government policy makers. The investigation extends knowledge of science fiction prototyping applications by employing the method in an area, physical ambulatory disability, not previously explored by research in the science fiction prototyping domain. Understanding the segments of the ambulatory disabled population identified by the present investigation should help manufacturers to focus on appropriate potential users their future promotional campaigns created to induce adoption of new mobility and transportation assistive products. Awareness of market segments should moreover enable charities and other support organisations that deal with people with ambulatory disabilities to pinpoint the characteristics of individuals who desire particular types of products (AV, personal robot, real-time assistance system, etc.). This is important considering the huge leaps in robotics and autonomous transportation technologies that are sure to take place in coming decades (see Pratt, 2015).

Outputs to science fiction prototyping processes can be used to stimulate strategic thought among urban planners and, by examining contrasting fictitious options, to improve planning relevance to stakeholders likely to be affected by plans (Kymalainen, 2016). Public policy needs to recognise the existence of disparate segments of people with disabilities when developing urban transportation systems and configurations. The present results clearly demonstrate the existence of substantive divisions of people with ambulatory disabilities with regard to preferences for various types of assistive technology. Cluster 1 seems to contain members for whom self-reliance represents a significant factor, implying that promotions targeted at this group of individuals should emphasise how a new assistive technology might facilitate greater self-reliance. A study of people with debilitating spinal injuries completed by Stewart and Bhagwanjee (1999) found that self-reliant individuals responded to challenge and the ability to exert control and to take decisions to greater extents than people with low self-perceptions of self-reliance. These themes could be incorporated into messages advocating new assistive technologies.

Members of cluster 2 were perhaps generally neutral in relation to new technological developments. People in cluster 3, however, appear to be less technologically minded than other participants. They were older, more likely to be female, had been disabled for longer, and had lower transportation self-efficacy and lower technology interest. Possibly, cluster 3 participants felt more comfortable with tried and tested technology. Again, this is valuable information for organisations charged with securing acceptance of specific new assistive technologies as, according to the present results, different groups of ambulatory disabled people seemingly prefer disparate types of assistive technology. Hence, for instance, marketing managers in companies that manufacture robots might beneficially target younger ambulatory disabled males whose disabilities are relatively severe and who are interested in new technologies. The marketing of autonomous vehicles might be aimed at (among other market segments) older females with less severe disabilities and people who are not particularly "technologically savvy".

Transportation self-efficacy and technology interest were posited to affect preferences, and these variables, in conjunction with others, did indeed significantly explain preferences (see Table 4). A majority (68%) of the sample expressed a preference for an exoskeleton of the type described in the prototype. The higher an individual's transportation self-efficacy and technology interest the greater the preference for an exoskeleton. It is relevant to note Kapeller, Nagenborg and Nizamis's (2020) finding that the demand for new and improved versions of exoskeletons, which cause less discomfort, have greater functionality and better cosmetic appeal (see Hill et al., 2017; Manns et al., 2019), has grown rapidly in recent years.

7.1. Implications, limitations, and areas for future research

Urban planners and others who may wish to stimulate the uptake of new transportation technologies among people with ambulatory disabilities might usefully consider measures to encourage transportation self-efficacy, which is known to be heavily associated with both willingness to change (Skarin et al., 2019) and self-confidence when using new modes of transport (Schreder et al., 2009). Levels of self-efficacy among people with disabilities, according to Block et al. (2010), can be improved substantially via training which would need to be provided by state and charitable organisations. There is a case, moreover, for seeking to increase the technology interest of individuals with disabilities, considering that "technology can be both a source of liberation and an agent of exclusion for disabled people" (Gregor et al., 2005 p.283). Ignorance of new technology, according to Nimrod (2018), can constrain the quality of life and satisfaction with life of a person with a disability.

Dew-Veal (2020) argued that, because uncertainty and poor information are major barriers to the use of transport by people with disabilities, the introduction of real-time assistance systems is likely to reduce the "transport accessibility gap". Within the UK for example, individuals with disabilities take 26% fewer trips than those without (p. 2). Presumably, future mobile real-time assistive systems will operate through future generations of smart phones, which will need to include built-in short-range communications radios (Pallone, 2017). Smart phone manufacturers should be encouraged to plan for this development. The widespread use of the metaverse in future decades will have many implications for non-disabled as well as for disabled travellers, given that new and more convenient ways of hopping and skipping across transportation networks will emerge (Liddell, 2021). Consequently, transport planners will be able to reshape the ways in which people move, and it is essential that plans incorporate the requirements of ambulatory disabled individuals.

An imagination workshop comprising a certain collection of people created the current prototype. A different set of individuals might have envisioned a different set of key elements to those presented. Nevertheless, the workshop participants in the study were drawn from functional areas that were highly relevant for the investigation and all were experts in their respective fields. It is unlikely, therefore, that the views of this particular group would differ substantially from those of other assemblies of appropriately qualified experts. The sample comprised people with ambulatory disabilities who had voluntarily joined a list of questionnaire respondents operated by a commercial market research company, undertaking the task out of interest and/or in return for small rewards for completing a certain quota of questionnaires. Thus, in recognition of possible biases in panel questionnaire responses the data was checked for evidence of casual and/or random completion of the document, no such evidence emerging.

As regards future research, prototypes for other forms of disability (visual impairment for instance) and alternative variables with the potential to affect preference structures need to be examined. Also, studies could examine how, in practical terms, science fiction prototyping could be employed by disability support organisations to trigger appropriate assistive transportation technology product development (see Craig, 2019). This would be desirable because, although the science fiction approach meets the challenge of how to involve representatives of people with disabilities in the design, testing, and implementation of transportation systems, many policy makers have been observed to regard assistive technology as little more than a means for enabling people with disabilities to adopt products designed for the general population (see Goggin and Newell, 2003 for information on this matter). If this occurs, urban planners may be unlikely to consider the special needs of people with disabilities when devising and implementing new transportation technologies (Ellis and Kent, 2011; Rocha et al., 2021). Problems could then arise which would have been avoided if representative organisations of people with disabilities had been consulted in the first instance, e.g., via science fiction prototyping.

As well as representatives of disability assistance organisations and manufacturers, individual lay people with ambulatory disabilities but who are not affiliated to any organisation could provide valuable contributions to the design of futuristic assistive devices. Chesbrough (2020) noted the many advantages of "open collaboration" of this nature including faster development of products, consideration of wider ranges of candidate solutions to complex problems, the application of diverse perspectives and user knowledge, and the capacity to leapfrog some early stages of the development process. Further advantages of open collaboration are potential increases in user acceptance of, and satisfaction with, developed products, and less need for development resources. Diverse views can be taken into account, and useless ideas for assistive products can be quickly abandoned (Chesbrough, 2006; Mustaquim and Nyström, 2014). The desirability of involving people with disabilities and/or their representatives in the design of assistive transportation technology has often been expressed (see for example, Oliver, 1996; Goggin and Newell, 2003; Galis, 2011). Yet, critics have alleged, new transportation technologies are frequently "designed for" and not "with" people with disabilities (Ellis and Kent, 2011; Bennett, 2017).

7.1.1. End notes

1. In contrast with the social model, the "medical model" presumes that a disability results from an impairment of a person's body or mind so that the individual requires treatment to make the person more like people without disabilities. It allegedly ignores social needs and can lead to loss of independence. See Oliver (1996) for details of various theories and models of disability.
2. The length of the protocol is at the lower end of the range typical of full science fiction prototypes (see Zhang and Callaghan, 2014). A short story of this length constitutes a "day in the life" vignette (Johnson, 2011) the "power of which lies in capturing current technological issues in society and transposing them into the future" (Birtchnell and Urry, 2013 p. 31). A further consideration was the need to include within the questionnaire a protocol of reasonable length for readers to peruse prior to completing the conjoint analysis.
3. Details of the Latent Gold clustering procedure are explained at https://www.statisticalinnovations.com/wp-content/uploads/LGtutorial1.pdf.

CRediT authorship contribution statement

Roger Bennett: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Rohini Vijaygopal:** Writing – review & editing, Formal analysis, Data curation, Conceptualization.

Data availability

Data will be made available on request.

Appendix 1. The Prototype

"Sarah, age 32 and paralysed from the waist down since early childhood, was awakened by her alarm clock as usual at 6.45am. The year is 2067 and the city where Sarah resides has been completely technology-driven for over two decades, meaning that every aspect of city life is controlled by the Internet of Things, through interconnected artificially intelligent devices, by sensors that track all movements, and through radio frequency identification (RFID) communications linked directly to Sarah's home and to all transportation facilities. Sarah's is helped to rise, shower and dress by her personal robot, which then carries her downstairs. Sarah purchased the robot, paying the full price, as she has taken advantage of a government scheme that paid the entire cost of her autonomous (driverless) vehicle (AV) and she could not have a personal robot as well without paying the full price (about the same as for an AV). If Sarah had not opted for an AV, the government would contribute the full the cost of a robot.

The personal robot itself is fully automated and controlled verbally either by speaking to it directly or through Sarah's wristwatch. It assists, inter alia, with dressing, lifting, cleaning and some household chores, and will accompany the ambulatory disabled owner anywhere: on the street, in shops and in transport venues and will give help at all times, e.g., with directions, transport timetables and information on nearby cafés and recreational facilities. The latest generation of personal robots are intelligent, multifunctional, learn-by-doing, will reply verbally to questions, and have acute hearing and vision, including face recognition and emotion sensing. For transportation, they can be attached to a passenger seat for stand-alone short journeys whereby the owner sits above a two-wheel scooter type device which, however, is only suitable for journeys of a few hundred meters. Longer journeys require an automated wheelchair or an exoskeleton.

After breakfast, Sarah mounts her automated wheelchair, which she controls through a mixture of voice commands and hand pressures exerted on a console embedded in one of the wheelchair's arms. The automated wheelchair itself was provided free-of-charge by the government and contains inbuilt robotic leg-like mechanisms that can lift the wheelchair up to 3 m in the air and will then "walk" the wheelchair up or down stairs and/or over any "normal" obstacle blocking Sarah's path. It also has two mechanical arms which extend up to 2.5 m in length and can remove small to medium sized obstructions in front of the wheelchair, even heavy ones. Sarah manoeuvres her wheelchair directly into her specially adapted autonomous (driverless) vehicle (AV), which she controls via voice commands and through a built-in console that she can operate through her eye movements. Sarah verbally instructs the AV to drive her the 9 km to her place of work, an advertising agency. On arrival Sarah disembarks and leaves the AV, which finds its own way to a parking space. Sarah's mechanical wheelchair arm opens the door to her employing company's building and the wheelchair's robotic legs carry the wheelchair upstairs to Sarah's office.

It is lunchtime, and Sarah has arranged to meet her friend Shirley in a café situated about 4 km from Sarah's place of work. Rather than recalling her AV, Sarah decides to travel to the café via public transport, for which she has to pay. She guides her automated wheelchair to a nearby transit point, along the way using her wheelchair's mechanical arms to shift some building debris blocking the pavement on which she is travelling. At the transit point the built-in robotic legs lift Sarah's wheelchair to eye-sight-level with the transit point's bus timetable and other information. The wheelchair is robotically lowered to the ground and Sarah awaits a bus which, on arrival, automatically lowers a ramp to enable her to enter and ride in one of several specially designated wheelchair spaces at the rear of the vehicle.

At the café, Sarah is met by Shirley, aged 36, who is another person paralysed from the waist down since childhood, and who also works in an advertising agency. However, instead of moving via an automated wheelchair, Shirley has opted to use a part-wearable and part-implanted exoskeleton (paid for by the state) that enables her to walk independently for distances of up to three and a half kilometres. Unlike Sarah, Shirley has opted for a personal robot under the government scheme, largely because she does not trust the reliability and safety of AVs and prefers the contact with others and feelings of security that she experiences when using public transport. The selection of an exoskeleton as opposed to an automated wheelchair was a matter of personal inclination, and the two women often discuss the relative advantages of the two options. Exoskeletons allow flexible and complex movements to occur with little effort and they enable the wearer to climb stairs, to go shopping, and to attend cinemas and performing arts venues more easily. They involve less sitting time and have psychological benefits in that the user may feel "less disabled" and less "different" in relation to the non-disabled public than is the case with someone in a wheelchair. Shirley can walk around obstacles in her path rather than having to shift them. By law, all entertainment venues must provide a certain number of especially wide seats suitable for visitors with exoskeletons. However, a wearable exoskeleton can be heavy (leading to tiredness), and the wearable part must be fitted to Shirley's body every morning. Fitting can be tedious, and thereafter a fall or electronic equipment failure could have annoying short-term consequences. A long period of training (paid for by the government) and adaptation to an exoskeleton is needed: Shirley had to spend eight weeks in a rehabilitation centre learning how to control her system.

Automated wheelchairs, conversely, are comfortable, highly manoeuvrable and may be used from morning to night without physical effort (no upper body strength is required). An automated wheelchair can navigate difficult terrain and will easily manage a steep incline. Little training is necessary: Sarah was able to operate her wheelchair after just a few hours of training and trial journeys. Many optional "add-ons" are available to make an automated wheelchair useful in special circumstances, more so than are available to people in exoskeletons. On the downside, travel in a wheelchair can be slow and the user cannot shop or visit entertainment venues as readily as someone in an exoskeleton. Cinemas and theatres are legally obliged to have facilities for visitors in wheelchairs but accessing these special viewing platforms can be slow and cumbersome. Also, riding in an automated wheelchair immediately identifies the passenger as disabled and "different". Reliance on ICT and Internet connections mean that ICT failures can result in the various facilities built into automated wheelchairs being out of action for a few hours, although their long-life batteries enable wheelchairs to move around irrespective of a temporary ICT breakdown. Sarah, like many other wheelchair users, did not feel comfortable about making the lifestyle changes that would be needed to convert and adapt to exoskeleton technology.

Sarah has purchased a subscription to an augmented virtual reality system developed from a metaverse technology first used in the 2030s. From her headset, Sarah can control her virtual reality avatar, which can plan and complete from start to finish any journey to and within most countries. All parts of the travel can be paid for within the virtual environment. The interiors of nearly all transport terminals, airports, train stations, etc., have been videoed and appear in the metaverse, together with the interiors of most hotels, restaurants, and entertainment venues. Thus, Sarah can pre-try any journey she has to make, selecting the best routes and schedules and, if appropriate, staying at suitable hotels. For instance, on a recent trip to visit her sister in another country Sarah arranged, within the metaverse, for her AV to drive her avatar to a flying taxi rank, where a waiting flying taxi flew the avatar to her sister's country. On arrival, the avatar took local public transport to a magnetically powered vactrain which then transported the avatar to her sister's city, where her sister would be waiting. Sarah finds this an extremely convenient way to plan and pay in advance for journeys.

Shirley, on the other hand chose instead to subscribe for about the same amount of money to a real-time messaging and assistance service for help with routine daily travel. The system provides Shirley with a continuous flow of information on local transport situations, and at traffic lights identifies her as an ambulatory disabled person. It calculates how long Shirley will need to cross the road and instantly adjusts the traffic lights to give more time to traverse the crossing. AVs approaching the lights are automatically alerted that a disabled individual is about to cross the road. At non-signalled crossings the system sends vibrations to Shirley's exoskeleton if an AV is approaching within a certain distance, again messaging nearby AVs that a person with a disability wishes to cross. If for any reason Shirley needs support the system will locate people physically near to Shirley who through the system have registered as (security checked) assistance volunteers and will send messages to the volunteers' mobile phones asking them to provide help. Information on people who reply is instantly transmitted to Shirley. The system keeps track of Shirley's pedestrian movements and walking speed while in her exoskeleton, and the data obtained is fed into the amount of extra time she needs at road crossings. Additionally, the system provides real time information on transportation timetables, traffic congestion, and any local transport infrastructure difficulties.

After lunch, Sarah and Shirley return to their places of work, both using public transport. Each has a mobile device that provides online information from city sensors about travel congestion, delays, and other matters of transportation interest to people with disabilities. All public transport vehicles have a couple of special spaces at the back reserved for people with disabilities and their equipment. Both Sarah and Shirley are grateful for the opportunities their respective means of travel and mobility provide for gaining and retaining paid employment, and for being able to socialise and travel around without human assistance."

Appendix 2. The Questionnaire

Apart from factual queries all items were scored using five-point agree/disagree scales.

Demographics and general

Household income and age categories gender, type of disability, education level, health (good/bad).
How long have you been disabled: less than 3 years; 3–5 years; 6–10 years; 11–20 years; more than 20 years?
I do/do not live alone.
I am: employed; unemployed; retired; a student; other.
What is the frequency (daily, weekly, fortnightly, monthly, less than once a month, never) of your:
(a) Work trips, (b) shopping trips, (c) recreational/social trips, (d) use of public transport?
Do you ever shop alone? Yes/No?
Do you drive? Yes/No?
My disability causes me to depend on other people when I am travelling. Yes/No?
What mobility aids do you use? Please indicate all that apply:
Power wheelchair; manual wheelchair; scooter; crutches; walker; walking stick; other.
Intensity of disability (informed by Hoenig et al., 1999; Forber-Pratt et al., 2017) (lambda = 3.2, alpha = 0.86).

(a) I need a lot of help to move around inside my house
(b) I need a lot of help with self-care (dressing, bathing, etc.)
(c) I need a lot of help with shopping, housework, laundry, etc.
(d) My disability greatly impedes my daily life

Transportation self-efficacy (informed by Schwarzer and Jerusalem, 1995; Van Beuningen, De Ruyter, Wetzels and Streukens, 2009) (lambda = 4.88, alpha = 0.80).

The following relates to your journeys using public or private transport outside your home and beyond its immediate surroundings.

(a) Getting around the city/town in which I live is something I can easily cope with
(b) I am sure I can overcome any problem I might experience while travelling
(c) Transportation is a difficult problem for me
(d) I feel confident about using public transport
(e) I get a sinking feeling whenever I have to travel beyond my home
(f) I need a lot of assistance in order to travel outside my home

Technology interest (adapted from Haboucha et al., 2017) (lambda = 3.75, alpha = 0.81).

(a) I usually try new products before my friends, neighbours, and other people I know
(b) I know more than others about the latest new products
(c) I am excited by new technology
(d) I have little interest in new technology (RS)
(e) I am a keen enthusiast where new technology is concerned

Appendix 3. Conjoint Analysis (Participants could conveniently slide each option up or down within the online questionnaire)

Please read the prototype and then follow the below instructions.

Here are eight combinations of attractive situations favouring people with ambulatory disabilities that are mentioned in the prototype. Please rank the various combinations in order of your preference. Give a score of 1 to the combination you find most attractive, a score of 2 to the combination you find next most attractive, and so on down to a score of 8 for the combination you find least attractive.

Within the following table and as stated in the prototype:

An *automated wheelchair* is one that has robotic arms that can remove obstacles in your path and reach high shelves, robotic legs that can climb stairs, is highly manoeuvrable and is controlled by voice commands. However, you stay in the wheelchair all the time.

An *exoskeleton* is a wearable apparatus that enables you to walk unaided for up to three and a half kilometres (just over 2 miles), to climb stairs, and generally move around. However, the apparatus must be fitted to you every morning, is heavy and hence is tiring.

Personal Mobility Assistive Technology	Personal Automation	Personal Assistance	Rank
You have an automated wheelchair of the type described	You have a personal robot of the type described	You prefer a subscription to the metaverse	
You have an exoskeleton of the type described	You have an autonomous (driverless) vehicle	You prefer a subscription to a real-time system	
You have an automated wheelchair of the type described	You have a personal robot of the type described	You prefer a subscription to a real-time system	
You have an exoskeleton of the type described	You have a personal robot of the type described	You prefer a subscription to a real-time system	
You have an exoskeleton of the type described	You have a personal robot of the type described	You prefer a subscription to the metaverse	
You have an automated wheelchair of the type described	You have an autonomous (driverless) vehicle	You prefer a subscription to the metaverse	
You have an automated wheelchair of the type described	You have an autonomous (driverless) vehicle	You prefer a subscription to a real-time system	
You have an exoskeleton of the type described	You have an autonomous (driverless) vehicle	You prefer a subscription to the metaverse	

References

Alvarez-Risco, A., Del-Aguila-Arcentales, S., Rosen, M., Yáñez, J., 2022. Social cognitive theory to assess the intention to participate in the Facebook Metaverse by citizens in Peru during the COVID-19 pandemic. J. Open Innov. Technol. Market Compl. 8, 142.

Asimov, I., 1975. How easy to see the future. Nat. Hist. Mag. 84 (4), 92.

Asplund, K., Wallin, S., Jonsson, F., 2012. Use of public transport by stroke survivors with persistent disability. Scand. J. Disabil. Res. 14 (4), 289–299.

Bandura, A., 1997. Self-Efficacy: the Exercise of Control. Freeman, New York.

Bell, F., Fletcher, G., Greenhill, A., Griffiths, M., McLean, R., 2013. Science fiction prototypes: visionary technology narratives between futures. Futures 50, 5–14.

Bennett, D., 2017. Scientific eventuality or science fiction: the future of people with different abilities. Futures 87, 83–90.

Bennett, M., Johnson, B., 2016. Dark future precedents: science fiction, futurism and law. Ambient Intell. Smart Environ. 21, 506–513.

Bennett, R., Vijaygopal, R., Kottasz, R., 2019. Attitudes towards autonomous vehicles among people with physical disabilities. Transport. Res.: Pol. Pract. 127, 1–17.

Bertos, G., Papadopoulos, E., 2019. Upper-limb prosthetic devices. In: Segil, J. (Ed.), Handbook of Biomechatronics. Academic Press, Cambridge Mass, pp. 177–240.

Bezyak, J., Sabella, S., Gattis, R., 2017. Public transportation: an investigation of barriers for people with disabilities. J. Disabil. Pol. Stud. 28 (1), 52–60.

Birtchnell, T., Urry, J., 2013. 3D, SF and the future. Futures 50, 25–34.

Biswas, P., Langdon, P., 2012. Developing multimodal adaptation algorithm for mobility impaired users by evaluating their hand strength. Int. J. Hum. Comput. Interact. 28 (9), 576–596.

Block, P., Vanner, E., Keys, C., Rimmer, J., Skeels, S., 2010. Project Shake-it-Up: using health promotion, capacity building and a disability studies framework to increase self-efficacy. Disabil. Rehabil. 32 (9), 741–754.

Blut, M., Wang, C., 2020. Technology readiness: a meta-analysis of conceptualizations of the construct and its impact on technology usage. J. Acad. Market. Sci. 48, 649–669.

Bradshaw-Martin, H., Easton, C., 2014. Autonomous or "driverless" cars and disability: a legal and ethical analysis. Eur. J. Curr. Leg. Issues 20 (3). Web JCLI.

Braun, R., 2019. Autonomous vehicles: from science fiction to sustainable future. In: Aguiar, M., Mathieson, C., Pearce, L. (Eds.), Mobilities, Literature, Culture, New York and London. Palgrave Macmillan, pp. 259–280.

Bubelíny, O., Kubina, M., 2021. Impact of the concept "smart city" on public transport. 14th international scientific conference on sustainable, modern and safe transport. Transport. Res. Procedia 55, 1361–1367.

Buhalis, D., Harwood, T., Bogicevic, V., Viglia, G., Beldona, S., Hofhacker, C., 2019. Technological disruptions in services: lessons from tourism and hospitality. J. Serv. Manag. 30, 484–506.

Burnam-Fink, M., 2015. Creating narrative scenarios: science fiction prototyping at Emerge. Futures 70, 48–55.

Carbonell, J., Sánchez-Esguevillas, A., Carro, B., 2017. From data analysis to storytelling in scenario building. A semiotic approach to purpose-dependent writing of stories. Futures 88, 15–29.

Carlson, J., Sallis, J., Conway, T., Saelens, B., Frank, L., Kerr, J., Cain, K., King, A., 2012. Interactions between psychosocial and built environment factors in explaining older adults' physical activity. Preventative Med. 54 (1), 68–73.

Carnevale, A., 2015. Robots, disability, and good human life. Disabil. Stud. Q. 35 (1), 1–10.

Chatterjee, S., Roy, S., 2021. A low-cost assistive wheelchair for handicapped and elderly people. Ain Shams Eng. J. 12 (4), 3835–3841.

Chen, Y., Silva, E., 2021. Smart transport: a comparative analysis using the most used indicators in the literature juxtaposed with interventions in English metropolitan areas. Transp. Res. Interdiscip. Perspect. 10, 100371.

Chermack, T., 2007. Disciplined imagination: building scenarios and building theories. Futures 39, 1–15.

Chesbrough, H., 2006. Open Innovation: the New Imperative for Creating and Profiting from Technology. Harvard Business Review Press, Massachusetts.

Chesbrough, H., 2020. To recover faster from Covid-19, open up: managerial implications from an open innovation perspective. Ind. Market. Manag. 88, 410–413.

Chiscano, M., 2020. Improving the design of urban transport experience with people with disabilities. Res. Transp. Bus. Manag. 41, 100596.

Clement, J., 2022. Metaverse: Statistics and Facts. Statista, Hamburg.

Cmar, J., McDonnall, M., Crudden, A., 2018. Transportation self-efficacy and employment among individuals with visual impairments. J. Vocat. Rehabil. 48 (2), 257–268.

Cooper, R., Cooper, R., 2019. Rehabilitation engineering: a perspective on the past 40-years and thoughts for the future. Med. Eng. Phys. 72, 3–12.

Coppola, P., 2017. Emerging technologies and models for transport and mobility. Transport. Res. Procedia 26, 1–2.

Craig, G., 2019. Science Fiction Prototyping. Sage Developer, 10 July 2019. https://medium.com/sagefuturemakers/science-fiction-prototyping-32bc2763767a. (Accessed 6 April 2022).

Crudden, A., Antonelli, K., O'Mally, J., 2016. Transportation self-efficacy and social problem-solving of persons who are blind or visually impaired. J. Soc. Work. Disabil. Rehabil. 15, 52–61.

Cserdi, Z., Kenesei, Z., 2020. Attitudes to forced adoption of new technologies in public transportation services. Res. Transp. Bus. Manag. 41, 100611.

Cugurullo, F., 2020. Urban artificial intelligence: from automation to autonomy in the smart city. Front. Sustain. Cities 2 (38), 1–14.

Darcy, S., Burke, P., 2018. On the road again: the barriers and benefits of automobility for people with disability. Transport. Res. 107, 229–245.

Dew-Veal, D., 2020. Future mobility and the opportunity to improve accessibility. Disabil. Horiz. 8 September 2020 https://disabilityhorizons.com/2020/09/future-mobility-and-the-opportunity-to-improve-accessibility/.

DFE (Department for Education), 2021. Education and Training Statistics for the UK 2021. Department for Education, London.

Dicianno, B., Sivakanthan, S., Sundaram, S., Satpute, S., Kulich, H., Powers, E., Deepak, N., Russell, R., Cooper, R., Cooper, R., 2021. Systematic review: automated vehicles and services for people with disabilities. Neurosci. Lett. 761, 136103.

Doerfel, M., 1998. What constitutes Semantic Network Analysis? A comparison of research and methodologies. Connections 21 (2), 16–26.

Dourish, P., Bell, G., 2011. Divining a Digital Future: Mess and Mythology in Ubiquitous Computing. MIT Press, Cambridge Mass.

Egbue, O., Long, S., 2012. Barriers to widespread adoption of electric vehicles: an analysis of consumer attitudes and perceptions. Energy Pol. 48, 717–729.

Ellis, K., Kent, M., 2011. Disability and New Media. Routledge, New York.

Endrizzi, I., Menichelli, E., Johansen, S., Olsen, N., Næs, T., 2011. Handling of individual differences in rating-based conjoint analysis. Food Qual. Prefer. 22 (3), 241–254.

Engelbert, J., van Zoonen, L., Hirzalla, F., 2019. Excluding citizens from the European smart city: the discourse practices of pursuing and granting smartness. Technol. Forecast. Soc. Change 142, 347–353.

Faller, J., Torrellas, S., Miralles, F., Holzner, C., Kapeller, C., Guger, C., Bund, J., Müller-Putz, G., Scherer, R., 2012. Prototype of an auto-calibrating, context-aware, hybrid brain-computer interface. Proceedings of the Annual International Conference of the. IEEE Engineering in Medicine and Biology Society, pp. 827–830.

Faria, B., Reis, L., Lau, N., 2014. A survey on intelligent wheelchair prototypes and simulators. In: Rocha, A., Correia, A., Tan, F., Stroetmann, K. (Eds.), New Perspectives in Information Systems and Technologies, vol. 1. Cham: Springer International Publishing, pp. 545–557.

Federici, S., Meloni, F., Bracalenti, M., De Filippis, M., 2015. The effectiveness of powered, active lower limb exoskeletons in neurorehabilitation: a systematic review. NeuroRehabilitation 37, 321–340.

Fergnani, A., 2021. Sci-fi as foresight methods: science fiction prototyping, future personas, 6 archetypes. Predict, 25 February 2021. https://medium.com/predict/sci-fi-as-foresight-methods-science-fiction-prototyping-future-personas-6-archetypes-3199de52f13b. (Accessed 28 September 2021).

Fletcher, G., Greenhill, A., Griffiths, M., Holmes, K., McLean, R., 2016. Creatively prototyping the future high street. Prod. Plann. Control 27 (6), 477–489.

Foley, A., Ferri, B., 2012. Technology for people, not disabilities: ensuring access and inclusion. J. Res. Spec. Educ. Needs 12 (4), 192–200.

Forber-Pratt, A., Lyew, D., Mueller, C., Samples, L., 2017. Disability identity development: a systematic review of the literature. Rehabil. Psychol. 62 (2), 198–207.

Galis, V., 2011. Enacting disability: how can science and technology studies inform disability studies? Disabil. Soc. 26 (7), 825–838.

Georghiou, L., Harper, J., Keenan, M., Miles, I., Popper, R., 2009. The Handbook of Technology Foresight: Concepts and Practice. Edward Elgar Publishing, London.

Goggin, G., Newell, C., 2003. Digital Disability: Social Construction of Disability in New Media. Rowman and Littlefield Publishers, Maryland.

Gordon, C., 2019. Science Fiction Prototyping. Sage Developer, New York. https://medium.com/sagefuturemakers/science-fiction-prototyping-32bc2763767a. (Accessed 9 June 2021).

Gorev, A., Popova, O., Solodkij, A., 2020. Demand-responsive transit systems in areas with low transport demand of "smart city". Transport. Res. Procedia 50, 160–166.

Gorgey, A., 2018. Robotic exoskeletons: the current pros and cons. World J. Orthoped. 9 (9), 112–119.

Graham, G., Greenhill, A., Dymski, G., Coles, E., Hennell, P., 2015. The science fiction prototyping framework: building behavioural, social and economic impact and community resilience. FCCR.NET Executive Impact Paper. No. 1. www.FCCRNet.orgJanuary2015.

Gregor, P., Sloan, D., Newell, A., 2005. Disability and technology: building barriers or creating opportunities? Adv. Comput. 64, 283–346.

Haboucha, C., Ishaq, R., Shiftan, Y., 2017. User preferences regarding autonomous vehicles. Transport. Res. 78, 37–49.

Halsey, A., 2017. Driverless cars promise far greater mobility for the elderly and people with disabilities. Washington Post, 23 November 2017. www.washingtonpost.com. (Accessed 12 October 2021).

Hill, D., Holloway, C., Morgado Ramirez, D., Smitham, P., Pappas, Y., 2017. What are user perspectives of exoskeleton technology? A literature review. Int. J. Technol. Assess. Health Care 33 (2), 160–167.

Hoenig, H., Horner, R., Duncan, P., Clipp, E., Hamilton, B., 1999. New horizons in stroke rehabilitation research. J. Rehabil. Res. Dev. 36 (1), 19–31.

Huang, J., Ford, J., 2012. Driving locus of control and driving behaviours: inducing change through driver training. Transport. Res.: Traffic Psychol. Behav. 15 (3), 358–368.

Johnson, B., 2011. Science Fiction Prototyping: Designing the Future with Science Fiction. Synthesis Lectures on Computer Science. Morgan & Claypool Publishers, New York.

Kapeller, A., Nagenborg, M., Nizamis, K., 2020. Wearable robotic exoskeletons: a socio-philosophical perspective on Duchenne muscular dystrophy research. Paladyn. J. Behav. Robot. 11 (1), 404–413.

Karavidas, M., Lim, N., Katsikas, S., 2005. The effects of computers on older adult users. Comput. Hum. Behav. 21 (5), 697–711.

Kassens-Noor, E., Cai, M., Kotval-Karamchandani, Z., Decaminada, T., 2021. Autonomous vehicles and mobility for people with special needs. Transport. Res.: Pol. Pract. 150, 385–397.

Kim, J., Huo, X., Ghovanloo, M., 2010. Wireless control of smartphones with tongue motion using tongue drive assistive technology. In: Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 5250–5253.

Knowles, B., Hanson, V., 2018. The wisdom of older technology (non)users. Commun. ACM 61 (3), 72–82.

Kuno, Y., Murashima, T., Shimada, N., Shirai, Y., 2000. Interactive gesture interface for intelligent wheelchairs. In: Multimedia and Expo (ICME), IEEE International Conference on Multimedia and Expo, vol. 2. IEEE Computer Society, New York, pp. 789–792.

Kuosa, T., 2016. The Evolution of Strategic Foresight: Navigating Public Policy Making. Routledge, London.

Kymalainen, T., 2016. Science fiction prototypes as a method for discussing socio-technical issues within emerging technology research and foresight. Athens J. Technol. Eng. 3 (4), 333–347.

Liddell, D., 2021. How the metaverse will change future mobility. Fast Company Magazine 1–4, 11 September 2021. https://www.fastcompany.com/90694275/how-the-metaverse-will-change-transportation-as-we-know-it.

Masachio, R., 2022. Can Persons with Disabilities Live in the Metaverse? Rockville VA, Ruh Global.

Manns, P., Hurd, C., Yang, J., 2019. Perspectives of people with spinal cord injury learning to walk using a powered exoskeleton. J. NeuroEng. Rehabil. 16 (94), 1–10.

Manzoor, M., Vimarlund, V., 2018. Digital technologies for social inclusion of individuals with disabilities. Health Technol. 8, 377–390.

Marks, G., 2015. The real reason noticed women don't go into technology. Forbes Mag. 16 May 2015 www.forbes/sites/quickerbettertech. (Accessed 9 October 2022).

Martino, J., 1980. Technological forecasting: an overview. Manag. Sci. 26, 28–33.

Michaud, T., Appio, F., 2022. Envisioning innovation opportunities through science fiction. J. Prod. Innovat. Manag. 39 (2), 121–131.

Mustaquim, M., Nyström, T., 2014. Designing information systems for sustainability: the role of universal design and open innovation. In: Tremblay, M.C., VanderMeer, D., Rothenberg, M., Gupta, A., Yoon, V. (Eds.), Advancing the Impact of Design Science: Moving from Theory to Rractice: Proceedings of the 9th International Conference, DESRIST 2014. Springer, Cham, pp. 1–16. https://doi.org/10.1007/978-3-319-06701-8_1.

Næs, T., Lengard, V., Johansen, S., Hersleth, M., 2010. Alternative methods for combining design variables and consumer acceptance with information about attitudes and demographics in conjoint analysis. Food Qual. Prefer. 21, 368–378.

Needle, D., 2021. Women in technology statistics: the latest research and trends. TechTarget, 2 july 2021. https://www.techtarget.com/whatis/feature/Women-in-tech-statistics-The-latest-research-and-trends. (Accessed 11 October 2022).

Nimrod, G., 2018. Technophobia among older Internet users. Educ. Gerontol. 44 (2–3), 148–162.

Njoku, J., Nwakanma, C., Amaizu, G., Kim, D., 2022. Prospects and challenges of metaverse application in data-driven intelligent transportation systems. IET Intell. Transp. Syst. 1–21 (in press).

Nygrén, N., 2019. Scenario workshops as a tool for participatory planning in a case of lake management. Futures 107, 29–44.

Oliver, M., 1996. Understanding Disability: from Theory to Practice. St Martin's Press, London.

Pallone, T., 2017. Smart traffic signals designed for pedestrians with disabilities. Eng. News. https://insights.globalspec.com/article/6547/smart-traffic-signals-designed-for-pedestrians-with-disabilities. (Accessed 19 September 2017).

Pamucar, D., Deveci, M., Gokasar, I., Tavana, M., Köppen, M., 2022. A metaverse assessment model for sustainable transportation using ordinal priority approach and Aczel-Alsina norms. Technol. Forecast. Soc. Change 182 (in press).

Parasuraman, A., 2000. Technology readiness index (TRI): a multiple-item scale to measure readiness to embrace new technologies. J. Serv. Res. 2 (4), 307–320.

Potstada, M., Zybura, J., 2014. The role of context in science fiction prototyping: the digital industrial revolution. Technol. Forecast. Soc. Change 84, 101–114.

Prajapat, M., Sikchi, V., Shaikh-Mohammed, J., Sujatha, S., 2020. Proof-of-concept of a stair-climbing add-on device for wheelchairs. Med. Eng. Phys. 85, 75–86.

Pratt, G., 2015. Is a cambrian explosion coming for robotics? J. Econ. Perspect. 29 (3), 51–60.

Rahman, M., Wirasinghe, S., Kattan, L., 2013. Users' views on current and future real-time bus information systems. J. Adv. Transport. 47 (3), 336–354.

Raisamo, R., Rakkolainen, I., Majaranta, P., Salminen, K., Rantala, J., Farooq, A., 2019. Human augmentation: past, present and future. Int. J. Hum. Comput. Stud. 131, 131–143.

Rocha, E., Mehta, N., Távora-Mehta, M., Roncari, C., Cidrão, A., Elias, Neto, 2021. Dysautonomia: a forgotten condition - Part 1. Arq. Bras. Cardiol. 116 (4), 814–835.

Ruiz-Olaya, A., Lopez-Delis, A., da Rocha, A., 2019. Upper and lower extremity exoskeletons. In: Segil, J. (Ed.), Handbook of Biomechatronics. Academic Press, Cambridge Mass, pp. 283–317.

Ryan, M., Gregory, A., 2019. Ethics of using smart city AI and big data: the Case of four large European cities. Orbit J. 2 (2), 1–36.

Schreder, G., Siebenhandl, K., Mayr, E., 2009. E-Inclusion in public transport: the role of self-efficacy. In: Holzinger, A., Miesenberger, K., Eeds, K. (Eds.), HCI and Usability for E-Inclusion. USAB 2009. Lecture Notes in Computer Science, vol. 5889. Springer, Berlin, Heidelberg, 311-311.

Schwarzer, R., Jerusalem, M., 1995. Generalized self-efficacy scale. In: Weinman, J., Wright, S., Johnston, M. (Eds.), Measures in Health Psychology: A User's Portfolio, Causal and Control Beliefs. NFER-Nelson, Windsor, UK, pp. 35–37.

SFE Ltd, 2023. Encyclopaedia of Science Fiction, fourth ed. Science Fiction Encyclopaedia Ltd, London.

Sirlantzis, K., Larsen, L., Kanumuru, L., Oprea, P., 2019. Robotics. In: Cowan, D., Najafi, L. (Eds.), Handbook of Electronic Assistive Technology. Academic Press, Amsterdam, pp. 311–345.

Skarin, F., Olsson, L., Friman, M., Wästlund, E., 2019. Importance of motives, self-efficacy, social support and satisfaction with travel for behaviour change during travel intervention programs. Transport. Res.: Traffic Psychol. Behav. 62, 451–458.

Sneath, D., Holbraad, M., Pedersen, M., 2009. Technologies of the imagination: an introduction. Ethnos 74 (1), 5–30.

Sousa, M., Dal Mas, F., Osório de Barros, G., Tavares, N., 2022. Artificial intelligence: technologies, applications, and policy perspectives. In: Jeyanthi, P., Choudhury, T., Hack-Polay, D., Singh, T., Abujar, S. (Eds.), Decision Intelligence Analytics and the Implementation of Strategic Business Management, Cham, EAI/Springer Innovations in Communication and Computing. Springer.

Stewart, R., Bhagwanjee, A., 1999. Promoting group empowerment and self-reliance through participatory research: a case study of people with physical disability. Disabil. Rehabil. 21 (7), 338–345.

Sykes, N., 2019. Are smart cities an opportunity or challenge for the disabled? TechTalks. July 17, 2019. https://bdtechtalks.com/2019/07/17/iot-smart-cities-accessibility-challenges/on. (Accessed 6 April 2022).

Tihic, M., Hadzig, M., McKelvie, A., 2021. Social support and its effects on self-efficacy among entrepreneurs with disabilities. J. Bus. Ventur. Insights 16, e00279.

Titchkosky, T., 2011. The Question of Access: Disability, Space, Meaning. University of Toronto Press, Toronto.

Tseng, F., Lin, Y., Yang, S., 2012. Combining conjoint analysis, scenario analysis, the Delphi method, and the innovation diffusion model to analyse the development of innovative products in Taiwan's TV market. Technol. Forecast. Soc. Change 79, 1462–1473.

Tsui, K., Kim, D., Behal, A., Kontak, D., Yanco, H., 2011. I want that: human-in-the-loop control of a wheelchair-mounted robotic arm. Appl. Bionics Biomech. 8 (1), 127–147.

Van Beuningen, J., De Ruyter, K., Wetzels, M., Streukens, S., 2009. Customer self-efficacy in technology-based self-service: assessing between-and within-person differences. J. Serv. Res. 11 (4), 407–428.

Van Dijsseldonk, R., Van Nes, I., Geurts, A., Keijsers, N., 2020. Exoskeleton home and community use in people with complete spinal cord injury. Sci. Rep. 10 (1), 15600.

Westjohn, S., Arnold, M., Magnusson, P., Zdravkovic, S., Zhou, J., 2009. Technology readiness and usage: a global-identity perspective. J. Acad. Market. Sci. 37 (3), 250–265.

Wolff, J., Parker, C., Borisoff, J., Mortenson, W., Mattie, J., 2014. A survey of stakeholder perspectives on exoskeleton technology. J. NeuroEng. Rehabil. 11, 169–180.

Woyke, E., 2016. The blind community has high hopes for self-driving cars. MIT Rev. 12 October 2016 www.technologyreview.com. (Accessed 6 April 2022).

Wu, H., 2013. Imagination workshops: an empirical exploration of SFP for technology-based business innovation. Futures 50, 44–55.

Yigitcanlar, T., Kamruzzaman, M., Buys, L., Loppolo, G., Sabatini-Marques, J., da Costa, E., Yun, J., 2018. Understanding smart cities: intertwining development drivers with desired outcomes in a multidimensional framework. Cities 81, 145–160.

Zawieska, J., Pieriegud, J., 2018. Smart city as a tool for sustainable mobility and transport decarbonisation. Transport Pol. 63, 39–50.

Zhang, S., Callaghan, V., 2014. Using science-fiction prototyping as a means to motivate learning of STEM topics and foreign languages. In: Callaghan, V. (Ed.), 2014 International Conference on Intelligent Environments. IEEE, Shanghai, pp. 353–356.

Zulqarnain, R., Melià-Seguí, J., Pous, R., Peig, E., 2017. Using augmented reality and internet of things to improve accessibility of people with motor disabilities in the context of smart cities. Future Generat. Comput. Syst. 76, 248–261.