

# A Study of Information Formulation in Auditory Map Systems

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## Abstract

The objective of this research is to find optimum ways of providing pedestrian route information in future support systems for visually impaired pedestrians. In this research, we refer to the auditory route information used by the visually impaired pedestrian as an "auditory map", and we analyze the constraints necessary for utilizing auditory maps when provided by electronic devices as well as the formulation of auditory maps. In this paper, we propose specifics for a postulate auditory maps input and output system, and, based on our demonstrations in real sites, formulate the information elements to be used in auditory maps within our system. In our system, auditory map consists of "nodes", "paths" and "connections". These information types are comprised of "reference elements", "orientation" and "movement" items. As results, reference elements are subdivided into "point", "linear" and "surface" elements, with 23 instances. This information can be further subdivided as necessary into "attribute information", "clue information", "added information" and "danger information". In our conclusion, we propose the auditory map systems with reference elements of 23 instances that complement orientation and mobility items (including 5 categories of 15 expressions).

**Keywords:** auditory map; people with visual impairment; navigation; pedestrian way; city planning.

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## 1. Introduction

The objective of this research is to find optimum ways of providing pedestrian route information in future support systems for visually impaired pedestrians. In this research, we refer to the auditory route information used by the visually impaired pedestrian as an "auditory map", and we analyze the constraints necessary for utilizing auditory maps when provided by electronic devices as well as the formulation of auditory maps.

### 1.1. The Current Status of the Visually Impaired

According to "Survey on the Actual Status of Children/Persons with Physical Disabilities (2001)", there are 306,000 visually impaired people in Japan. The term "visual disabilities" includes people with functionally blind and partially sighted, so blanket statements about all visually impaired people cannot be made. In general, however, the number of

people with Class 1 visual impairment, that is, people with extreme difficulty in using vision while walking, is 105,000, 34.9% of all visually impaired people in Japan.

According to the studies, the frequency at which visually impaired people leave their homes is low, even compared with those with other forms of physical impairment. While the ratio of visually impaired who go out almost daily is low, the ratio of those who go out only about two or three times a month is high (Fig. 1). As such, we can imagine current conditions, under which the pedestrian environment is extremely difficult for the visually impaired. Difficulties faced by the visually impaired when being out their homes include inconveniences related to the use of public transportation, difficulties in using roads and stations, and a sense of danger due to automobiles, etc., and the visually impaired face these problems to a greater degree than the physically impaired as a whole (Fig. 2). As such, future attempts to create "barrier free" environments must work to resolve these problems from the standpoint of the visually impaired.

### 1.2. Current Pedestrian Support Systems

As humans, we orient ourselves to our current position and our destination and move about by creating a coordinate system for the area around us based on a physical (positional) relationship

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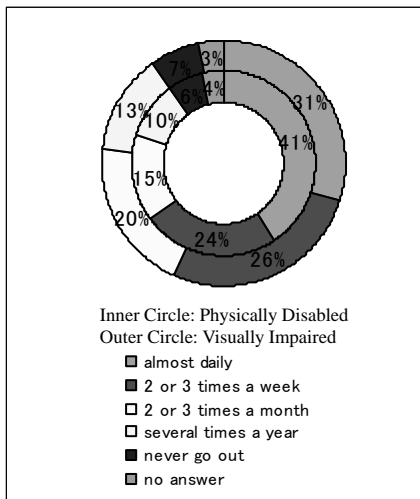


Fig. 1 Frequency of Being Out

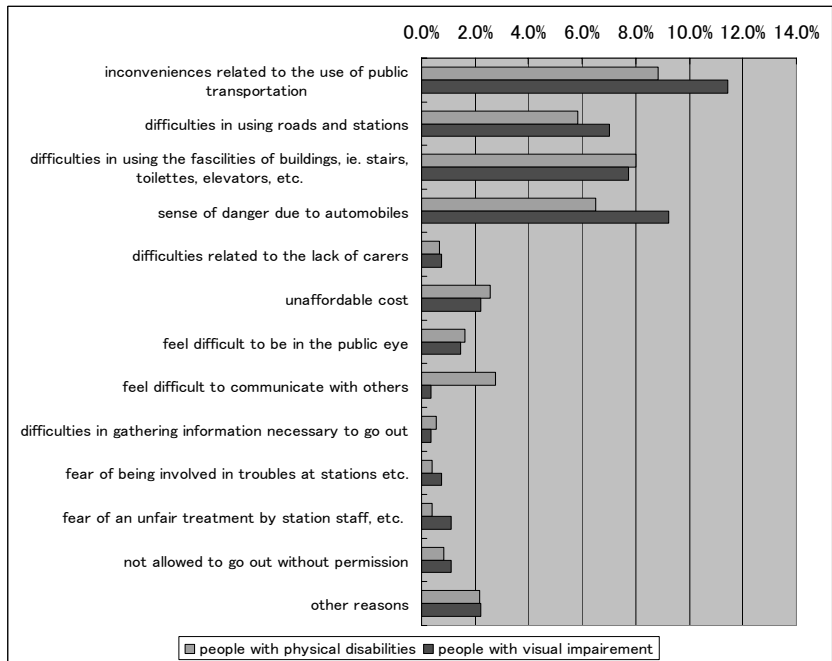


Fig. 2 Difficulties Faced by the Visually Impaired & Physically Disabled When Being Out Their Homes

between reference elements and ourselves (Fig. 3). When creating this coordinate system, we extract suitable reference elements from the surrounding environment, be they natural elements or built ones. For the visually impaired, hardware measures are needed in the form of reference elements that can assist them in recognizing surrounding spaces, and in the form of portable devices that can read or perceive these reference elements. In such cases, the types of information that must be prepared can be divided into three types. The first is location information (reference element information) related to factors that indicate what sort of meaning a specific location has. The second is orientation information (location information plus another reference element) related to the physical (positional) relationship between a certain location and another location. The third is navigation information (orientation information plus movement information) that formulates a plan determining which route should be selected in order to proceed to the destination

Based on this perspective, the positioning of current pedestrian support systems that provide a vision for the visually impaired can be summarized as shown in Fig. 4.

1) *Tactile guide blocks* for the visually impaired provide orientation information that is perceived by touching the blocks with a cane. The blocks indicate

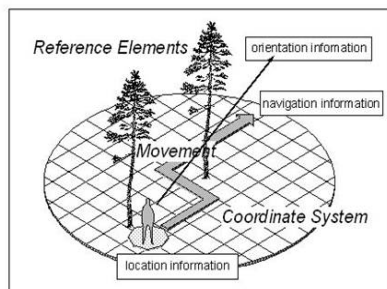


Fig. 3 The 3 Types of the Information for Wayfinding

either "proceed" or "stop".

2) *Handrails*, touched or gripped by the palm of the hand, can be used for orientation. By placing *Braille information on handrails*, they can also be used to provide location information, for example, what can be found at the end of the stairway.

3) *Guide chimes* are often installed at locations such as the top of ticket vending machines in railway stations. These devices continuously emit a sound that provides the visually impaired with location information indicating the location of something "necessary". *Tactile maps* can also often be seen in railway stations, but these maps cannot be accessed unless a person has prior knowledge of where the map itself is, or unless there is a guide chime marking the location of the map. However, because these maps are stationary, the user must remember all of the information that was provided in order to follow the given route to the destination.

4) An *ETA (Electronic Travel Aids)*<sup>2)</sup> system, such as "Mowat Sensor", "Laser Cane" and "Sonicguide", is a portable device which do not require any installation of stationary landmarks, and is used that provides the visually impaired person with orientation information.

5) *EOA (Electronic Orientation Aids)*<sup>2)</sup> systems provide users with necessary information through the use of a portable device that interacts with landmarks.

With verbal landmark systems, the visually impaired person carries a device that emits a weak electric signal. The landmark (receiver) responds to the signal, and a speaker provides verbal information about the landmark, that is, location information. In order to accurately identify the location of the user, some systems use *RFID (Radio frequency identification)*.

With "Talking Sign" systems on the other hand,

the portable device serves as the receiver, using an infrared receiver to receive auditory information or an ID from the landmark (electronic label). Using the direction of the infrared beam, the system can also provide orientation information leading to the landmark.

6) The systems described above primarily use devices with sensors intended to substitute for vision. In order to provide navigation information, however, "subjects" information must also be added. That is, it must be possible to register the destination and to map the location of the user, which constantly changes. As such, *navigation systems for the visually impaired* can provide, for the first time, information about the interactive relationship between the user and the surrounding environment.

Navigation systems for the visually impaired, however, are all still at the research stage. Methods used to detect the location of the user include positional information devices such as GPS systems or RFID systems.

## 2. Auditory Map System

### 2.1. Auditory Maps

An important factor in pedestrian support systems for the visually impaired is the system interface. Careful consideration must be given to how the words and expressions in the guidance information can be used to provide maximum support utilizing the remaining senses and mobility of the visually impaired user.

An auditory map is extremely simple – an O & M (Orientation and Mobility) trainer, etc., records statements pertaining to route guidance onto a tape, and the visually impaired person plays back the tape while walking. Auditory map experiments were conducted in the 1970s, when tape decks finally reached a portable size. Today, playback devices are on the market that are extremely lightweight and allow the user to easily jump to various points in the recording, making such devices easier to use than ever before. However, regardless of how advanced performance of playback device and the Navigation Systems have become, if the information content is not carefully and completely checked, the system cannot become one that will actually provide support to the visually impaired user.

### 2.2. The Provision of Information in Auditory Mapping.

Blasch (1973) states that an auditory map requires two types of maps – a route map and a district map. A route map is, in addition to the actions for movement that a sighted person performs automatically based on visual information,

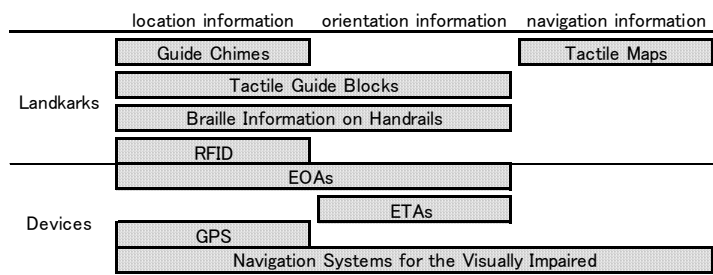


Fig. 4 Current Support Systems for Visually Impaired Pedestrians

such as "proceed", "stop" and "turn", it is also necessary to describe things like the method of using a cane and methods of perceiving information other than sight-based information, including information about risks. This additional information is necessary in order to provide navigational information to the visually impaired.

It can also be said that a district map provides navigation information prior to the start of actual movement by the visually impaired person. Accordingly, because the map provides advance information about the image of the entire area in which the target route exists, a district map supplements the information of a route map and serves to augment the knowledge of the visually impaired person by, for example, providing a means of dealing with situations in which the person deviates from the intended route.

## 3. Considerations of information formulation for an Auditory Map

### 3.1. Surmised Methods of Use

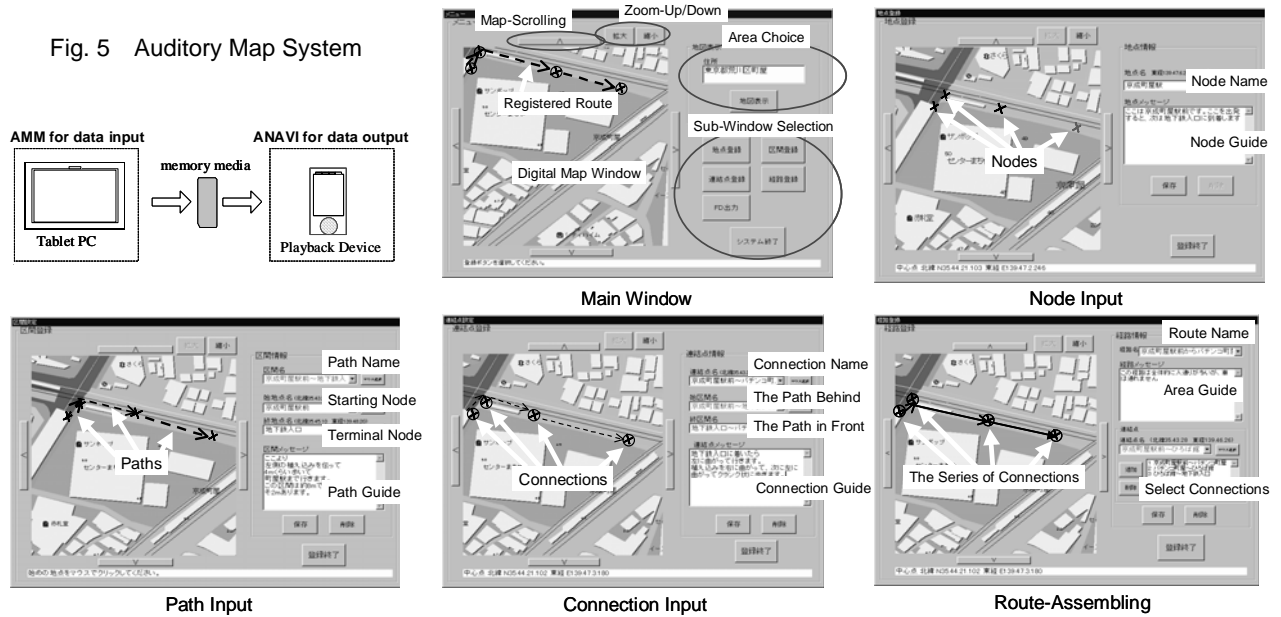
In regard to routes that may be used only a few times a year, or even just one time, for work, leisure activity, etc., it would be difficult to conduct O&M trainings in preparation for the use of such routes. In addition, for movement throughout a town or urban area, it would not always be possible to arrange for human helpers to provide guidance whenever needed. Therefore, pedestrian support systems or auditory maps could be considered particularly effective in such cases.

As such, for this research, we have focused our consideration on the provision of guidance for routes that link frequently-used transportation facilities (stations or bus stops) and other major facilities.

### 3.2. The System Concept

The "auditory maps system" discussed in this paper is based on the produced experimentally by Yokoyama, Nomura, and Shojima et al. (2000). The system consists of two subsystems, an auditory map maker (AMM) that constructs a database of a route on an electronic map, and an auditory map navigator (ANAVI) that can be easily operated by the visually impaired and has functions for selecting

Fig. 5 Auditory Map System



and "replaying" the desired route(Fig.5).

With the AMM, an environment is created in which detailed guidance information collected at the site is converted into a database using a specified text format. The information is organized into four modules and saved – "Node Guides" used in location, "Path Guides" (guidance from one node to the next node) and "Connection Guides" (guidance based on the relationship between one path and the next path) used in orientation, and a "Area Guide" used as a district map. Simply by changing the combination of the information for nodes, paths and connections, it is possible to generate multiple route maps through the same area. Orientation information is divided into "path" and "connection" information so that guidance information that differs based on the next direction of progression can be divided into "connection guides", making it possible for multiple routes to share the path guides. "Node guides", "path guides" and "connection guides" correspond to a route map, and "route guides" correspond to a district map.

AMM guidance data generated by the method described above is transferred to the ANAVI using memory media. In the future, we hope to use volunteers throughout the country to collect information about numerous routes, and to be able to distribute this information to the visually impaired nationwide using the Internet.

### 3.3. Demonstration of the System

We installed the test voice data of auditory maps as described above to the "Talking Sign" system and conducted the demonstrations in real sites (Fig. 6). The subjects were 3 visually impaired people (1 functional blind and 2



Fig. 6 A scene from the demonstration

partially sighted) and 32 sighted people (including an O & M trainer) each with an eye mask on. Two routes (length=50m, number of corners=2) were chosen. All of the subjects finally arrived at the destination. At the goal, we asked the subjects the problematic points of the auditory maps and summarized the comments and data into following formulation in Auditory Maps.

## 4. Results of Demonstration

### 4.1. Common Items Related to the Creation of Auditory Maps

a) *Length of Guidance Statements*: a guidance statement should be approximately 200 Japanese characters, with a maximum length of 300 Japanese characters. This is because statements that are too long cannot be fully remembered.

b) *District Map (Area Guide) Contents*: in order to conform to the guidance statement guidelines described above, the content of a district map should be limited to the minimum information required for safety. For routes that will only be used a few times a year, verbose information could actually interfere with the ability to comprehend the necessary information.

c) *About the Use of Absolute Direction (Cardinal Directions)*: with district maps, absolute (cardinal) directions are used as necessary to explain an area, but with route maps(Connection Guide), directions are based on relative bearings (forward/backward, left/right). This is because the use of absolute directions in an area with which the user is not fully familiar could result in expressions that are more difficult to understand.

d) *Proper Nouns*: for proper nouns such as place names, names that are not well-known may sound odd to the user, so it must be identified the type of Chinese character by reading in Japanese.

e) *Preferred Expression Based on the Device*

*Systems*: a route is made from a combination of paths, and one path is basically considered to be an area from one turn until the next turn. However, in order to allow for the sharing of data with other routes, an area may be divided at a certain point even if no turn is made, such as at a T-junction. In such cases, statements like "keep going" could be confusing to the visually impaired, so a clear indication of direction will be given, such as "go straight". Attempts will also be made to avoid expressions for other node names that can change due to order relation, such as "the start/end of \*\*\*".

f) *Addition of Backup (Secondary) Instructions*: depending on the environmental conditions of an area, it may be better for the user to stop while listening to the instructions, to listen while walking, or to proceed slowly. Such instructions will be added to the system. In places with numerous fixed obstacles, instructions for avoiding the obstacles will be added. Information will also be added as necessary to make it possible to determine if the user has gone too far and then help the user get back to the designated route.

g) *Unification of Style*: in order to avoid confusion resulting from the use of a variety of expressions by an unspecified number of people creating auditory maps, guidance statements should, as much as possible, follow specified formulas, and styles should be unified. In particular, expressions related to movement, and expressions related to orientation, such as direction and distance, will be selected from a list of concise expressions such as those shown below (see Yokoyama and Nomura(1999)).

- 1) "Go along \*\*\*", "Go up (down) \*\*\*", "Walk \*\*\* meters", "Go as far as \*\*\*", "Walk along the right (left) side"
- 2) "Cross \*\*\*", "Go over (pass through) \*\*\*"
- 3) "Leave \*\*\*", "Go out into \*\*\*", "Go into \*\*\*", "Stop at \*\*\*"
- 4) "Turn right (left) at \*\*\*", "Face the right (left) side"
- 5) "Search for \*\*\*", "Find \*\*\*"

#### 4.2. Individual Items Related to Auditory Map Creation

For the location information for each type of reference element, the necessary types of information must be selected from the following list and descriptions provided.

a. *Attribute Information* (Information such as physical shape, etc., that will help the user anticipate what he or she will find.)

b. *Clues* (Information that is useful for finding the reference element.)

c. *Added Information* (Information at the point of use that can be provided to the visually impaired user.)

d. *Danger Information* (Information used to

avoid dangers.)

We surmise that descriptions of various types of reference elements will be included in the corresponding information, with point elements (PE) described in node information, linear elements (LE) described in path information, and surface elements (SE) described in node information or in path information, depending on the context (See Appendix).

#### 5. Conclusions

In this paper, we proposed specifics for a postulate auditory maps input and output system. According to the information types we postulate to be used in auditory maps within our system, our auditory map consists of "nodes", "paths" and "connections". These information types are comprised of "reference elements", "orientation" and "movement" items. As results from our demonstrations in real sites, reference elements were found to be subdivided into "point", "linear" and "surface" elements, with 23 instances of these reference points listed. Reference elements information was further subdivided if necessary into "attribute information", "clue information", "added information" and "danger information". We finally propose the auditory map systems with reference elements of 23 instances that complement orientation and mobility items (including 5 categories of 15 expressions).

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## Appendix : Descriptions of Various Types of Reference Elements

### Exits and Entrances (PE)

Attribute Information  
 •width of \*\*meters  
 •Indicate if present or not – car stop, fence, threshold, gate, door, gate door  
 •Indicate if automatic or not – door  
 Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 •Indicate if present or not – changes in surface finish  
 Added Information  
 •Indicate if present or not – interphone  
 •Indicate if present or not – Braille information board or tactile map  
 Danger Information  
 •Indicate if present or not – change in level  
 •direction of the boundary of a roadway and method for detecting the boundary

### Reception (PE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Added Information  
 •Indicate if present or not – Braille information board or tactile map

### Passage (LE)

Attribute Information  
 •Indoor or outdoor?  
 •width of \*\*meters  
 •Indicate if present or not – slope, direction of slope  
 Clues  
 •Indicate if present or not – changes in surface finish  
 •Indicate if present or not – hand rail  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Clues and Danger Information

•Indicate if present or not and connected or not – curb, guardrail, fence, shrubbery, drainage ditch, side ditch, melted snow drainage ditch, arcade, etc.  
 •Indicate if a lid (manhole cover) is present or not and lid status – drainage ditch, side ditch, catch basin, etc.  
 •Indicate if protrusions are present or not – electric pole, vending machine, street light, mailbox, roadside tree, fire hydrant, garbage bin, street sign, advertising sign

Danger Information  
 •Indicate if present or not – change in level  
 •Indicate if ordinarily present or not – parked automobiles and bicycles  
 •direction of the boundary of and method for detecting the boundary

### Stairs (LE)

Attribute Information  
 •width of \*\*meters  
 •shape (stairway type: straight, curved, and circular)  
 •number of steps  
 •Indicate if present or not – midway landing  
 Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired at the beginning and the end

•Indicate if present or not – changes in surface finish  
 •Indicate if present or not and connected or not – side walls and side panels  
 •Indicate if present or not – hand rail  
 Added Information  
 •Indicate if present or not – Braille markings on handrails indicating the direction of a destination, etc.

Danger Information  
 •Indicate whether or not a slope is steep  
 •Indicate if present or not – slip stoppers, nosing protrusions, open riser stair (Will a cane or foot catch on these items?)  
 •Is there sufficient height below the stairway (to avoid hitting the head)?

### Ramps (LE)

Attribute Information  
 •width of \*\*meters  
 •Indicate if present or not – bends and curves  
 •Indicate if present or not – midway landing  
 Clues

•Indicate if present or not – tactile guide blocks (points) for the visually impaired at the beginning and the end  
 •Indicate if present or not – changes in surface finish  
 •Indicate if present or not – hand rail  
 •Indicate if present or not and connected or not – side walls and side panels  
 Added Information  
 •Indicate if present or not – Braille markings on handrails indicating the direction of a destination, etc.  
 Danger Information  
 •Indicate whether or not a slope is steep  
 •Is there sufficient height below the ramp (to avoid hitting the head)?

### Escalator (PE)

Attribute Information  
 •Going up or down?  
 Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired at the beginning and the end

### Elevator (PE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Added Information  
 •Indicate if present or not – voice announcements of the floors  
 •Indicate if present or not – Braille information board or tactile map

### Toilets (PE)

Attribute Information  
 •direction of entrance to men's and women's restrooms  
 Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Added Information

•Indicate if present or not – Braille information board or tactile map

### Public Telephones (PE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Danger Information

•Indicate if protrusions are present or not

### Information Boards (PE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Added Information  
 •Indicate if present or not – Braille information board or tactile map  
 Danger Information

### Information Bureaus, Booking Offices (PE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Added Information  
 •Indicate if present or not – Braille information board or tactile map

### Ticket Gates (PE)

Attribute Information  
 •width of \*\*meters  
 •Is the ticket gate an automatic ticket gate?  
 Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired

### Ticket Vending Machines, Ticket Windows (PE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 Added Information  
 •Indicate if present or not – Braille information board or tactile map

### Concourses, Waiting Areas, Halls, Lobbies, etc. (SE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 •Indicate if present or not – changes in surface finish  
 Danger Information  
 •Are there protrusions – benches,

drinking fountains, etc.?  
 •Indicate if present or not – change in level

### Pedestrian Plazas, Station Plazas (SE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 •Indicate if present or not – changes in pavement  
 Added Information  
 •Indicate if present or not – Braille information board or tactile map  
 Danger Information  
 •Are there protrusions – benches, drinking fountains, etc.?  
 •Indicate if present or not – change in level

•Indicate if present or not – changes in level between the plaza and rotaries, roads, facilities  
 •Indicate if ordinarily present or not – parked automobiles and bicycles  
 •direction of the boundary of a roadway and method for detecting the boundary

### Roads, Road Shoulders, Sidewalks (LE)

Attribute Information  
 •width of \*\*meters  
 •Indicate if present or not – slope, direction of slope  
 •Indicate if present or not – bike paths  
 •traffic regulations (direction of a one-way street, etc.)  
 Clues

•Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 •Indicate if present or not – changes in pavement  
 Clues and Danger Information

•Indicate if present or not and connected or not – curb, guardrail, fence, shrubbery, drainage ditch, side ditch, melted snow drainage ditch, arcade, etc.  
 •Indicate if a lid (manhole cover) is present or not and lid status – drainage ditch, side ditch, catch basin, etc.

•Indicate if protrusions are present or not – electric pole, vending machine, street light, mailbox, roadside tree, fire hydrant, garbage bin, street sign, advertising sign  
 Danger Information

•Indicate if present or not – change in level  
 •Is the roadway to the left or right of the current position? Method of detecting the direction  
 •Indicate if present or not – change in level between the current position and facilities along the road or path  
 •traffic volume  
 •Indicate if ordinarily present or not – parked automobiles and bicycles

### Crosswalks, Intersections (SE)

Attribute Information  
 •width of \*\*meters  
 •shape (differences between crossroads, T-junctions, 5-way intersections, etc., Have intersection corners been cut-off?)  
 •distance (meters) to other side, direction to other side  
 •Indicate if present or not – sidewalk on other side of the road  
 •Indicate if present or not – slope (drainage slope), direction of slope  
 •Indicate if present or not – medial strips  
 •Indicate if present or not – traffic signals

•Indicate if present or not – bike path  
 •traffic regulations (one-way or two-way street, present or not – cars turning left, cars turning right, etc.)  
 Clues

•Indicate if present or not – tactile guide blocks (points) for the visually impaired at the beginning and the end  
 •Indicate if present or not – change in level between road and sidewalk, location of curb (between road and sidewalk, between sidewalk and roadside, etc.)  
 •necessity for squaring crossing

•method of determining if the traffic signal is green  
 •position of automobile stopping line (for a red light)

Added Information  
 •Indicate if present or not – control box for auditory traffic signals  
 Danger Information  
 •traffic volume

### Points of Intersection with Branch Roads (Side Roads), Vehicle Entrances (Driveways) to Parking Lots, etc. (SE)

Attribute Information  
 •width of \*\*meters  
 •Indicate if present or not – curb ramp, corner cut; direction of these items  
 Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 •Indicate if present or not – changes in level, curbs, smoothing  
 •Indicate if present or not – changes in pavement  
 Danger Information  
 •Is the roadway to the left or right of the current position? Method of detecting the direction  
 •traffic volume

### Bridges (LE)

(Information other than information necessary for roads, road shoulders, and sidewalks)  
 Clues and Danger Information  
 •Indicate if present or not and connected or not – curbs, railings, sidewalks

### Subterranean Passages (LE)

(Information other than information necessary for roads, road shoulders, and sidewalks)  
 Danger Information  
 •Is there sufficient height (to avoid hitting the head)?

### Grade Separation Facilities for Pedestrian and Viaduct (LE)

(Information other than information necessary for stairs, elevators, escalators, bridges, and subterranean passages)

Attribute Information  
 •Indicate if present or not – stairs, elevators, escalators  
 Added Information  
 •Indicate if present or not – Braille information board or tactile map  
 Danger Information

•Is the roadway to the left or right of the current position? Method of detecting the direction  
 •traffic volume

### Railroad Crossings (SE)

Attribute Information  
 •width of \*\*meters  
 •Indicate if present or not – crossing gates, alarms  
 •walkway width of \*\*meters  
 •distance (meters) to other side, direction to other side  
 •Indicate if present or not – slope, direction of slope  
 Clues

•Indicate if present or not – tactile guide blocks (points) for the visually impaired at the beginning and the end  
 •Indicate if present or not – changes in pavement  
 Danger Information

•Is the roadway to the left or right of the current position? Method of detecting the direction  
 •Indicate if present or not – changes in level, slopes

### Bus Stops, Taxi Ranks (PE)

Clues  
 •Indicate if present or not – tactile guide blocks (points) for the visually impaired  
 •Indicate if present or not – poles  
 Added Information  
 •Indicate if present or not – Braille information board or tactile map  
 Danger Information

•Are there protrusions – benches, information boards, etc.?  
 •Indicate if present or not – change in level  
 •Is the roadway to the left or right of the current position? Method of detecting the direction