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The Application of Geographic Information Systems to Support Wayfinding for People with Visual Impairments or Blindness

Susanne Zimmermann-Janschitz

Abstract

People with visual impairments or legal blindness are relying on differing, comprehensive information utilized for their individual mobility. Increasing the personal mobility of people with disabilities and thereby achieving a self-determined life are major steps toward a more inclusive society. Research and applications on mobility issues of people with visual impairments or blindness mainly focus on technical applications or assistive orientation and navigation devices, and less work is covering the individual needs, e.g., regarding the information required for wayfinding. Moreover, active participation of people with disabilities in research and development is still limited. ways2see offers a new online application to support individual mobility in context of pre-trip planning for people with visual impairments or blindness based on a Geographic Information System (GIS). Obstacles, barriers, landmarks, orientation hints, and directions for wayfinding are generated by user profiles. The underlying network for GIS analysis is designed as pedestrian network. This individually coded network approach integrates sidewalks and different types of crossings and implements various orientation and navigation attributes. ways2see integrates three research realms: firstly, implementing a participative and transdisciplinary research design; secondly, integrating personalized information aligned with the individual user needs; and thirdly, presenting result of GIS analysis through an accessible designed user interface.

Keywords: geographic information systems, GIS, disabilities, visual impairments, blindness, mobility, orientation, navigation, wayfinding, network analysis

1. Introduction: why another orientation and navigation tool?

Geographic information science is a well-established approach in the context of navigation, wayfinding, and orientation—as long as the focus is given to motorized vehicles, e.g., Google, OpenStreetMap, etc. With rising importance of sustainability issues during the last decades, alternative modes of transportation gained interest, and geographic information systems (GISs) were progressively used, also for analyzing cycling and walking behavior [1, 2]. A GIS is an analytical tool to manage, store, analyze, and visualize spatial information. Simplified it can be seen as a digital map including a database to access and investigate spatial relations.

Narrowing down wayfinding and orientation to pedestrians and especially to persons with disabilities, up to now research is still at the beginning. However, demographic changes, the rising demand for (social) sustainability, and therefore strategies of equity and inclusion to generate diversity and to overcome barriers in Western societies force geography to provide (spatial) answers for the elderly and people with disabilities.

The need for autonomous and independent mobility underlines the demand of people with disabilities and the elderly for social equity and their full participation in society and in societal life [3, 4]. Contrary to these requirements, the design and development of urban space, the lack of offers in (public) transport infrastructure and information, and barriers in the built environment and above all in the mindset of civil society still exclude people with disabilities. Particularly exposed are people with visual impairments or legal blindness; they consequently experience a reduced mobility in their daily life. This can be underpinned by some statistical figures, e.g., more than 50% of persons with visual impairments in Austria perceive themselves as moderate up to severely mobility impaired [5].

Existing GIS applications to increase the mobility of people with disabilities can be categorized upon various parameters; among others one key element is the type of disability [6]. GIS approaches for persons physically restricted in their mobility like wheelchair users, persons with crutches, parents with strollers, or elderly people show a wide variety in theoretical discussions as well as in practical implementations, mostly focusing on accessibility issues [7–11]. Solutions to support independent mobility for persons who are visually impaired or blind often remain either on a theoretical level or as project ideas, as special solutions or prototypes. Concerning their spatial extent, they are typically valid for a limited space like university campuses or small districts of cities; others require cost-intensive devices that are sometimes yet difficult to manage [12, 13].

However, people with visual impairments or blindness can benefit from the possibilities to plan and prepare their activities in space, as long as the supporting tools fulfill a number of requirements. Tools have to provide information about accessibility of facilities and the built environment and additionally have care for accessibility of information through a manageable and easy-to-operate user interface and an appropriate description of route directions.

The paper presents the theoretical background of a "GIS4all" and, in particular, the results of the project "ways2see," which implements the theory for people with visual impairments or blindness. GIS4all is a framework, which intends to conceptualize the scope of action for the application of an inclusive, trans-, and interdisciplinary GIS providing answers for spatial information, orientation, and navigation issues of people with and without disabilities. Since persons with visual impairments or blindness require complex and alternative spatial information for wayfinding, the focus of the application project "ways2see" was given to this user group.

The design and product development of the assistive tool ways2see are supporting orientation and navigation as pre-trip planning instrument for people with visual impairments or blindness. ways2see provides information on facilities as well as routing information adapted to the needs of the target group, which will support them or assist persons in preparing ways in so far unknown environments. The goal of ways2see is twofold. (1) The design and presentation of information for the target group include special cartography on the one hand and on the other hand, an applicable web-user interface at the front end which is capable for screen readers. (2) The individual selection and description of routes presented by the tool are comparable to the description used by orientation and mobility (O&M) trainers,

including hints and landmarks for orientation, warning of obstacles, and simultaneously avoiding barriers in the routing.

The underlying network for pedestrian routing was developed using ArcGIS Desktop and Server, and the application ways2see is based on ArcGIS Web AppBuilder. The development embodies a participative and iterative process, following the motto of inclusion, "nothing about us without us," not only with the goal to produce an assistive tool for the target group but also to raise awareness in society for the topics of disability and inclusion.

2. Theoretical background

The origins of tools intended to increase the mobility of people with visual impairments or blindness can be seen in tactile maps, reaching back hundreds of years [14]. With the evolvement of information and communication technologies (ICT) in the mid of the last century, electronic and assistive tools gained importance [13]. Since then, various approaches, using wearable devices (e.g., electronic white canes) and sight replacing aids up to robotic help, have been developed and evaluated from various scientific backgrounds (e.g., see [15, 16]). Geographic information systems as integrative part of mobility solutions do not play an important role in these reviews; sometimes they are even not mentioned. One reason for this can be seen in the mapping part of the software, since (digital) maps—regardless on which device they are presented—barely meet the needs of visually impaired users.

Although showing a bottleneck with maps, GISs offer main advantages: the possibility to address spatial relationships as well as processes and present spatial analytical results. Based on the spatial and therefore geographical perception, GIS applications for mobility issues of people with visual impairments or blindness can be split into four main scopes: (1) the field of application or use, (2) the spatial environment, (3) the information and navigation aspects, and (4) the presentation and communication of information and/or the analytical results. The following discussion reflects the literature mainly since 2010, and a detailed description of approaches before is given in [16, 17].

(1) An overall classification of the applications is dealing with the category and purpose of usage. This reflects on the one hand the application fields like tourism purposes, emergency management or planning, and decision support tools [18–22]. On the other hand, the purpose of the trip can be split up upon the use in form of pre-trip planning or on-trip planning. Pre-trip applications show a focus in web applications and discuss various accessibility aspects of maps (user-oriented content, design, and functionalities), the design of the interface, and the degree of interactivity as well as the communication to the users [22–24]. With the availability of GPS, on-trip applications gained interest. They are mainly used for navigation and routing in different surroundings, using various devices (smartphones, wearable and portable assistive technology, etc.). Additionally, they give special interest to critical situations along the routes, e.g., intersections or obstacles [25–28].

(2) Taking a closer look at the spatial environment, the orientation and navigation support give emphasis either on indoor settings [29, 30], outdoor navigation [31–33], or a combination of both [34]. Golledge et al. [35] elaborated one of the basic approaches, discussing the spatial context of mobility for people with visual impairments or blindness. Since different technologies have to be integrated to define the position of the person along a route on-trip, a combination with different technologies (RFID, Bluetooth, DGPS, etc.), regarding the surrounding where the

navigation takes place, is involved, including tracking functionalities to determine the accurate and current position [26, 31, 36].

(3) Analyzing the information and data necessary for navigation purposes, three different core elements to enhance the process are crucial. Landmarks or navigation hints are added to improve wayfinding and the descriptions of directions [37–40]. Obstacle detection helps to increase "safe" orientation and navigation in unknown areas [21, 41, 42]. Additionally, a special focus is given to critical locations or areas along routes. Especially intersections need a more detailed description, respectively, and a different navigation process [28, 43, 44]. Finally, the integration of pedestrian paths is critically important to be able to distinguish between left- and right-hand side of a street [45].

(4) The bottleneck of GIS for people with visual impairments or blindness was already identified in the mapping part. Therefore, the presentation of information and transfer to the users has to include adopted visual elements [46–48] as well as audio and/or haptic assistive devices [33, 49–52]. This important front-end part of mobility assisting electronic devices leads to a second component of accessibility issues. Next to the accessibility of the urban environment, which can be indicated as first issue, the assistive tools themselves have to be accessible, including web accessibility. This means the operability of the software similar to the accessibility of the presented information, e.g., as maps have to be provided with special/universal design and extended/substituted with haptic and/or acoustic information.

The discussion of recent work on increasing individual mobility of persons with visual impairments or blindness finally results in a list of challenges, which are addressed in ways2see and are tackled in this paper:

- Availability and density of detailed spatial data

- Data about critical areas, e.g., intersections and crossings

- Lack of data about pedestrian path network

- Possibility to personalize information, e.g., directions

- Accuracy of positioning during the navigation process (in- and outdoor)

Roentgen et al. [39] summarized in their review that "The limited accuracy of the turn instructions and the 'roughness' of the information provided were regarded as insufficient." [37] conclude furthermore "Therefore there is a requirement to not only improve the availability and accessibility of graphical information but also to provide more context sensitive information (e.g. via profiles and points of interest) as geographical data is of little use on its own for understanding the environment, and the relationship between the individual and their surroundings."

3. Methods

The structure of the methods corresponds with the results and discussion (Section 4).

3.1 Fundamentals of ways2see in a framing model GIS4all

The project ways2see is embedded in a wider context with an overall goal and general idea: to design and implement a GIS4all, a GIS which presents spatial information to all persons with (and without) disabilities, regardless of the type of
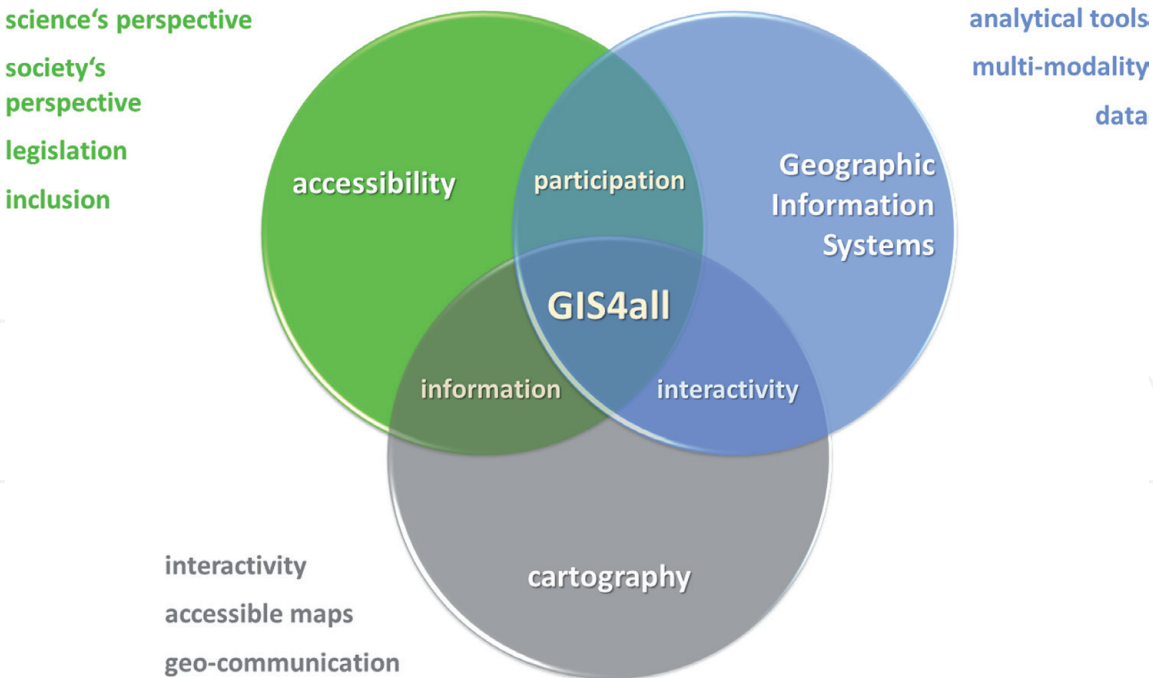
Figure 1.
Three pillars of GIS4all.

their disability. The intention of this inclusive approach is firstly to conceptualize a theoretical framework for GIS and secondly to transfer the scientific results into practice by designing a marketable product, namely, ways2see (https://www.barrierefrei.uni-graz.at/ways2see).
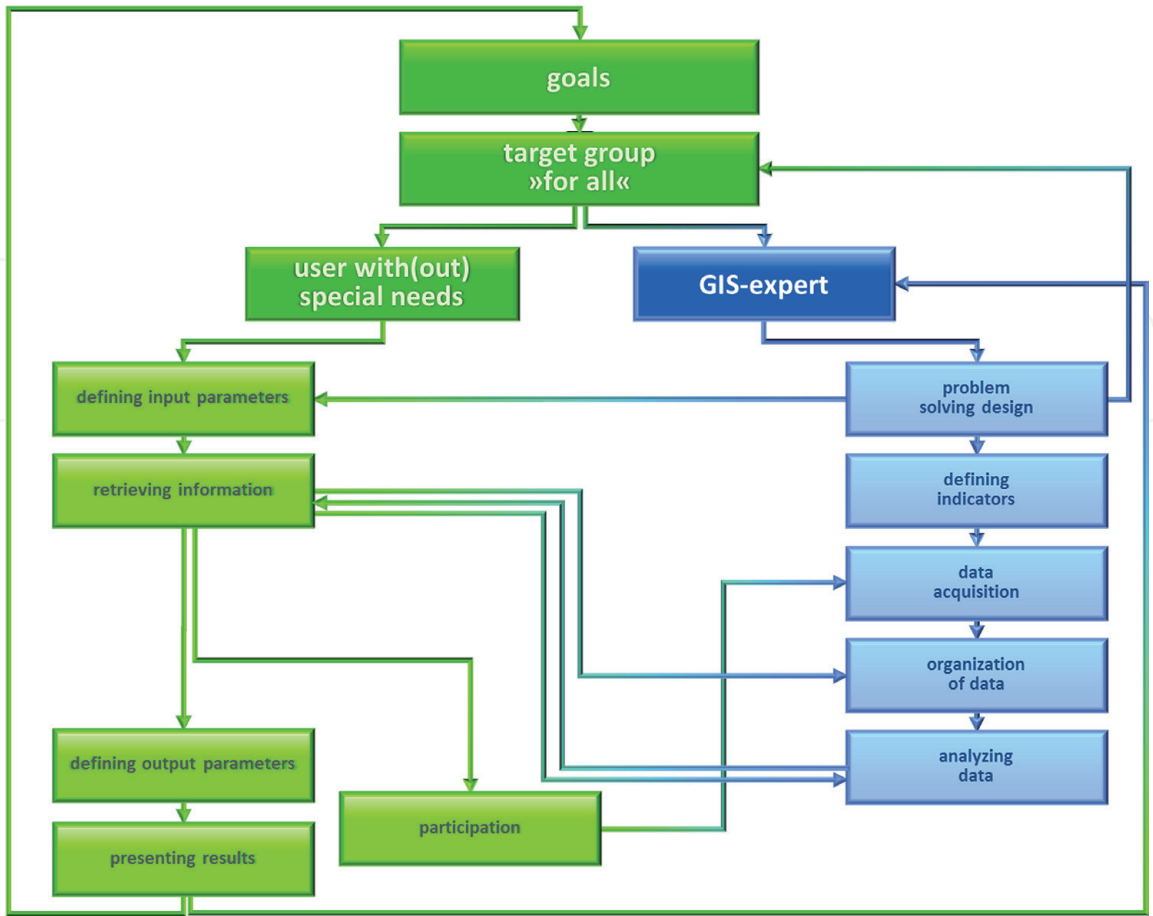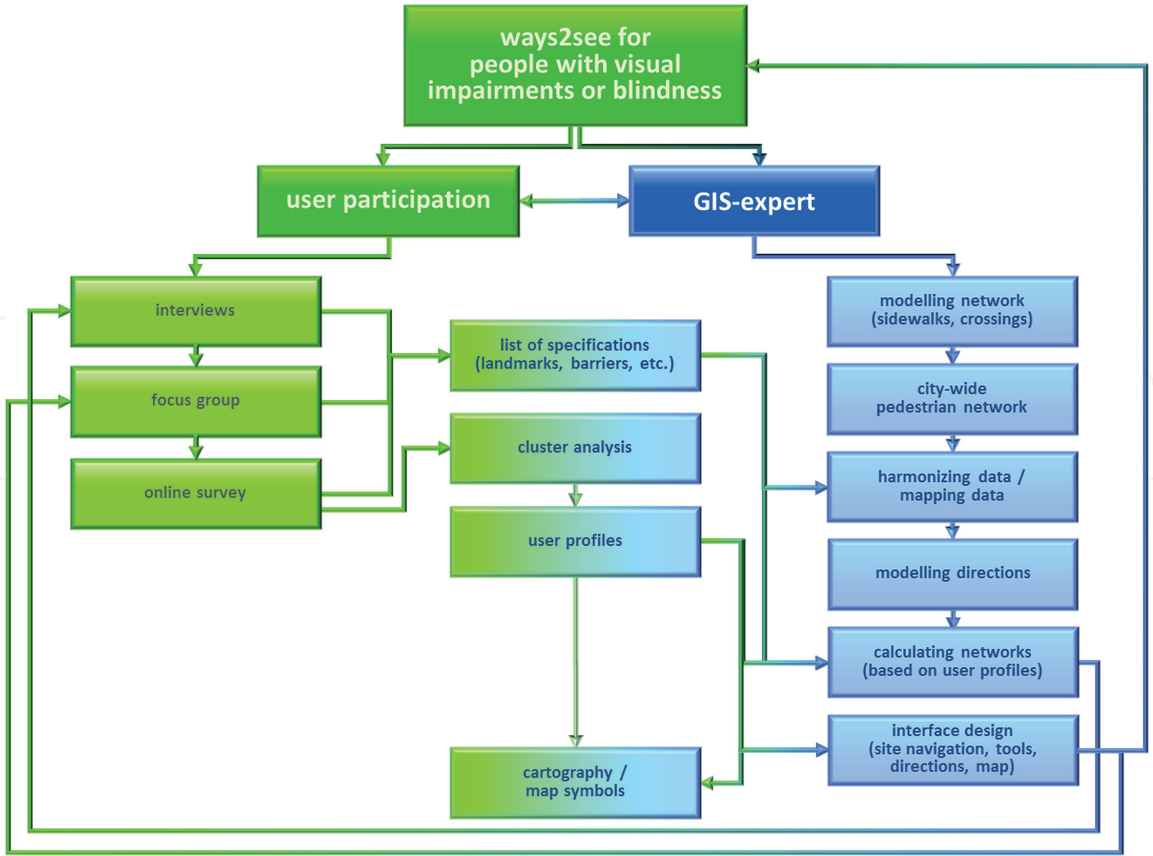

Figure 2.
Conceptual model of GIS4all.

Figure 3.
Applied methods and generated results in ways2see.

The framing model GIS4all results from a theoretical discussion, including three main disciplines: disability studies, cartography, and GIS [17]. **Figure 1** illustrates these three pillars along with topics significant for the GIS4all model.

The literature review resulted in a construction kit made up of detailed building bricks for implementation. **Figure 2** shows the conceptual model of GIS4all, which also works as system model and GIS model. The overall intention of GIS4all is to present information to people with (and without) disabilities through an online platform toward four strategies: the information can be retrieved (1) using easy language, (2) is supported with a sign language avatar, and (3) is including needs for people with physical impairments as well as (4) people with visual impairments or blindness. The model illustrates the process design and will be transferred to ways2see (Section 4.2, **Figure 3**) narrowing down the concept "for all" to people with visual impairments or blindness.

3.2 Inclusion: together toward new ways

The integration of prospective users in the development and design process of ways2see, based on the motto "nothing about us without us," is following a trans-disciplinary procedure with iterative interactions with the target group, people with visual impairments and blindness. Special and thorough interest is given to the active integration of persons with visual impairments or blindness and participative processes, conducting the following methods:

- Guided interviews with orientation and mobility trainers

- In-depth interviews with users from the target group

- Focus group work with participants of the target group, O&M trainers, and educational staff

- Design workshops with participants of the target group, O&M trainers, and educational staff

- A nationwide online survey with people with visual impairments or blindness

The results of the online survey were analyzed with descriptive and exploratory statistical analyses. A hierarchical cluster analysis, intended to highlight unknown structures within the data, is used to identify inherent information in the data about the specific needs of the target group. The cluster analysis was conducted in IBM SPSS Statistics 23, using Ward's algorithm with squared Euclidean distance, and resulted in five clusters as user profiles (Section 4.2).

Clarke et al. [53] indicate a need for careful consideration of involving users, due to the various and different needs of the target group. Additionally, participation raises the chance for acceptance and a wider use of the final product. Martin et al. [54] stated that especially communication tools and screen readers are more likely to be abandoned compared to, e.g., tools to assist in daily living, if not reflected carefully and making the target group aware before ready for the market.

Following the inclusive approach of ways2see with the integration of people with visual impairments or blindness into the development and evaluation process, further workshops with the target group, discussions, and a comprehensive testing of the prototype were conducted. The integration process can be defined as iterative and mutually supportive and beneficial for both sides—the prospective users and the project team.

3.3 Pedestrians, not motorized vehicles: a network for people with visual impairments or blindness

As stated before, most navigation systems use street centerlines as a basis for their routing algorithm. Since this lacks precision for wayfinding for people with visual impairment or blindness, a network based on sidewalks was generated using zonal information. Along with the sidewalk-based network oriented toward the needs of pedestrians, additional technical or GIS-oriented challenges of ways2see were addressed through the following methodological approaches:

- Automated data processing and implementation through scripts, extended with data collected through fieldwork

- Definition of network attributes to serve the different needs

- Design of a user-oriented interface, based on user profiles, including application design as well as cartographic design

- Implementation of ways2see as a marketable product

Spatial analyses are executed in ArcGIS Desktop 10.4, the GIS functionalities are using ArcGIS Server 10.3 capabilities, and the implementation is using the Developer Edition of ArcGIS Web AppBuilder.

3.4 Accessibility through the user interface and map design

The interface design starts off with a focus toward compatibility with the most commonly used screen readers and Internet browsers, retrieved from the project online survey and the information presented by the [55]. Parallel to compatibility issues, the design has to include the possibility to deploy different contrasts and colors to the users, following the individual needs.

The user interface of ways2see is designed using the Developer Edition of ArcGIS Web AppBuilder. The two analytical tools—wayfinding and orientation as well as looking for point of interest (POI) in the surrounding—are implemented using pre-defined widgets in the Web AppBuilder, adapted through coding. Establishing ways2see on a project server using ArcGIS Server 10.3 allows full adaption of the map to the project needs as well as integrating the concept of vector tiles, which provides a faster map access.

3.5 Quality attracts users

To assure the quality of ways2see, to increase the probability of use, and to inform the user group of the availability of ways2see, three strategies finally need to be mentioned. Next to the participative development process, prospective users conducted comprehensive testing using the prototype. Prior to this, ways2see passed extensive testing by the project team. Quality assurance was additionally provided through an external evaluation of the project after implementing the prototype. Since the evaluator shows next to his GIS skills special expertise in cartography, the final product also benefits regarding map design and definition of user-oriented map symbols.

4. The way to a marketable tool: ways2see results and discussion

4.1 Study area: the dimension of a citywide project offers new challenges

The city of Graz with about 290,000 inhabitants and an area of 127 km^2 (49 mi^2) and 1200 kilometers (745 miles) of streets and path brings a new dimension into the design, development, and implementation of an O&M supporting tool. Especially the dimension of the city makes it necessary to compete with the amount of data—firstly regarding the acquisition of information and secondly due to the modeling and automatization of data, which has to be processed and updated on a regularly basis. The long history of the city, Graz received its city arms in 1245, can be seen in the structure of the city. A historic downtown area in combination with prospering suburban areas, mostly in the south and hilly and less populated spaces in the northeast, requires a model, which reflects various situations concerning sidewalks, intersections, or street crossings. Furthermore, the inner city as a UNESCO World Cultural Heritage with various historic sites bears hurdles toward the reduction of barriers and an inclusive urban planning.

4.2 User profiles for accessing personalized information

Guided interviews with four O&M trainers and two persons from the project cooperation partner Odilien-Institute were conducted to estimate the need for the application ways2see. The results served as basis for a focus group work, with the goal to get a more detailed view on information and data needed for ways2see. The group consisted of 31 people, including 16 people with blindness.

In terms of gender, the group was split into around one-third female and two-third male participants.

The results of the theoretical and methodological discussion, the focus group work, and the expert interviews build the background for an online survey intended to reach a wider audience and to broaden the perspectives. One constraint associated with the online questionnaire is that predominantly persons with visual impairments or blindness, which are able to handle a computer or are supported by an assistive person, can provide answers. Another limitation is given with the way the audience is addressed. The target group is contacted through federations of people with visual impairments or blindness, where persons register on an optional basis, since there is no organization in Austria, where all persons of the target group are recorded. Despite this, the answers provided by the target group offer a classification of needs of people with visual impairments or blindness regarding their mobility in daily life.

A list of specifications, including points of interest, landmarks, orientation hints, dangerous spots, and movement barriers, is compiled from the guided and in-depth interviews, the focus group work, and the online survey. The list of specifications was generated from a feasibility study, dealing with the availability and possibility of automated data integration. The result is indicating the limits of ways2see from a technical perspective on the one hand and the limitation regarding data acquisition on the other hand. For example, it is neither possible to implement movable obstacles like bicycles parked on sidewalks into the system nor to map the citywide lowering of sidewalks for driveways. This is also contrasting the idea of integrating freely available data or automated data acquisition for ways2see when ensuring quality as well as timeliness of data.

The nationwide survey shows a response rate of 11%. 1000 people were contacted in the online survey, which is a comparably small portion of 318,000 persons with visual impairments or blindness (thereof 3000 blind) in Austria [56]. The reasons for this are stated in Section 3.2—one reason is that people with visual impairments or blindness cannot be addressed through a central institution and a second reason is that the survey was conducted online.

The cluster analysis, based on the results of the online survey, presents five clusters in the heterogeneous group of people of visual impairments and blindness:

- Cluster 1: Accompanied

- Cluster 2: Elderly blind

- Cluster 3: Independent adults

- Cluster 4: Tech-savvy, age 20–40

- Cluster 5: Congenitally visually impaired, age under 20

A detailed description of the results of the cluster analysis is documented in [57]. These groups of prospective users work as initial point to deviate the user profiles, which are implemented in the network generation and user interface of ways2see. The following four profiles are implemented in ways2see, evaluated in focus group work and in a design workshop with persons of the target group:

- Short routes preferred, regardless of infrastructure of crossings.

- Tactile pavement and accessible pedestrian signals preferred.

- Avoid crossings without tactile pavement and accessible pedestrian signals, and show all orientation hints.

- Choose individual settings.

Figure 3 illustrates the methodological approaches combined with the essential results of the design and development of ways2see. It is reflecting and applying the conceptual model of GIS4all given in Section 3.1 for the target group of people with visual impairments or blindness (**Figure 2**).

4.3 A new pedestrian network for the city of Graz and new routing information for the target group

As stated in the theoretical background, the generation of a pedestrian network based on sidewalks is critically important, since people with visual impairments or blindness need to distinguish between the left-hand side and right-hand side of a street. Most of the available navigation tools use centerlines of streets as basic network information—even for pedestrian routing. Consequently, this leads to a coarse representation of directions, since they are based either using terminology involved in car navigation and/or imprecise guidance. Persons with sight are still able to navigate following these directions, since they rely on landmarks like street names, signs, etc. People with visual impairments or blindness need more specific, additional information, for example, where they are walking along (a wall, a fence, etc.), the distinction and location of "safe" crossings, landmarks that are ascertainable with the white cane, or barriers and objects which bear a danger.

Another challenge is that pedestrian networks are commonly not available in city data and their generation is cost- and time-intensive. ways2see uses a semiautomatic generation of the pedestrian network based on the centerlines of sidewalks. The attempt to use the methodology of [58], who developed a standardized procedure to generate sidewalks based on fixed distances from the street centerlines, failed due to varying street width and a lack of availability of this information in the data. Neis and Zielstra [59] used OpenStreetMap as data source for network generation, likewise offering limited level of detail and too general for the target group. The deduction of sidewalk centerlines for ways2see is using the zoning map, which indicates traffic zones including the street, the sidewalks and parking areas, etc. In combination with street centerlines of the Graph Integration Platform [60], a freely available dataset of the open government data, sidewalks were calculated and integrated, using ArcGIS scripts. The advantage of this approach is the potential to transfer the model to other cities/regions. The model achieves an accuracy level of 86%. Although only 14% of line segments are left to be inspected, the whole city was reviewed in fieldwork. This decision was taken to get sidewalk information at the best quality, since some particular information cannot be derived from other data sources.

The generation of the pedestrian network includes modeling intersections and crossings. A considerable portion of the target group relies on crossings equipped with accessible pedestrian signals, which has to be documented in the modeling process. In case of inexistence of crosswalks and (accessible) pedestrian signals, intersections without infrastructure were modeled by using scripting to avoid long detours. This situation is found predominantly in the suburban parts of the city with single-home setting.

The sidewalk-oriented pedestrian network works as basis but requires additional attributes for the orientation and navigation of people with visual impairments or blindness. A major challenge turned out in adding directional linear-based information to the network. The information, what kind of objects a person is moving along as well as where (linear) objects are located, e.g., house walls, fences, etc.,

is an important element of orientation and navigation information for the target group. Especially linear-based information is missing in existing tools. The possibility to include this kind of information in the direction settings is not provided in the network generation of ArcGIS. Additionally, the complexity of data cannot be represented in the standard network model. The network allows the combination of orientation features along the road like surface, availability of sidewalks, and use of sidewalks as well as landmarks and barriers to calculate the route, but not their display in the directions, which are provided to the user for wayfinding. Challenges identified with assigning necessary data to the network are encountered with new strategies to include this information through the adoption of the background xml files and direction settings. To produce a clear result without redundant information, the directions have to be post-processed before presenting to the user.

The final result is a citywide network, representing the centerlines of sidewalks, including crossings as unsecured crossings, crosswalks with and without pedestrian signals, and crossings using accessible pedestrian signals (**Figure 4**). A modeling process realized with scripts and Python makes this important step transferable to other regions.

The attributes of the pedestrian network are representing the requirements of the target group and are based on the list of specification (Section 4.2). The attributes, which are detailing the navigation information, are:

- Directional representation of objects along the sidewalk

- Availability, type, and surface of sidewalks

- Landmarks, obstacles, and barriers

Figure 4.
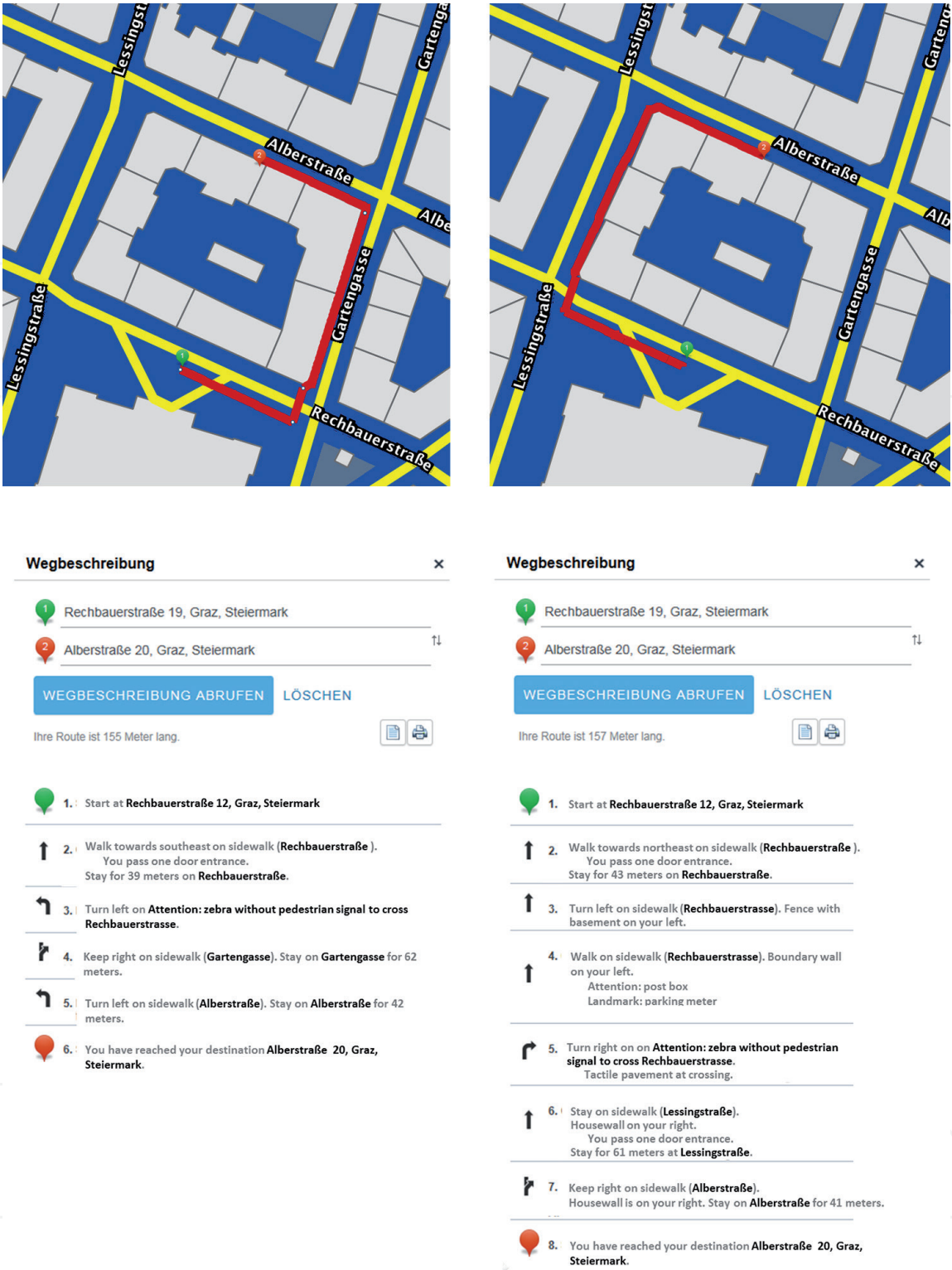*Basic elements of the pedestrian network, city of Graz.*

Figure 5.
Example of routes based on two different profiles. Left, short routes preferred; right, show all orientation hints.

Based on the user profiles given in Section 4.2, these attributes are differently combined and weighted in the network. This is resulting in differing routing results and directions presented to the users, based on the selected profile.

Figure 5 exemplarily shows the main components of two different descriptions of directions. The user profile "short routes preferred" needs less orientation hints. The profile "avoid crossings without tactile pavement and accessible pedestrian signals, show all orientation hints" uses a detailed description of the route and avoids "unsecured" crossings.

4.4 Design of the user interface: new ways to see

The user interface of ways2see is concise, easy to use, self-explanatory, and accessible. It is integrating the user profiles resulting from the cluster analysis (Section 3.2). ways2see as an Internet-based application is all-time available.

The interface is using a straightforward navigation strategy, with the following steps:

- Welcome and introduction of the tool including links to a glossary and help

- Decision for the user profile to be used (**Figure 6a**)

- Decision, what to do:

  1. Retrieving directions between two addresses or retrieving directions between current position and an address (**Figure 6b**)

  2. Searching for POIs and retrieving directions to a selected POI (**Figure 6c**)

- Presentation of the result:

  1. Detailed directions for wayfinding (according to the selected user profile) (**Figure 7**)

  2. Map visualizing the route as well as POI (**Figure 7**)

  3. Text-based list of addresses of POI

- Option to export the information for "offline" or analogue use

On the first view, the map-focused design of Web AppBuilder seems to be a contrary to the goal of accessibility. However, the concise and minimal design with a comprehensive task menu offers the possibility to adapt the interface toward the needs of accessibility and compatibility with screen reader software. Therefore, a pre-defined template is adjusted through removing needless functionalities and adding text labels to menu elements. Text labels support on the one hand visibility and identification of menu buttons with the screen reader; on the other hand, they are selectable with the keyboard. Next to the keyboard first strategy, the interface is navigable with mouse and touchscreens. The user interface has the advantage of an automated arrangement of buttons and tools depending on the used end device (computer screen, tablet, smartphone). As indicated with the straightforward strategy, the buttons are offered consecutively step by step. Consequently, a button is offered only, if necessary selections, e.g., choosing the user profile, have already been made. The decision of searching for a POI or selecting a wayfinding process can only be done after defining the user profile.

Finally, the map, which is split up into a base map and additional layers presenting target group-oriented information, has to be briefly discussed. The base map shows the basic city structures including street centerlines, green areas, rivers, and buildings, following the idea of [61], who developed a base map for Austria. Additional layers will integrate cartography for visually impaired users. As stated in Section 3.3, special interest is given to the directions, since this is the most essential result for users not able to read the map due to their limited sight. Directions have to
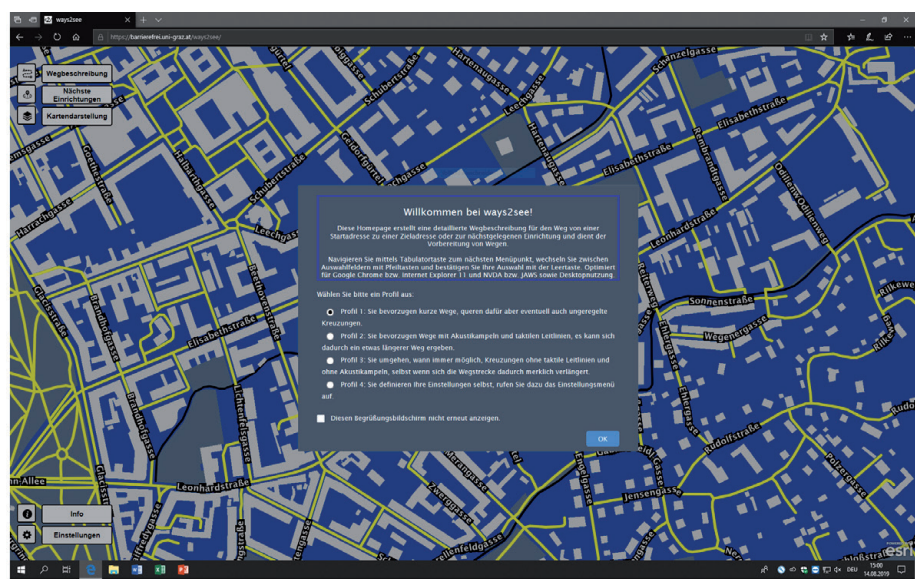
(a)
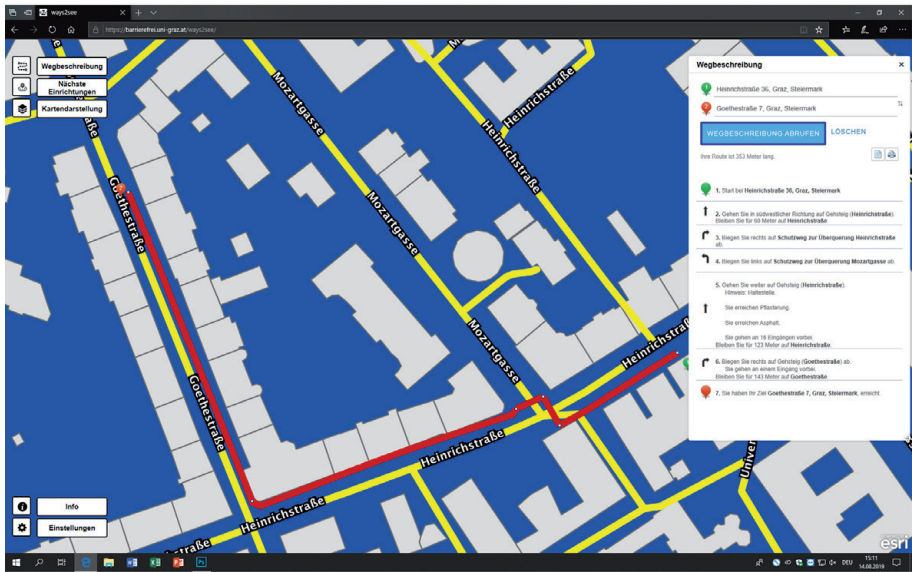
(b)
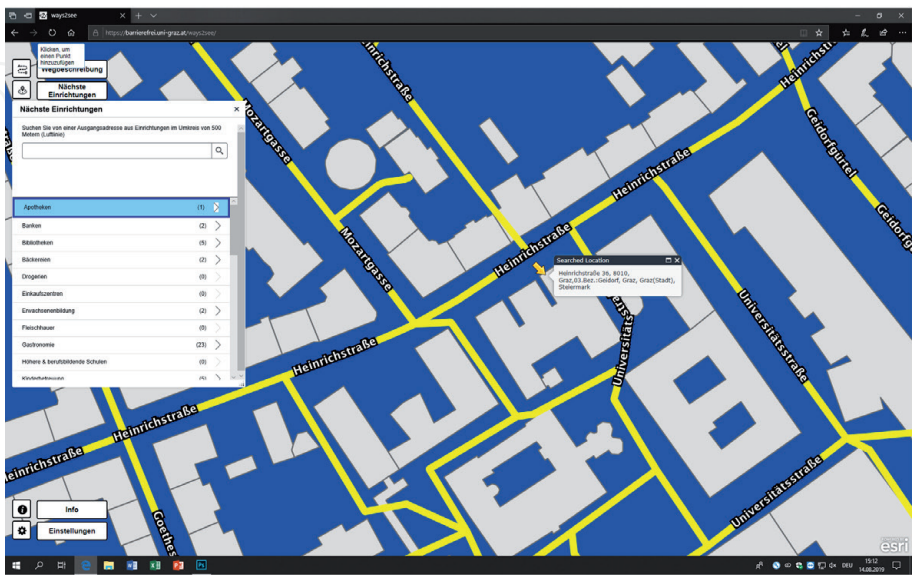
(c)

Figure 6.
(a) Welcome screen of ways2see offering basic information and selection of user profile. (b) Wayfinding between two addresses. (c) Search for facilities in the surrounding area.
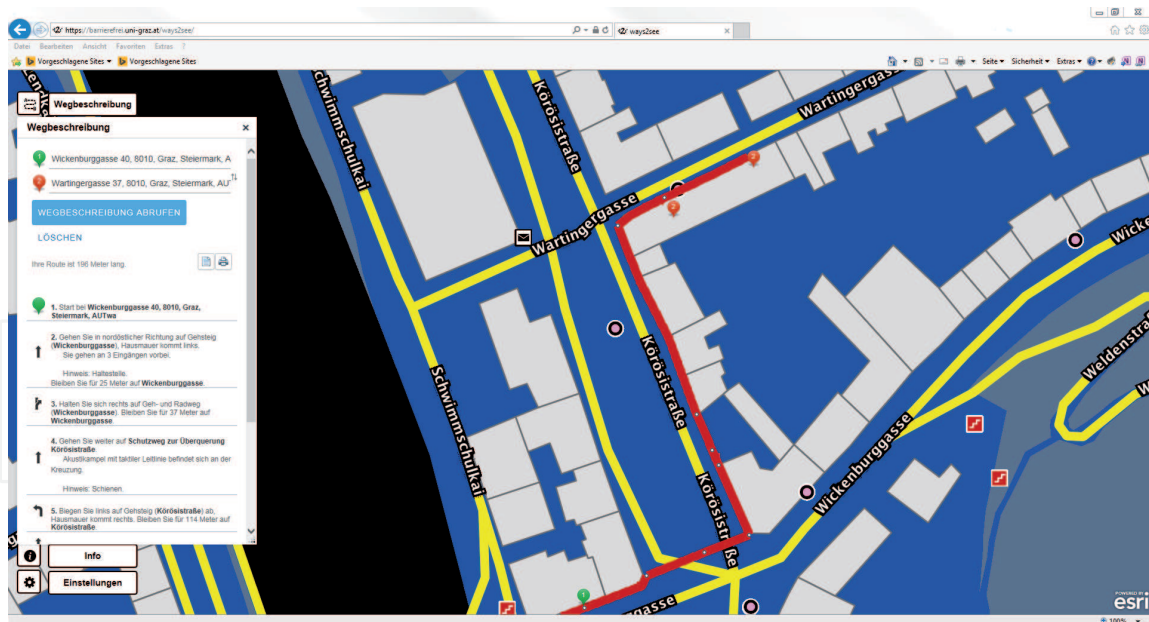
Figure 7.
Map with directions based on a selected user profile.

be readable with screen readers and can be exported—either to be used for adding further, personalized information or to be used on-trip. Routes, obstacles, barriers, and landmarks as well as points of interest are displayed using special designed map symbols. Furthermore, the performance of different browsers was tested regarding the implementation of personal settings (size and color schemes,) and the design of the user interface was adopted toward the most common browsers. However, the map component is challenging, since every browser handles the presentation of the map differently. At this point, it has to be mentioned that ways2see was developed for the screen readers NVDA and JAWS 16.0.

As restriction has to be indicated, outdated software might not offer compatibility and/or present optimized map result. As participatory part of ways2see initially, the integration of data provided by users (crowdsourcing) was conceived (cp. **Figure 2**). Although this is still on the project agenda, the technical realization opens up a completely new dimension due to the necessity to review and georeference the information as well as to think about the validity of data and user registration issues.

5. Conclusion

People with disabilities and their (spatial) needs are still at the edge—in society as well as in geography/science. To allow people moving away from this fringe, an essential step can be made by increasing the personal and individual mobility. Mobility means independency, e.g., from assisting persons, is enhancing quality of life, and finally is widening the individual (spatial) scope, which potentially leads to more interrelation and inclusion in society.

ways2see offers a new tool to people with visual impairments or blindness, which increases the personal mobility by supporting orientation and wayfinding for pre-trip planning. The user interface of ways2see is designed toward the needs of the target group and offers the possibility of personalization through different user profiles. The results of pre-trip planning are (1) information about facilities in the surrounding and/or (2) personalized directions for wayfinding toward these facilities or defined addresses. As a difference to existing tools, the results show (3)

an extensive number of attributes presented as orientation and navigation hints along routes, (4) a user profile based indication of obstacles for the avoidance of barriers, and (5) personalized directions through the integration of this information in the routing analysis. The user profile-oriented results can be provided through GIS analysis on an expert level behind the scenes, where spatial data is analyzed with different network settings. Special focus hereby is given to the definition of the basic network, using sidewalks and adapting the standard network settings to the requirements of ways2see.

Parallel to offer user-oriented and customizable information as routes and route directions, the results are presented to the target group in an accessible way by specific interface design, map layout, and map symbols. The Internet platform itself and the list of addresses as POI and directions are available with and are suitable for screen readers. ways2see can be described as accessible tool providing information about accessibility.

The combination of spatial information; its analysis with geographic technologies, namely, GIS; and the application toward a marginalized group underpins the potential of geography in disability studies by a clear positioning of the competence for spatial approaches. ways2see is the result of a participative process, integrating persons with visual impairments or blindness through iterative steps into the development process. Different strategies were elaborated and are used to meet the needs of the target group. Inter- and transdisciplinarity is guaranteed through the partner network and allows the development of a marketable product.

In a future perspective, ways2see not only provides spatial information as orientation and navigation information but shows the potential to work as supporting tool in urban development and planning processes and can help to reduce barriers in the urban environments and—furthermore—in our minds. It is also intended as one way to raise awareness in society and herewith to promote social sustainability and inclusion.

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