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The SOLID model of accessibility and its use by the public transport operators

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Abstract. Public transport could be the only transport means for some people, in particular those with disabilities. Accessibility of public transports is thus essential to enable everyone to participate in the society, for example by accessing to employment, healthcare and leisure activities. Legislative framework and regulations ensure minimum accessibility standards, but are not always enough to ensure effective accessibility. In this paper, the SOLID model of accessibility and its main components are presented. This model has been developed through public consultations and experiments with people with visual impairment, and then refined through experiments with other populations and discussions with public transport companies. Then the paper presents examples of usage of the model for improvements in public transports in and out of the disability context. This illustrates how the model is a useful tool to identify accessibility issues and propose solutions in different domains such as architecture, vehicle design, traveller information or smartphone application. The paper also demonstrates how research on disability is relevant to work on the general human condition.

Keywords: Accessibility, Passenger information, Public transport, Disabled passengers

1 Introduction

Mobility, defined as the ability to move within community environments that expand from home [1] is an essential requirement to participate in society, i.e. access to employment, education, healthcare and social and leisure activities. Public transports can be the only transport means at a distance from home for some people, especially for those who cannot or no longer drive, for example people with impairments [2, 3]. A lack of access to a reliable transport means lead to isolation and social participation restrictions [3].

According to social models of disability, for example the International Classification of Functioning, Disability and Health (ICF) by the WHO [4], or the Disability Creation Process (DCP) of Fougeyrollas and colleagues [5], disability results of the restriction of participation in activities due to the interaction of environmental barriers and personal difficulties. Thus, if public transports are not adapted, the mobility of people with

physical or sensorial impairments may be hindered, but also that of those with more temporary difficulties, such as people with bulky luggage, pregnant women, or people with young children, including strollers [6]. However, mobility and therefore social participation can be facilitated for all, when environment is optimized, for example when access to public transports is barrier-free.

In France, the law on accessibility introduced on the 11th of February 2005 aiming to achieve accessibility for all in 2015 lead to improvements in several areas, such as education, employment, built environment, transportation, and internet. However, its implementation has been insufficient, so much so that a revised timeframe has been put into place. Indeed, despite the immediate needs of users with impairments, accessibility can take a long time to implement, especially in the context of transport infrastructures (tracks, stations, stations), whose renewal rate is around 50 years. A distinction must therefore be made between improvements that can be made quickly and at low cost (particularly on vehicles), modifications made as part of renovation, and accessibility application as part of the implementation of new transports. Furthermore, although legislative framework and regulations ensure minimum accessibility standards, it is necessary to go further, and think about an effective accessibility, which meets the real needs of individuals.

Nonetheless, it is not only the physical accessibility of the vehicle that guarantees access to public transports, but the accessibility of the entire chain of mobility (Fig. 1), from the planning of the journey to the exit of the vehicle, including the management of disturbed and emergency situations [7]. A journey using public transport is a succession of phases in different environments, where the users are either walking, in a stationary infrastructure or immobile (or almost) in a moving vehicle. Each of these phases is accompanied by different levels of physical, perceptual and mental effort [7], which also varied according the abilities and impairments of the users. For example, by using the think aloud method with participants with visual impairments in journeys including the use of public transport, we found that it was in multimodal hubs poles that the participants expressed the most difficulties [8, 9]. In addition, stress was more expressed in the three following situations: large spaces, crossings (road or tram track) and stairs [8, 9].

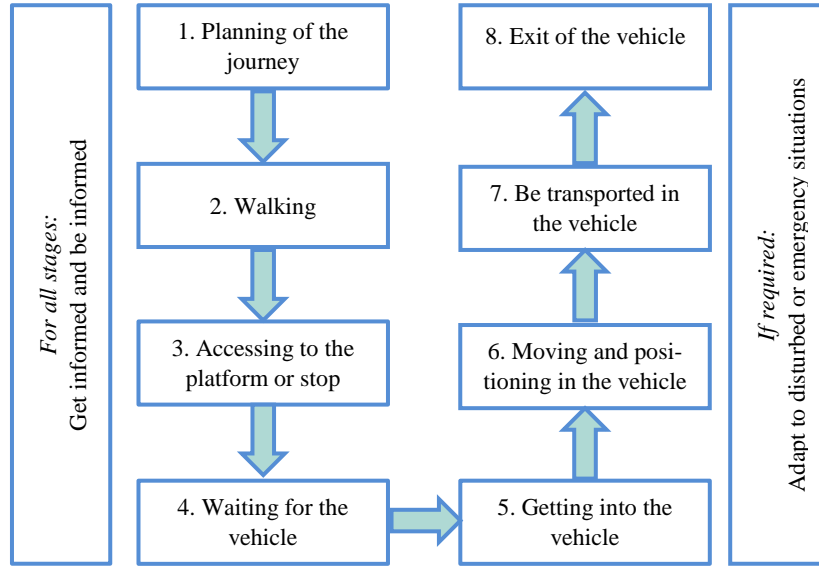


Fig. 1. Stages of the mobility chain of the public transport users

Ensuring effective accessibility for all users of public transport and enabling them to reach their destination safely requires considering the physical aspects, but also providing them with the information necessary for their orientation, at all stages of the mobility chain. These different elements will be developed in the following section, which describes a model of accessibility called SOLID, with a focus on public transport and data transport.

2 The SOLID model

SOLID is an accessibility model, which describes the representations of transport users in the entire chain of mobility. SOLID is an acronym for five elements ensuring an optimal accessibility of transport systems: Safety, Orientation, Localization, Information, Displacements. This model describes the travel purposes, the travel zones, the user needs and information nature. This model has been developed through public consultations and experiments with people with visual impairments, aiming at developing solutions to improve public transport accessibility [7, 10]. Then the model has been refined through experiments with other populations and discussions with public transport companies. This model lets the analysis of problems and solutions or validates the accessibility of system by decomposing all the phases involved in the mobility chain including a public transport system [11].

2.1 Travel purpose

Depending on the cause of the trip, there are four categories of pedestrian travel purpose: 1) physical activity, such as walking or running, 2) social relations with others,

such as going for a walk while talking, 3) getting to know the environment (for example, a new neighbourhood, touring), and 4) reaching a goal, a person, or an object.

The travail purpose has an effect on the experience. For example, taking the stairs to reach a train that is close to departure may be stressful, while taking the stairs for physical activity may be motivating.

During the same travel, these different purposes can be associated, they can also be priority or secondary. In the context of public transport use, the last purpose is prioritized, although the others should not be neglected.

2.2 Travel zones

The traditional division of the travel environment from transport companies view includes 3 zones: the ticket validation zone, the platform zone and the zone of transportation.

The SOLID model proposes another division of the travel environment, in 4 zones. The first one is the **open zone**, which is multifunctional: not all pedestrians who come here will take public transport, and there are commercial, cultural and residential activities. Even if it is not dedicated to transportation, vehicles (bus, streetcar, scooter, etc.) can be found there. This open zone is traditionally non-considered by transport companies. The second zone is the **access zone**, where the main activity of the people in this zone is to go to the transfer zone (which will be described next) or to return from it. The access zone is equivalent of the ticket validation zone of companies. The third zone is the **transfer zone**, which consists of the platform (or curb, for buses) and the vehicle entry/exit platform. This is where the vehicle docks and departs and where passengers are transferred to and from the vehicle. It is a time pressure zone where safety can be engaged. Finally, the **zone of transportation** is the interior of the vehicle, with the exception of the vehicle entry/exit platform, where the user is moved while remaining immobile. In the traditional division of transport companies, the vehicle entry/exit platform is included in the zone of transportation.

2.3 User needs: Safety, Orientation, Localization, Information and Displacements

The acronym of the model refers to the different need of transport users. Firstly, the main responsibility of the transport systems is to ensure the **safety** and the security of the users at all phases of the journey, and in all circumstances.

The safety of transport users may be hindered in multiple ways, especially if they have disabilities. The main several kinds of risks are strokes, collisions between users, falls, and theft or assault. In the case of visual impairments, falls can be caused by perceptual alteration, attentional saturation due to an excessive amount of information to be processed, or the absence of information concerning an empty space (for example stairs or an unclosed trap doors). The presence of posts, poles, and protruding elements at the head level increases the risk of strokes. Poor flow guidance can lead to collisions between different users, and some ambiances related to architecture favour the risk or the feeling of risk of theft or assault. For someone with balance disorders, sudden starts

and stops of vehicles can be a source of falls, especially if the person has not had time or space to sit down.

Transport systems, infrastructures and human-machine interfaces should be designed to alleviate all these kinds of risks. In addition, in case of dysfunction, incident, or accident, special safety procedures should be adapted to all types of impairments.

The transport users have to maintain a correct **orientation** during the journey. It requires having indications of the direction to be taken at each journey portion. These indications can be stored in memory (mental image of a map or an itinerary) or timely provided by infrastructures and human-machine interfaces. Standard signs or display panels are usual for indicating directions, but standard signs may not be used by all the users (for example people who are visually impaired, foreigners or illiterates). In addition, maintaining a straight path can be difficult for blind people, and understanding abstract written information (e.g., acronyms) or pictograms and navigating space and time can be difficult for some people with intellectual impairments [12, 13].

Furthermore, in case of modification of the initial itinerary (disruption, works, detours), the users must be able to find an alternative route, which can be challenging if the information needed is not provided in an appropriate format.

The transport users need to know at any time their **localization** in relation to required points of interest, such as entrances and exits, ticket barriers, bus stop, station or platform. They also need to know the relative position between secondary points of interest, for example ticket offices, information displays, maps, stairs, escalators, lifts, toilets, and commercial installations. Systems that confirm to the users that they reached strategic points or intermediate milestones help visually impaired users locate themselves, and reassure users with anxiety.

Throughout the travel chain, users must be able to access the **information** necessary for their orientation and location, and for directing them to points of interest. This information can be obtained through active research by the users, for example to verify their position or other travel information, particularly crucial in the case of visual impairments or anxiety. Information can also be broadcast to users (they are informed). In order to be perceived and understood by all types of users, the information could be disseminated with different sensory channels. In addition, visual information (written language and pictograms) must be disseminated in adequate formats, in terms of font, contrast, size, luminosity, and auditory information must be audible through the background noise and adequate in terms of structures and delivery speed.

Information about the presence of alternative routes, allowing the use of an escalator or elevator, will also facilitate the journey of users with walking difficulties. The information provided can also be enriched with train destinations, arrival times and disruptions or delays, as well as commercial or tourist information, useful for all types of users.

A journey involving public transportation use involves different types of **displacements**. There are pedestrian phases, phases in which users are immobile (or almost) in a moving vehicle, lift or escalator, and transitions between these phases, such as entering and go through the station, finding the correct platform and entering the vehicle and leaving it, without forgetting the procedures to follow in case of an emergency. Generally, pedestrian phases require the greatest physical effort, while transition phases

require the greatest perceptual and cognitive effort. However, this depends of the characteristics of the users and their difficulties; for example, in a wheelchair, it can be physically difficult to get in and out of a vehicle (a transition phase) when the horizontal and vertical gaps are high.

2.4 Information nature

In the context of public transport, three types of information can be characterized, when classified according to their periodicity. **Event-based information** is short-lived, and informs about a specific event (arrival of a vehicle, traffic interruption) whose relevance for the transport user disappears after the event is over. The duration of this type of information is less than the daily cycle. **Contextual information** is temporary information that lasts for a certain period of time (e.g., maintenance), whereas **structural information** is asynchronous or planned (e.g., programmed schedules).

3 The SOLID model, a tool for implementation of accessibility in public transports

In France, public transport is organized by a multitude of stakeholders: authorities in charge are different according the areas concerned (national transport, regional transport, suburban transport and urban transport), and each public transport authority uses (private or public) operators [8]. In addition, urban infrastructures such as roadways, sidewalks, sidewalk sign are on the responsibility of regions or conurbations.

Hence accessibility of the mobility chain relies on a variety of stakeholders, and they do not share a common guideline, that leads to a lack of continuity and coherence between the different places travelled during a journey, in terms of physical architectures, information provided, ways to buy a ticket and their interoperability in the case of a multimodal journey, line characterizations and so on. This phenomenon is illustrated by the Fig. 2, which presents maps of three different transport networks (urban, suburban bus and suburban train), all focusing on the central railway Perrache station, in Lyon, France.

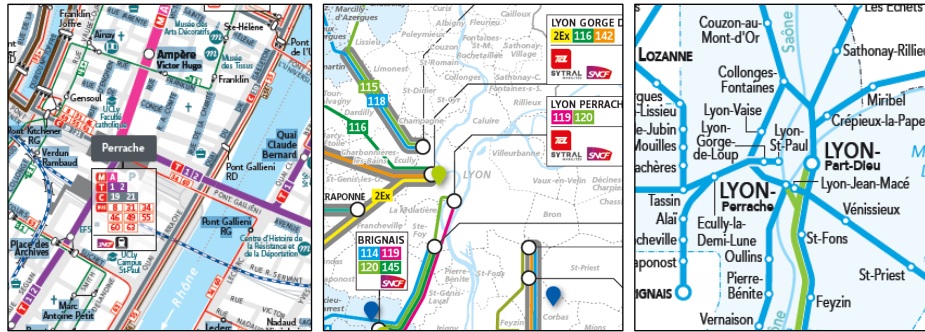


Fig. 2. Maps caption from urban, suburban bus and suburban train networks focusing in the Perrache station (Lyon, France).

The SOLID model was used in consultations/confrontations involving the first author of the present paper in the various departments of the transport operators of the Ile de France region, or in Lyon. These consultations took for example the form of Q&A sessions, organized by the department of disabled passengers with each of the services (two sessions per service). Some concrete application issues were then studied in depth in the framework of working groups, for example for the layout of a station with the architects' department or for the improvement of the lexicon and grammar of traveller messages with the information systems department. About 20 projects were conducted, for example AUTOMOVILLE, RAMPE, DANAM, Guide Urbain, INFOMOVILLE, SIV1, SIV2, Atlas Sonore, Besoin d'Humain, Ma Lanterne, and IMAGE [10, 14–18]. These different projects were the subject of partnership agreements with operators with confidentiality clauses that do not allow us to reveal all the details or to publish. Two examples of application of the SOLID model will be described in the following sub-sections.

3.1 Grammar and lexicon of traveller information

Within the framework of the working group on the grammar and lexicon of traveller information, the SOLID model has allowed an optimization of the messages broadcasted in case of traffic disruptions on the metro lines [19].

Initially, traveller information was built on the basis of maintenance and traffic management messages. The messages were not homogeneous, since they partly depended on the line managers, but the cause of the disruption always came first, the line number always came late, and action to be taken for users (when there was one) always came last.

An underlying element of the SOLID model is that transport users can become contributors to traffic regulation. Indeed, if transport users have the right information, they can implement the most optimal strategy for themselves, e.g. decide to wait or to look for an alternative route, depending on their own constraints (safety, travel time). The working groups thus led to a homogenization of the lexicon used, and of the proposed order, by presenting, and in this order: 1) the line concerned, 2) the type of disruption (e.g.: interruption or slowdown), 3) the section concerned (e.g.: between two stations), 4) the approximate duration of the disruption, and, possibly, 5) its cause.

With this new homogenized grammar, users do not have to wait for the end of the message to know if they are concerned, and the message gives them all the information they need to decide for themselves what action to take.

3.2 Personalized route calculation

Both policy makers and transport operators want an accessibility label for legal reasons. They would like to show that they are consulting (and they are), and they are looking for a proof of result of their accessibility actions. With the development of journey planners, disabled travellers and their representatives prefer personalized accessibility in which the calculation takes account of their disability. The SOLID model was used in a project of an application for guidance of people with all types of impairments in a

complex train station (Paris Gare de Lyon, France; *Ma Lanterne* project [16]). In this project, a weighting matrix that considers the nature of the layout and the nature of the disability was developed for personalized route calculation inside the station. This project has shown the relevance of this personalized approach, and at the same time has been one of the supports for the development of the NeTEx (Network Timetable Exchange) database of the Transmodel standard [20]. The NeTEx database support information exchange of public transports data such as network, timetable and fare information (including multimodal fares) for passenger information and Automated Vehicle Monitoring Systems. The database collects and integrates data from different transport operators, and reintegrates it as it evolves through successive updates, and data considers the accessibility.

The example of the staircase will allow us to illustrate because it links different SOLID elements: the construction of the NeTEx standards database, the concerns of route calculation and the issues between the political-administrative transport authorities and the public transport management companies on the one hand, and the disabled travellers and their representatives on the other. A staircase is a blocking element for wheelchair users and an element of hardship for people with walking difficulties, with a cane, or people with cardiac or respiratory difficulties.

In the case of a person with two crutches, the difficulty is not the same when going up or down the stairs. Stairs are therefore vectored. The difficulty in going up (a hardship factor in the Displacement section of the SOLID model) becomes the risk of falling and colliding with other travellers in the descent (i.e. the Safety section of the model).

In the case of a person with two crutches on the stairs, the existence of a handrail to assist the ascent and to secure oneself on the descent is a design component that improves the accessibility of the stairs. This handrail must therefore appear in the NeTEx descriptor base. The SOLID model is therefore a contributor to the database.

The presence of this handrail is important not only because it reduces both the effort to climb the stairs (hardship) and the risk of falling when descending, but also because it makes it possible to define a weighting gradient in an itinerary calculation that takes the disability into account. Thus, the precision of the calculation can integrate a time requirement (train at departure for example) which is found in the fourth travel purpose (reaching an object).

We should specify that in our example, the hardship is physical, but in other situations, this hardship can be cognitive (in particular for people with cognitive or sensory difficulties) or of communication (for example for the deaf people)

4 Conclusion and future directions

The SOLID Model was initially created based on the issues faced by blind people in public transports. It was then generalized to other sensory impairments, then to cognitive impairments, then to all impairments, then tourists and finally to all transport users. While ensuring the accessibility of the mobility chain provides comfort for all, it is crucial for people with impairments. Indeed, travellers with impairments can avoid the non-adapted or uncomfortable environments by lengthening their journey by taking a

longer alternative route, or even by giving up going somewhere. The present paper illustrates how a conceptual model of accessibility, the SOLID model, can be used by operators to identify accessibility issues in the mobility chain. However, the model does not define how to ensure this accessibility. The elaboration of specifications based on the SOLID model, developed in consultation with transport operators, users and researchers, would allow the implementation of concrete, coherent and common solutions for the accessibility of public transport.

The SOLID model can help to achieve a minimum level of comprehension of the real needs of different types of users for other transport means and in other contexts. For example, although autonomous vehicles are often presented as a solution for those who cannot drive, our recent literature review on non-rail autonomous public transport vehicles shown that few studies investigated needs, expectations and concerns of people with impairments toward autonomous vehicles [10]. Moreover, lack of awareness of disabled situations of from municipalities stakeholders' authorities and employees is one of the barriers to the implementation accessibility measures in municipalities identified in a recent scoping review [21].

Finally, this paper illustrates how research can be used by stakeholders to improve transport accessibility and comfort, and how interaction with transport stakeholders can refine research models. It also shows how research on disability is relevant to work on the general human condition.

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