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EVALUATING ACCESSIBILITY TO UNDERGROUND TRANSPORT SYSTEMS: ANALYSIS OF THE SANTIAGO - CHILE METRO

EVALUACIÓN DE LA ACCESIBILIDAD PARA SISTEMAS DE TRANSPORTE SUBTERRÁNEO: ANÁLISIS DEL METRO DE SANTIAGO - CHILE

AVALIAÇÃO DE ACESSIBILIDADE PARA SISTEMAS DE TRANSPORTE SUBTERRÂNEO: ANÁLISE DO METRÔ DE SANTIAGO DO CHILE

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RESUMEN

Considerando que una parte importante de la población mundial vive con algún tipo de discapacidad y que la esperanza de vida aumenta, el hecho de tener un transporte accesible permitiría que las personas mejoraran su calidad de vida, accediendo a más oportunidades socioeconómicas. A partir de un diseño descriptivo mixto (cualitativo etnográfico y cuantitativo), este artículo presenta una herramienta de evaluación del nivel de accesibilidad en el uso del tren subterráneo para personas con discapacidad visual, física, cognitiva y auditiva. Se analizaron los datos de 30 estaciones del Metro de Santiago de Chile, estudiando el desplazamiento desde el exterior a la estación, la permanencia en zona de pagos y el desplazamiento hacia andenes y combinaciones. De los indicadores evaluados, los que tienen relación con el desplazamiento hacia el andén son los que presentan menores niveles de accesibilidad, ya que no responden a todas las necesidades para los distintos tipos de discapacidad analizados.

Palabras clave
discapacidad sensorial, discapacidad física, discapacidad cognitiva, metro, accesibilidad

ABSTRACT

Considering that a significant part of the world's population lives with some disability and life expectancy is increasing, accessible transportation would allow people to improve their quality of life and access more socioeconomic opportunities. Based on a mixed descriptive design (qualitative, ethnographic, and quantitative), this article presents a tool for evaluating the level of accessibility to subway trains for people with visual, physical, cognitive, and hearing disabilities. Data from 30 Metro stations in Santiago de Chile were analyzed, studying movements into the station, permanence in the payment area, and movements toward platforms and connecting lines. Among the indicators evaluated, those related to getting to the platform have the lowest levels of accessibility, as they do not meet all the needs of the different types of disabilities analyzed.

Keywords
sensory impairment, physical disability, intellectual disability, subway, accessibility

RESUMO

Considerando que uma parte significativa da população mundial vive com algum tipo de deficiência e que a expectativa de vida está aumentando, dispor de um transporte acessível permitiria que as pessoas melhorassem sua qualidade de vida, tendo acesso a mais oportunidades socioeconômicas. Com base em um projeto descritivo misto (qualitativo, etnográfico e quantitativo), este artigo apresenta uma ferramenta de avaliação do nível de acessibilidade no uso do metrô para pessoas com deficiências visuais, físicas, cognitivas e auditivas. Foram analisados dados de 30 estações de metrô de Santiago do Chile, estudando o deslocamento do exterior ao interior da estação, o tempo de permanência na área de pagamento e o deslocamento para as plataformas e combinações. Dos indicadores avaliados, os relacionados ao deslocamento até a plataforma são os que apresentam os níveis mais baixos de acessibilidade, pois não atendem a todas as necessidades dos diferentes tipos de deficiência analisados.

Palavras-chave:
deficiência sensorial, deficiência física, deficiência cognitiva, metrô, acessibilidade.

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INTRODUCTION

According to World Health Organization (WHO) data, 16% of the world's population has a disability (World Health Organization, 2023). Of this figure, about 85 million people are in Latin America. In 2022, the over-60s in the region represented 13.4%, and projections indicate that this number could increase to 25.1% in 2050 (ECLAC, 2022). The relationship between both statistics is relevant because the prevalence of disability increases with age.

This also affects urban development and, more specifically, transport, as older people with difficulties getting around and people with disabilities (hereinafter, PWD) often only have access to public transportation to get around, or this is their preferred option. It is for this reason that it becomes essential to evaluate both the needs of the population regarding infrastructure in each country and the importance of the spatial position between public infrastructure and housing, as this leads to the development of PWD's socio-economic opportunities (Lima et al., 2019; Sze & Christensen, 2017).

There are different studies on the phenomenon of accessibility in urban areas. Some analyze accessibility to a place, as well as the effective way to help people get to their destination (Jiron & Mancilla, 2013); others have studied satisfaction with travel (Lättman et al., 2019; Grisé et al., 2019; Wong, 2018); or with the different forms of transport (Wong et al., 2017; Bascom & Christensen, 2017).

On the other hand, the topic of study of this work is the research of Srichuae et al. (2016), who investigate the factors that affect the mobility of older people, such as the distribution of public spaces with accessible transport services and the ability to travel unassisted, highlighting the need to include universal design principles. Cochran (2020) analyzes the experiences of PWD when using transportation, pointing out that there needs to be more analysis of travel behavior as it represents one of the barriers to using transportation. Sze and Christensen (2017) review accessible transport design guidelines in the EU, UK, and Hong Kong that could affect travel behavior, activity patterns, and choice of transport for PWD, emphasizing that accessible design should be implemented in a more integrated transport network approach.

In Chile, different authors (Jirón & Mancilla, 2013; Vecchio et al., 2020) have addressed diverse research approaches to understand social exclusion from urban everyday mobility. Within these is the study of accessibility, which includes the physical-spatial conditions or how barriers can be understood from their spatiality as those limitations that subjects encounter daily in their movements through the city.

Concerning accessibility and mobility, the work of Kaufmann et al. (2004) redefines accessibility as a structuring dimension of social life, far from simply being a connection between points. "Motility," which encompasses socio-spatial mobility, is an asset that varies between individuals, groups, and institutions in access, competition, and appropriation. This approach highlights the complexity of relationships between social and territorial structures, connecting accessibility with the ability to access and appropriate goods, information, and people in different local and geopolitical contexts.

In this way, accessibility, within the framework of motility, becomes a critical component for understanding the dynamics of highly mobile societies. In the case of Cass et al. (2005), it is emphasized that the notion of accessibility is complex and goes beyond describing the exclusion of social groups from specific services, as it focuses on spatial awareness and is related to the mobility of citizens. By linking the interconnected society with the dispersion of everyday life, the author identifies the growing "mobility burden" in society. In addition, the importance of considering the spatial and temporal dimensions of transport provision and the connection with social networks that people want to be a part of is underlined, highlighting the dynamics and importance of networks in social inclusion.

Continuing with the search for accessibility analysis, Lucas et al. (2016) propose using the ethical theories of egalitarianism and sufficiency as a theoretical framework to evaluate Spatial Accessibility Indices, highlighting the need to identify indicators and thresholds in collaboration with the parties involved, especially with people that have fallen further behind concerning this index.

In another aspect, the subway train or metro is an essential means of transport for urban mobility, and, therefore, it is necessary to review their accessibility. Most publications focus on reviewing and analyzing their characteristics based on an individual's ability to cover the distance between origin and destination (Bascom & Christensen, 2017), where the travel time (Márquez et al.,

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2019; Park et al., 2022; Wong, 2018), waiting time (Vandenbulcke et al., 2009) or walkable distances (Yun, 2019), are analyzed. Although Prasertsubpakij and Nitivattananon (2012) propose a 24-indicator evaluation method for the Bangkok metro, the study focuses on interviews that evaluate the satisfaction of a broad group of users. However, it does not include sensory or cognitive disability. Thus, the need for an exhaustive analysis of the place and the components that allow comparable access and use for people with diverse abilities is evidenced (Shen et al., 2023; WHO, 2023).

According to the WHO, disability exists when there is no adequate relationship between the environment and a person's functional abilities, and, therefore, there is a limitation in activities or restrictions to social participation (World Health Organization, 2023). Therefore, built environment barriers will cause PWD to experience reduced functional capacity. This group faces more barriers when traveling due to physical, sensory, and cognitive limitations, resulting in fewer trips, shorter routes, and longer travel times (Shen et al., 2023). Because of this, in America, more than 33% of the PWD choose not to travel (Brumbaugh, 2018). Considering that the PWD travel primarily for medical reasons (Krahn et al., 2015) and that the population is aging, it is necessary to reduce these barriers in infrastructure and transport so that a PWD can move freely and independently to any public or private space.

Thus, by focusing on spatial and physical barriers in transportation, a universal design that everyone can use to the greatest extent possible without needing any adaptation or specialized design is expected (Iwarsson & Stahl, 2003). For this, universal design is based on seven principles: equitable use, flexibility of use, simple and intuitive use, perceptible information, tolerance to error, low physical effort, and size and space of approach and use (Iwarsson & Stahl, 2003). To apply these principles, a universal design, unlike an accessible design that seeks to design only for the specific group with disabilities and thus generates exclusion (ISO, 2001), must integrate accessibility and usability features from the beginning, eliminating all preconceived ideas and embracing the social inclusion of the largest possible number of users, regardless of their condition.

Given the above, this article presents an assessment tool for the level of accessibility in the use of a subway for visual, physical, cognitive, and auditory PWD. This tool analyzed the data collected from 30 Santiago de Chile Metro System (SMS) stations, studying the displacement from the outside to the metro line, the time in the payment area, and the displacement to the platform.

METHODOLOGY

This study has a mixed qualitative-quantitative approach. From the point of view of its design, it is a sequential descriptive approach (Hernández Sampieri et al., 1997), with an initial qualitative ethnographic phase (Hammersley & Atkinson, 2007) that explores the accessibility needs in the Santiago de Chile Metro System for PWD, and a second quantitative phase that consists of determining an assessment system to report about the level of accessibility in the metro stations.

In the ethnographic phase, the consent of PWD using the Santiago de Chile Metro System was obtained to collect data through field participant observations, informal conversations, and semi-structured interviews (from people in wheelchairs, older people with displacement problems, blind people, and caregivers of older person with cognitive issues). This process was carried out over 64.5 hours between August and September 2021, where different stations of several lines of the Santiago de Chile Metro System were visited to obtain a broad and representative perspective. Audiovisual recordings of the stations were taken, and relevant architectural elements were measured, making tours with PWD. The data collected were systematized using tables of qualitative and quantitative indicators.

An ethnographic approach based on the compressed model proposed by Jeffrey and Troman (2004) was followed to ensure the naturalness of the observed behaviors. The data analysis at this stage was based on the Grounded Theory principles (Glaser & Strauss, 1967), which allowed organizing and analyzing information rigorously through coding techniques to generate interrelated categories and subcategories. The triangulation of the information obtained involved comparing data from several sources, reviewing information from other researchers, and contrasting the researchers' observations, which determined the validity of the information collected.

In the quantitative stage, an assessment methodology was designed based on the systematic literature review and previous qualitative findings. Evaluation indicators were identified (mainly focused on the spatial physical barriers), and parameters

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were assigned to determine the level of accessibility. To validate the methodology, the stations of Line 5 of the Santiago metro system were analyzed, considering the following characteristics:

- This is one of the three oldest lines in the system, so there are unresolved accessibility criteria.
- It is the system's longest line and has the highest number of stations (30 stations).
- The line runs through the most communes (10) with different socioeconomic strata.
- It has three types of construction systems: elevated, street level, and underground stations,
- It has the largest number of combinations with other lines and intermodal stations.
- It travels through strategic points, such as universities, clinics and hospitals, public spaces, and historical and commercial centers.

CASE STUDY

The Santiago public transport system incorporates all the public transport buses of the capital, Metro-Tren Nos (surface train line), and the Santiago de Chile Metro System. The latter is the axis of the system, one of the city's most important means of public transport. The Santiago de Chile metro system began to be structured during the 1960s and currently has six lines covering 142.4 km (Figure 1). In November 2017, when Line 6 began operating, an average of more than 85,000 people were transported per hour (Santiago Metro, 2020).

Figure 1. Spatial and descriptive configuration with data on length, number of stations, number of communes served, % of the overall public using the Santiago de Chile Metro System lines, and location of the analyzed stations. Source: Preparation by the authors.

Since 2012, Metro S.A., the company that runs the metro system, has enacted an accessibility plan to adapt to current requirements. One of its objectives was to provide elevators to all the network's stations, completed in 2019 (Metro de Santiago, 2020). In addition, the remodeling included activating configurable two-way doors in stations, preferential spaces in cars for people in wheelchairs, communication devices between passengers and drivers, LED maps to indicate upcoming stations, and cameras inside the trains. This plan will allow PWD circulating on the network to have greater accessibility from their entry to the station until their exit.

RESULTS AND DISCUSSION

REVISION OF BARRIERS AND NEEDS

The PWD accompanied on their different routes through the Santiago Metro had the following types of disabilities:

1. visual, understood as those deficiencies, limitations, and restrictions that a person with an ocular disease faces when interacting with their physical, social, or attitudinal environment (Espinosa-Muñoz, 2016; Alarcón & Vizcarra, 2016; Shen et al., 2023);
2. physical, people who, for different reasons, have difficulty moving, either temporarily or permanently (Saéz-González, 2020; Olivares-Medina et al., 2019; Shen et al., 2023);
3. cognitive, which involves limitations of intellectual functioning, as well as adaptive behavior in the conceptual, social, and practical domains (Brusilovsky, 2014; CEAPAT, 2018); and
4. auditory, people who, when interacting with the environment, face barriers that prevent their access to auditory-oral information and communication given by the language (Espínola-Jiménez, 2015; Agudelo-Zapata & Cadavid-Ospina, 2016).

The barriers and needs encountered were described through a literature review and experiential tours where the interviewees reported on their assessments. They were later categorized according to the type of disability (Table 1). Some of these assessments served as the basis for creating the evaluation indicators.

Table 1. Disabilities – Barriers. Source: Preparation by the authors.

Visual Disability	Physical Disability	Cognitive Disability	Auditory Disability
Lack of tactile guides	Lack of escalators or not operational.	Lack of contrast on the elevator buttons.	Lack of visual information inside trains regarding the location and upcoming stations
Lack of tactile warning at the beginning and end of stairs and platform	Height and diameter difference in handrails	User support people with no training in disability	Lack of information through screens in elevators
Horizontal difference between the car and the platform	Lack of a preferential window.	Lack of suitable information for cognitive PWD when faults occur in the subway.	Lack of lighting information on some trains when there are service outages or station closures.
Lack of auditory information in elevators.	Lack of configurable two-way doors	Poorly located signs, with little or no lighting.	Lack of timely information on platforms due to failures in information monitors.
Lack of adequate lighting at some points.	Height of elevator buttons out of reach for People in Wheelchairs (PiW)	Information mural with incomprehensible symbology for cognitive PWD	Lack of information on trains about the status of elevators at certain stations
Lack of tactile guide at the entrance, ticket office, elevators, and stairs.	Height of information murals not accessible for PiW	Confusing digital information (Metro line- weather and advertising) - some turned off.	
Lack of tactile guide at the entrance, ticket office, elevators, and stairs.	Vertical difference between the car and platform.		
Lack of vending or rail-card charging machines with Braille or audio system	Platform seats at inappropriate height.		
	Ramps with steep slopes		

DEFINITION OF INDICATORS

For a greater understanding of the journey from the user's perspective, the areas a journey comprises were separated. These areas will be called "Travel Moments" and will be defined as:

- Moment 1: ENTRANCE-E: This includes all the spaces from the exterior entrance and main accesses to the ticket office area, which are the access by fixed stairs, escalators, or elevators, including their connections with the different areas they comprise, either the vending and rail-card charging machines area, ticket office windows, connection with the turnstile and elevators that go to the platform, among others.

- Moment 2: TOWARDS PLATFORM-P: This includes the route from the turnstile to the platform area. It includes internal stairs, escalators, elevators, and the platform itself.

- Moment 3: COMBINATION-C: This involves all the parameters detected from when a user leaves the train to the combination to another line or intermodal station. This parameter only applies to stations with a combination with other lines or a connection with some intermodal station.

To analyze the level of accessibility of each of the travel moments, different indicators related mainly to spatial physical barriers were evaluated, which together gave a score. The scores of each indicator were averaged according to the station's configuration, and based on the final score obtained, the level of accessibility was provided. The scale to evaluate the criteria is VG (very good), 2 points; G (good), 1 point; B (bad), 0 points.

Table 2 below details the number of indicators found and the ideal maximum scores for each travel moment. Then, Table 3 presents each of the indicators associated with moments E, P, or C, as appropriate, with their respective evaluation scale and associated scores.

Table 2. Number of indicators and ideal scores associated with the moments. Source: Preparation by the authors.

Moments	Number of indicators	Ideal Score
Entrance (E)	24	48
Platform (P)	9	18
Combination (C)	15	30

Table 3. Evaluation indicators. Source: Preparation by the authors.

Moment	Indicator	Evaluation scale		
		Very Good (2p)	Good (1p)	Bad (0p)
E	Main access screen	There is information on the status of the metro	This is information, but it is not updated	Does not exist
E/P/C	Staircase handrails	It has two handrails. One at 90 cm from the FFL and the second at 60 cm from the FFL. And a diameter between 3.5 to 5.0 cm (Figure 2a)	It has one handrail at a height of 90 cm from the FFL and a diameter of 3.5 to 5.0 cm.	There are handrails, but they have a height and diameter different from those established. (Figure 2b)
E/P/C	Escalators	They are two-way	They are one-way	Does not exist
E/P	Elevator and stairlift	There are, and they both work	There is one or one that does not work	Non-existent, or neither of them work
E/P	Tactile warning	Color contrast at the beginning and end of all stairs and access to cars (platform limit)	Color contrast in some accesses to cars and stairs	Does not exist
E/P	Flight of stairs	Sections of 15 steps separated by a break of at least 120 cm	Sections between 16 to 18 steps separated by a break	Flights of more than 18 steps without a break
E/P	Stair tread and riser	Tread 28 cm and riser 18 cm	Tread less than 28 cm or riser more than 18 cm	Tread less than 28 cm and riser more than 18 cm
E	Tactile guide connection at entrance	There is a connection between stairs, ticket office, and turnstile. (Figure 3a)	There is a partial connection between stairs, ticket office, and turnstile.	Non-existent (Figure 3b)
E	Tactile guide connection to the elevator that leads to the outside	Elevators, ticket office, turnstile, and preferential door access are fully connected.	A partial connection exists between elevators, ticket office, turnstile, and preferential door access.	Does not exist
E	Ticket office window	Preferential with suitable height for PWD	Preferential without suitable height for PWD	Does not exist
E	Recharging/consultation/ purchase machines	There are. Suitable height between 90-120 cm from the FFL	There are. Without a suitable height between 90-120 cm from the FFL	Non-existent
E	Recharging/consultation/ purchase machines at the ticket office	They have a voice and Braille navigation system.	They have a voice or Braille navigation system.	There is no navigation system.
E	Entrance door for wheelchairs and pushchairs to the platform	Configurable two-way door.	Manual door	Non-existent or help must be asked to use it

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Moment	Indicator	Evaluation scale		
		Very Good (2p)	Good (1p)	Bad (0p)
E	Elevator	The size allows a wheelchair to enter, turn around, and leave (150 cm in diameter). Alternatively, it allows entry and exit in the direction of travel.	110 by 140 cm in size, only allows a wheelchair to enter (forwards)	Is not big enough for a wheelchair or does not work
E	Elevator door	Minimum width: 90 cm. Automatic and sliding opening.	Minimum width: 90 cm. Manual and folding opening.	It does not have an elevator, or it does not work.
E/C	Elevator buttons	Located at a height between 90-120 cm from the FFL (horizontal preference)	Some are located at a height of more than 120 cm from the FFL	Located more than 120 cm from the FFL, they do not work, or there is not one
E	Elevator Command buttons with embossed Braille system	All have them. Suitable height.	Some have them. Or unsuitable height	Without Braille system
E/C	Audio and screen in the elevator to announce the level	Both working	There is one or just one works	Non-existent or damaged
E	Elevator ramp access	There is side protection on the entire slope when it is > 150 cm in length.	There is side protection on only part of the slope when it is < 150 cm in length.	There is one without side protection.
E	Elevator exit space	Allows maneuvering (diameter 150 cm)	Allows maneuvering with difficulty (diameter < 150 cm)	Non-existent or with obstacles
E	Security camera and call button in the elevator	Both working	There is one or just one works	Non-existent or damaged
E	Sound and light signal in the elevator to notify doors are closing	Both working	There is one or just one works	Non-existent or damaged
E	Tactile guide elevator entrance and exit	There is tactile warning and color contrast.	There is only yellow color contrast	Does not exist
E/P	Location information (exits, combination, emergency exits, information murals, location of elevators)	Has good lighting, suitable height, and without obstacles	Has some obstacles that prevent seeing it	Does not have good lighting or suitable height and has obstacles
P/C	Route	There are no gaps in the route	There are gaps but with protection	There is no protection for the gaps
P	Platform tactile guide	There is one, and it is connected with a vertical exit element (Figure 4a)	There is one but without a connection	Does not exist (Figure 4b)
P	Preferential waiting area	Close to elevators and stairs	Away from elevators or stairs	Does not exist
P	Tactile warning /color contrast at the end of the platform	Both	Only a yellow stripe, no tactile tread	Non-existent
P	Platform seats	All at 46 cm from the FFL	Some less than 46 cm from the FFL	Non-existent, or some are more than 48 cm from the FFL
P	Digital information element on the status of stations, metro, and train lines.	Electronic screens and televisions.	Only televisions	Non-existent, they cannot be read, or they do not work.

Moment	Indicator	Evaluation scale		
		Very Good (2p)	Good (1p)	Bad (0p)
P/C	Informative plans (platform) Line change information (combination)	They have good lighting, no obstacles, and are suitable to be seen by PiW.	They do not have good lighting, have obstacles, or are at a height that does not allow them to be seen by PiW.	Does not exist
P	Vertical and horizontal differences between platform and train	Does not exist	Minimum difference	There are many differences. The PWD needs help to get in/out.
C	Tactile guide connection between elevators connecting two lines	It is continuous	it is interrupted	Does not exist
C	Tactile guide connection between stairs connecting two lines	It is continuous	Only at the beginning or end of the stairs	Does not exist

Here are some excellent examples of the indicators (a) and others that need attention (b):

Figure 2a. Example of a staircase with double handrails on its edges. Source: Preparation by the authors

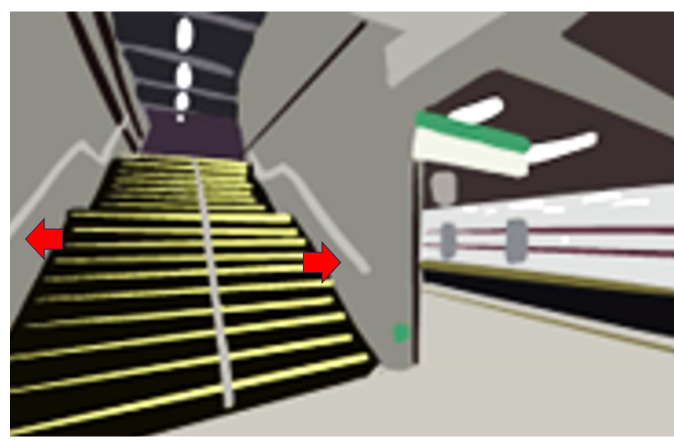

Figure 2b. Example of a staircase with a single handrail (at the edges and center). Source: Preparation by the authors

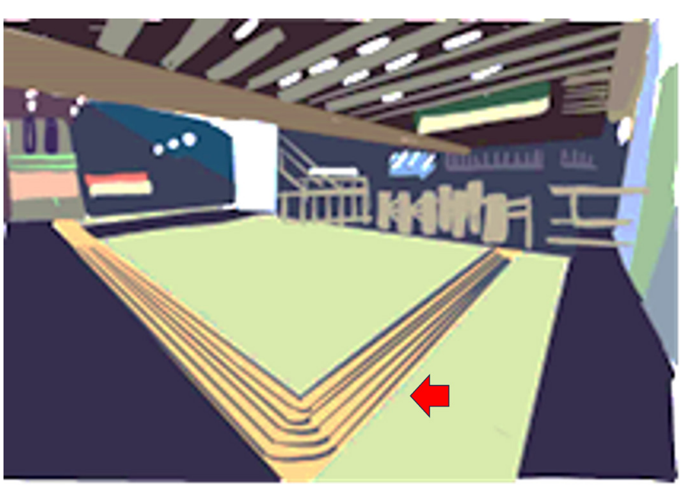

Figure 3a. Example of a complete connection of the tactile tread between the ticket office and the access to the turnstiles. Source: Preparation by the authors

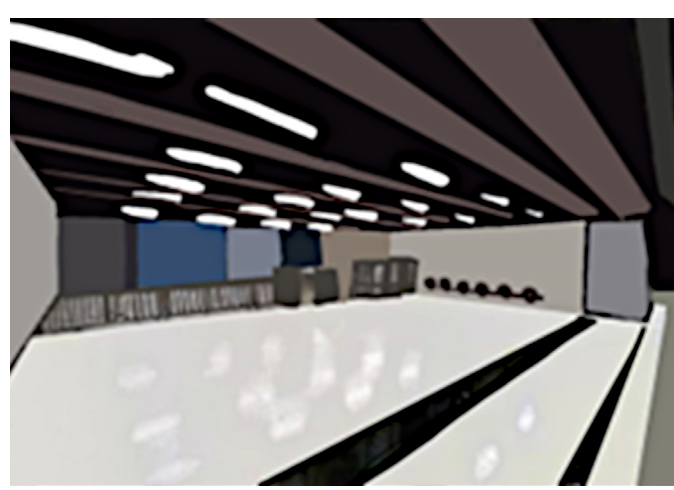

Figure 3b. The entrance to a station has no tread, only colors on the pavement. Source: Preparation by the authors

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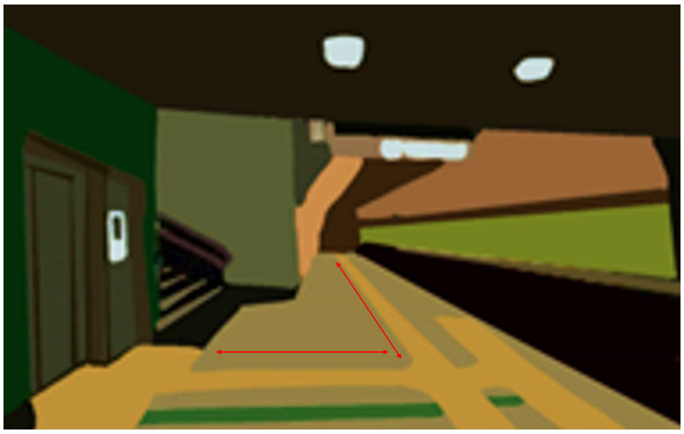

Figure 4a. Tactile tread on the platform that connects throughout its route with a vertical exit element (elevator).
Source: Preparation by the authors

Figure 4b. The platform has no tactile tread (only a yellow stripe that warns of its edge).
Source: Preparation by the authors

It is important to note that, due to the characteristics and constructive systems in each station, not all the indicators are necessarily applied, so not all of them could obtain the maximum scores indicated by travel moment (Table 3). For this reason, the percentage compliance at each travel moment was calculated. The sum of all the moments gives the total score per station. The division of the total score obtained versus the total possible score gives the percentage compliance with the accessibility levels defined in Table 4.

Table 4. Levels of accessibility. Source: Preparation by the authors.

% compliance	Levels of accessibility
80% - 100%	Very Well Adapted
60% - 79%	Well Adapted
40% - 59%	Partially Adapted
20% - 39%	Poorly Adapted
< 20%	Very Poorly Adapted

The application of the methodology is shown through the results of 5 stations selected for their special systems and configurations:

Underground Station (Bellas Artes)
Elevated station with two levels (San Joaquin)
Elevated station with 5 levels (Mount Tabor)
Combination station with another line (Ñuble)
Combination station with an intermodal station (Bellavista de La Florida).

EVALUATION OF THE STATIONS

Of the five stations evaluated, the Bellavista de la Florida station (underground, intermodal connection and access to shopping center, identified with letter E in Figure 1) was the one that obtained the lowest percentage as a station (52%), at the entrance (56%) and combination (39%). The low evaluation is due, among other aspects, to the fact that the main entrance does not have elevators, escalators, or access ramps. Thus, the only way that PWD can access or leave the station is by requiring the help of guards or companions. Also, the combination with the namesake intermodal does not have a good connection and accessibility. One of the problems detected regarding communication for intermodal access that mainly affects people with cognitive disabilities is the use of information panels with contradictory information (Figure 5). On the other hand, a problem identified affecting people with visual impairments is the lack of a tactile tread at the beginning and end of stairs (Figure 6).

Figure 5. Contradictory information on the intermodal connection route panels (where two different directions are observed).
Source: Preparation by the authors

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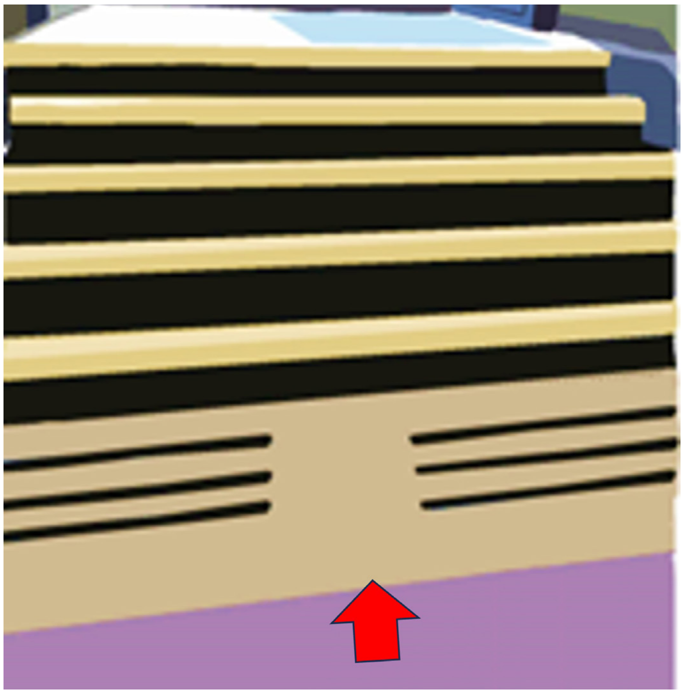

Figure 6. Lack of a tactile tread on the access to stairs that are only identified with a yellow stripe.
Source: Preparation by the authors

On the contrary, the Ñuble station (station with street level entrance, elevated platform, and combination with another line, marked with the letter C in Figure 1) is the one that obtained the highest percentage (69%). This is mainly due to its connection with Line 6 (inaugurated in 2017), whose design implied improved accessibility issues. Its ENTRY and COMBINATION criteria obtained high scores (71% and 78%, respectively). However, the platform area had a low rating due to the lack of tactile tread and its connections with the stairs, which affected its overall evaluation. This station is the only one on Line 5 with automatic access at its main entrance and machines adapted for all users.

Meanwhile, the San Joaquin station (station area with access to universities and medical centers, marked with the letter D in Figure 1) reached 57%. Like most stations, its lowest score is presented in PLATFORM (53%), mainly due to its lack of tactile tread and connection with the elevator and stairs. The station has only one elevator that is not always operational, which forces PWD to request help from guards or companions or even to go to the next station to access or exit the metro system.

The next station evaluated, which is Bellas Artes (underground station, access to the historic center of the city, marked with the letter B in Figure 1), does not have a tactile tread on the main access that connects to the ticket office or along the platform, which makes it difficult for visually impaired people to move around. In addition, the seats are well above the required 45 cm high. Nor does it have escalators or stairlifts if the elevators do not work. That is why its overall accessibility level (58%) is affected by the PLATFORM indicators (50%).

Finally, the Monte Tabor station (elevated station, shopping center access, identified with the letter A in Figure 1) has its lowest score in PLATFORM (57%), again due to the lack of a tactile tread, including its connections with elevators and stairs. Even so, it received a good score in ENTRANCE (69%) for having two-way escalators.

Table 5 summarizes the results of the application of the evaluation in each of the moments a journey comprises in the Santiago Metro, analyzing Entrance (E), Platform (A), and Combination (C).

Table 5. Results of the evaluated stations. Source: Preparation by the authors.

Station	E	P	C	Average	Level station
Bellavista de La Florida (letter E - Figure 1)	27/48 56%	18/30 60%	7/18 39%	52%	Partially Adapted
San Joaquín (letter D - Figure 1)	28/46 61%	16/30 53%		57%	Partially Adapted
Ñuble (letter C - Figure 1)	10/14 71%	17/30 57%	14/18 78%	69%	Well Adapted
Bellas Artes (letter B - Figure 1)	32/48 67%	15/30 50%		58%	Partially Adapted
Monte Tabor (letter A - Figure 1)	29/42 69%	17/30 57%		63%	Well Adapted

CONCLUSION

Based on the different problems PWD have when using public transport, it was possible to raise a series of indicators, mainly related to spatial physical barriers, which allowed the creation of a tool for assessing the level of accessibility in the Santiago de Chile Metro network. It was concluded from its application in some representative stations that most old stations obtained the lowest scores in the "PLATFORM" criterion but good results in the "ENTRANCE" criterion, mainly due to recent elevator installations in those stations.

Although Metro de Santiago S.A. has indeed made improvements on the issue of accessibility, these have focused on physical disability and, therefore, are still insufficient in incorporating the needs of other disabilities. This situation allows making the recommendation that the next adaptation and remodeling works should focus on those criteria with the lowest scores obtained by the stations to improve their level of accessibility. In addition, to expand the vision of accessibility in public transport, evaluating other spaces, such as intermodal connections or the space surrounding a Metro station, would be interesting.

On the other hand, as the work focused on analyzing spatial physical barriers, it was easier to assess the needs of people with physical or visual disabilities onsite. Although an attempt to incorporate indicators for people with hearing or cognitive disabilities, in the next version of the methodology, more sensory aspects could be analyzed in the analysis.

Finally, it is important to mention that, given the relevance of accessibility issues, regulatory changes that are being updated should be continuously considered (such as SD30, which was modified after conducting this study). The contribution of this proposal is that it is evolutionary and includes, eliminates, or updates the indicators presented here.

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