Effects of the Built Environment on Pedestrian Accessibility in Neighbourhoods in Southern Chile. The case of Temuco, Chile

A Zumelzu¹, M Estrada¹, C Jara², C Peña²

¹Instituto de Arquitectura y Urbanismo, Universidad Austral de Chile
²Escuela de Arquitectura, Universidad Austral de Chile

Email: antonio.zumelzu@uach.cl

Abstract. The aim of this article is to evaluate the effects of the built environment on pedestrian accessibility in two neighborhoods in the area of Alemania Avenue, in the city of Temuco, Chile. The methodology integrates three evaluation methods: the method Morpho to explore the morphological conditions that influence walkability; The method developed by Emily Talen to measure walking distance to local services and facilities; and People Following method from Space Syntax theory to evaluate which spatial factors influence the choice of routes and to explore the distance that people walk between their points of interests. Results show that the choice of routes that people take to reach a destination is not defined by the shortest route, but rather by the spatial quality of streets and street frontages. The study suggests that elements such as blind walls, the absence of green spaces and the decrease in the size of sidewalks on streets affects negatively in the choice of routes, and consequently pedestrian accessibility. The article concludes with recommendations for urban planning neighborhoods towards a more sustainable future.

1. Introduction

In various intermediate cities in southern Chile, small-scale connections within urban mobility networks have lost importance. This situation has generated an increase in the need for greater transfers and excessive dependence on the car, generating environments that promote higher traffic, poor walking environments, pollution, and the loss of the quality of public space [11] [21]. Local governments have dedicated a large number of resources to the production of infrastructure for motorized mobility means under the old paradigm of modernity and progress, many times they segregate more than they connect, without considering pedestrians as the main axis of urban development [18]. This generates that the inhabitants do not have full access to the various networks that make up the city. Although in Chile there are initiatives to collect information about the territory at the governmental level [30], these are still isolated and do not generate methodological protocols to develop more in-depth studies and even less databases of the specificities required to assess the conditions of pedestrianization of the built environment. For this, it is necessary to advance in the development of new tools and methodologies that require support towards urban planning and design of neighborhoods with greater pedestrian orientation, as a crucial axis to direct the positive transformation of these cities towards a more sustainable future.

The objective of this article is to evaluate the effects of the built environment on pedestrian accessibility in two neighborhoods in transformation in the Alemania Avenue sector in the
intermediate city of Temuco, Chile. Monteverde and Llaima neighborhoods are evaluated in this research. The article is structured in three parts. First, a critical review about the concepts of accessibility and its relationship with sustainability is carried out. Subsequently, an empirical analysis is made integrating three methods: The Morpho method [33] to explore the morphological conditions that influence passability. The method developed by Emily Talen is used to assess pedestrian access within the neighborhoods [38] this defines the walking distance to local shops and services.; and the People Following method by the Space Syntax theory [20] [40] to evaluate the relationship between a movement path and another within the system and the distance a person walks between their points of interest and their route choice.

Finally, we propose recommendations to guide the urban design of neighborhoods towards a more sustainable path according to the results.

2. Accessibility and sustainability in the built environment: A critical review

Accessibility is one of the most important and long-standing sustainable dimensions of theories of "good" urban form [24] [29] [36]. In relation to sustainability, the concept of accessibility has been deeply explored in the scientific literature and its studies have been diverse. Studies focus on approaches to the degree to which environments are compatible with the needs of pedestrians and cyclists as a concern about the effects generated by the built environment on people's physical activity and health [5] [27] its relationship with the principles of intelligent growth and active living environments through the pedestrian distance to basic needs [15] [3] its relationship with the effects on the environment through the reduction of the carbon footprint and energy costs in displacement [9] [8] its relationship with social equity issues [37] [10] and its relationship with the effects on social and collective capital in neighborhoods [28] [23] [26].

As concerns about urban sustainability increase in the future, it is recognized that walking is the most important mode of urban transport and that it generates multiple benefits in a community. Besides, walking is a free activity and its benefits at the neighbourhood level are associated not only with the scope of equity and the increase of social capital at the community level but also with personal well-being related to the longevity of good mental and physical health [4] [6]. In this sense, walkable access to services and equipment is an essential part of urban sustainability, in which the quality of the built environment and its morphological elements play a fundamental role.

2.1. Built environment components that influence on pedestrian accessibility

In scientific literature, there is a wide discussion about the effects of the built environment on pedestrian accessibility. For example, several studies have mentioned the importance of smaller blocks based on their apparent benefits for pedestrian movement [35] [13] [12]. Jane Jacobs was one of the first to mention that most blocks should be short; “that is to say, the streets and the opportunities to turn corners must be frequent” [24], since this would allow more encounters and greater interactions between people. Similarly, Whyte [41] mentions the importance of specific design parameters of street facades in promoting greater pedestrian accessibility. He points out that a walkable street has a healthy relationship between private or semi-public life within buildings and the outside public world, arguing that “dead” uses, such as businesses without display cabinets, banks, offices, parking lots and storage areas or warehouses with empty walls should not be placed along a public street. On the other hand, uses such as restaurants can help improve the pedestrian life of a street. Another considerable element is the placement of the kitchen windows, as well as other construction elements, which encourage sitting and can improve the social life of the street and make it more accessible. Jan Gehl [17], on the other hand, mentions the importance of the ground floors of buildings in contributing to creating urban environments that improve walking activity. In his book Cities for People, Gehl mentions the importance of mixed uses at the building level, and presents the problems of urban design related to walking, such as acceptable walking distance, providing public spaces freely and without obstacles, avoiding stairs, sidewalks, lines of straight vision, and interesting things to see at eye level [17].
However, in recent years the evidence shows that these conditions are not necessarily better. For instance, Sevtsuk et al. [34] show that block lengths have a non-linear relationship with accessibility, in which shorter blocks are not better for pedestrian traffic, but include other conditions such as the presence of trees in the street, wide sidewalks, mayor porosity on street fronts, street fronts with parking lots, blind walls, or fronts with glass facades, and if there is sufficient connectivity between the streets and a low volume of traffic. This has been reaffirmed by other research that has identified the infrastructure of public space over block sizes [39] [1]. In the literature, there is a common agreement that indicators of a "good" operation suggest that blocks between 60-70 meters are pedestrian optimal, 100 meters well-gearied are very convenient for pedestrians, while 200 meters or more are very inconvenient to promote pedestrian mobility. Distance is a fundamental factor in relation to what a person is willing to walk to a point of interest [31] [33] [44].

Regarding the evaluation of pedestrian accessibility, there are many measurable characteristics that facilitate its empirical evaluation. Various measures have expanded significantly in the last decade, in response to interest in connecting urban neighborhood design with travel behaviors and physical health outcomes [14] [19] [32]. For example, a commonly accepted rule in the literature is that a neighborhood can be considered pedestrian accessible if commercial services and stores, and all that one needs for daily life, are within 400 to 800 meters of their homes [3] [16] [42]. Besides, there is general agreement in the literature about the maximum time that a person is willing to walk to a service or commerce at the neighborhood level - which on average - is 10 minutes. Talen [37] [38] suggests that the average walking speed is 1.4 m/sec, which is classified as “an easy and healthy walk around the neighborhood”, 5 minutes of walking cover 400 meters and 10 minutes of walking cover 800 meters. A 30-minute walk, or 2.4 km, is considered a "reasonable upper limit" to define the maximum distance that people are willing to walk, and therefore the maximum size of a walkable neighborhood. These metrics are based on average walkable speeds determined from travel surveys [7] [22].

3. Materials and methods

3.1. Study area

Two neighborhoods located in the sector of Avenida Alemania, to the west in the city of Temuco, are explored in this investigation. The cases correspond to Monteverde and Llaima neighborhoods (Figure 1).

Llaima neighborhood emerged in 1968 as a fifteen-hectare neighborhood, for a low and medium-sized social class. Its general structure distinguished by typologies of semi-detached, collective, and block housing, grouping a total of 376 homes. A civic center that groups a community green area, an elementary school, a church, and local commerce facilities in a mixed area with collective housing is structured as a central nucleus. A large part of the semi-detached houses of the complex was expanded by modifying the original urban grain, to give rise to the appearance of cabins - second rental housing - for students due to the presence of the Universidad Autónoma de Chile in the sector. The structure of the unit is recognizable by the order and clarity of the application of the design principles of the Clarence Perry Neighborhood Unit [43].
Monteverde neighbourhood is located along San Martín Avenue between Javiera Carrera Street and Andes Street. It was built during the 1960s through the CORVI program. Monteverde has a high residential occupation, consisting entirely of a semi-detached house with one floor, with modular blocks that are ordered both north-south and east-west. It has two interior public squares, a neighbourhood headquarters, a kindergarten, and a commercial centre located on one of the squares with green areas.

3.2. Methods

The methodology integrates three methods to assess the effects of the built environment on pedestrian accessibility. First, the Morpho method, elaborated by Oliveira [33] is used to analyze the scalar patterns of the environment and its influence on passability. The method defines the application of two morphological criteria:

3.2.1. Dimensions of street blocks frontages. Block size assessment involves the division of blocks into groups, defined by the GIS (Geographic Information System) tool of "natural breaks", according to the width of the block facades.

3.2.2. Plot size dimension. For this study, the total area of the plot is calculated through the GIS tool (Geographic Information System).

To assess pedestrian accessibility, two methods are used. First, the method developed by Emily Talen [38] to measure the walking distance to local commerce and services. This method consists of measuring the number of residential plots within a radius of 400 meters close to services, equipment, and commerce, divided by the area of extension. An average walkable speed of 1.4 meters per second is used, classified as an average walk around a neighborhood [38]. The GIS platform is used to calculate the average walking distance.

Second, the method of People Following by the theory of Space Syntax [40] is used to evaluate two aspects: evaluate which environmental factors influence the choice of a movement path, and the distance a person walks between their points of interest and their route choice. By tracking people, the average distance a person walks between their points of interest and their route choice is measured. For route tracking, a radius of 400 meters is defined. During fieldwork, about 25-50 people are followed for a representative sample.

4. Analysis of results

The results of the morphological analysis are illustrated in the maps of Figure 2 and Figure 3; together with Tables 1 and 2. The results show that blocks in Llaima neighborhood have a greater diversity of sizes and length of street façade. Both Llaima and Monteverde have an average façade length ranging between 82 m and 65 m, mostly blocks well connected and very convenient to promote pedestrian activity (Table 2). However, the grouping of shops and services varies. For instance, in Llaima...
neighborhood, non-residential uses such as services, schools, and businesses are grouped around its central square. While Monteverde is generated in a central square and along San Martín and Andes Streets, in blocks that have an average facade length of 63 meters.

Regarding the size of the lot, Llaima owns 73% of buildings adapted to new non-residential uses. With type plots of 9.5 m front with 19 m deep, type blocks are generated that are sorted in both directions, always maintaining the width of two houses, but varying their length with more or fewer homes per side. This has generated the emergence of local economies, which have changed the building use of housing without transforming the original typology, maintaining the readability and scale of the neighbourhood

| Neighborhood          | Maximum (m) | Minimum (m) | Mean (m) |
|-----------------------|-------------|-------------|----------|
| Monteverde (21 blocks)| 149.01      | 8.43        | 67.8     |
| Llaima (21 blocks)    | 523.20      | 20          | 82.5     |

Table 1. Calculation of average dimensions of street block frontages in Monteverde and Llaima neighborhoods.

| Neighborhood       | Number of plots | Plot size average (m²) | Built proportion (%) | Number of buildings per plot |
|--------------------|------------------|------------------------|----------------------|-----------------------------|
| Monteverde (21 blocks) | 363              | 283                    | 25                   | 1.9                         |
| Llaima (21 blocks)   | 327              | 1257                   | 47                   | 1.2                         |

Table 2. Comparative table of average plot size of Monteverde and Llaima neighborhoods.

Figure 2. Average values of street block frontage dimensions and plot sizes in Llaima neighborhood.
Figure 3. Average values of street block frontage dimensions and plot sizes in Monteverde neighborhood.

Table 3 and Figure 4 show the maximum values reached for accessibility, through the measurement of the number of residential plots within a radius of 400 meters close to trade and services. There is a high value of accessibility in the Monteverde neighbourhood since it has a higher density of housing compared to Llaima.

Table 3. Accessibility and walking distances values in neighborhoods. Source: authors.

| Criteria                              | Neighbors          | Llaima                     | Monteverde                |
|---------------------------------------|--------------------|----------------------------|----------------------------|
| Node of activity/centrality           |                    | Llaima Square              | Monteverde square          |
|                                       |                    | (Av. San Martin)           |
| Number of residential plots           |                    | 920                        | 1210                       |
| (number of residential plots within   |                    |                            |                            |
| 400 m. tract of services and facilities) |                    |                            |                            |
| Pedestrian accessibility              |                    | 0,34                       | 0,45                       |
| (mean count of residential plots      |                    |                            |                            |
| close to facilities)                  |                    |                            |                            |
| Quality of built environment          |                    | Good                       | Poor                       |
| Infrastructure of amenities           |                    |                            |                            |
| Public spaces                         |                    | Good                       | Good to Poor               |
| Green areas                           |                    | Very good                  | Good                       |
| Walking Access to local amenities     |                    |                            |                            |
| (min.)                                |                    |                            |                            |
| Llaima square                         |                    |                            |                            |
| Green prackets/ community places      |                    | 7,8                        | good                       |
| Local shop                            |                    | 5,5                        | very good                  |
| Primary school                        |                    | 7,6                        | good                       |
| Church                                |                    | 7,5                        | good                       |
| Monteverde square                     |                    |                            |                            |
| Fire station                          |                    | 8,9                        | good                       |
| Corner shop                           |                    | 9,4                        | good                       |
| Green prackets/                       |                    |                            |                            |
| 9,2                                   |                    | good                       |

Target distances (m.)

300 - 400 m walk
In relation to movement routes, the analysis of *People Following* shows that in Llaima neighbourhood the pattern of movement flow is distributed heterogeneously within the neighbourhood. This pattern is due to two reasons. First, the preference of people thanks to the diversity of uses offered within the neighbourhood. There is a greater supply of essential stores, such as greengrocer's shops, grocery stores, and bakeries within a maximum of ten minutes on foot. The highest intensity of occupation is mainly concentrated in the main square where pedestrian activity predominates over the vehicular. The diversity of services within the neighbourhood and the high mixture of uses become two important elements that generate movement attraction since people not only go to make basic purchases but also it increases in social interactions abroad.

| Community places | Bakery | 9.4 | Good |
|------------------|--------|-----|------|
| Community centre | 9.5    |     | Good |

*Figure 4.* Residential plots within 400 meters of a node of services and facilities. Source: authors.

With respect to the choice of routes, the analysis shows disparate results between the two selected neighbourhoods. In places where there is a high density of housing per block, a person prefers to take a walkable journey of 10 minutes and not one of 5 minutes to make basic purchases such as groceries.
or fruits. In Monteverde neighbourhood, the expansive growth of housing gives the high density of housing. This is due to the increase in rental housing, through the expansion of housing towards the sides and the entrance garden for the same use (residential) due to the effect generated by the universities of the sector. This generates the appearance of blind walls and loss of the urban profile of the street in some interior streets, which affects the pedestrian accessibility of the neighborhood. The above, because it increases the insecurity of these routes, mainly in the corners where the most visible spaces occur.

Pedestrian accessibility decreases in areas of higher housing density, especially in blocks in interior streets of the Monteverde neighborhood, which have a low presence of green areas, low quality of sidewalks, street fronts and absence of entrance garden. Per the People Following analysis, people prefer to walk through safer places to go shopping, this associated with spaces with higher spatial quality. Therefore, an effect is generated in the public space associated with the low pedestrian load and that explains the factor of choice of a path, which is not associated with the shortest distance between its points of interest (Figure 5A y 5B).

![Figure 5A. Movement pattern and choice of routes within Llaima neighborhood.](image-url)
5. Discussion
The analysis has shown that the pattern of pedestrian movement is different between neighbourhoods. While the pattern of movement in Llaima neighbourhood is more heterogeneous and with better spatial distribution, given by the diversity of services, grouping them in a central square and the size of the apple fronts, in Monteverde the movement pattern is influenced by five factors that modify people’s choice of routes: housing density per block, infrastructure quality of housing typology, quality of public space, mixed-use, and green areas. In Llaima, due to the concentration of services around a central square and along a single street, people tend to find the shortest and easiest route to access the service they need, being the size of the block a fundamental factor for the choice of pedestrian routes. Along with this, the presence of green areas in the widest streets and paths, mixed land uses and the presence of entrance gardens in the housing typology are factors that promote greater pedestrian movement. These conditions generate a heterogeneous public space which people prefer to use to reach their destination (Figure 6).

Compared to those streets that are more homogeneous in terms of housing typology without entrance garden, blocks too dense that generate alterations in the public space through the expansion of private housing, generating blind walls towards the street that transmit a feeling of greater insecurity, people are less likely to transit through them. This demonstrates what was raised by some authors such as Whyte [41] and lately by Sevtsuk et al. [34] The presence of blind walls, absence of green areas, and a decrease in the size of the sidewalks on the streets affects pedestrian accessibility. In these places, people prefer to use routes of greater distance that have greater spatial quality, given by the presence of entrance garden, a greater presence of green areas, wider paths, fronts with a greater percentage of windows and residential accesses.
6. Conclusion

This study demonstrates that morphological elements, such as the size of blocks or the plot size, do not directly affect an environment promoting greater pedestrianization. Rather, there are other elements associated with spatial quality that promote a greater pedestrian condition in neighborhoods of this type of context. On the above, it is shown that the choice of routes that people take to reach a destination is defined by the spatial quality of the street. People choose routes with a greater presence of entrance garden, green areas on the streets and high quality of public space infrastructure, given by wider paths, fronts with a higher percentage of showcases. On the other hand, elements such as blind walls - due to the increase in housing density in blocks, the absence or low quality of green areas, and the decrease in the size of the sidewalks in the streets negatively affect the choice of routes, and consequently accessibility.

This article recommends that initiatives associated with urban design in this type of context should be oriented towards the development of new instruments that support the work of regulatory control. For instance, the development of “form-based codes” would strengthen the relations between the physical environment and the public space of at the regulatory level. This would allow the design of appropriate forms and scales of development, without compromising the factors of the built environment that are fundamental to promote a greater degree of pedestrians, which is reflected in the high social life and collective activity in the neighbourhoods of southern Chile.

Acknowledgements

Our thanks to CONICYT Chile for funding this research under the project FONDECYT number 11160096, and to Universidad Austral de Chile.

References

[1] Aghaabbasi M et al 2018 Sust. Cities. Soc. 37 pp 475-484.
[2] Al_Sayed et al 2014 Space Syntax Methodology 4th Edition (London: UCL).
[3] Barton et al 2010 Shaping Neighborhoods: For Local Health and Global Sustainability (London: Routledge).
[4] Barton et al 2015 The Routledge Handbook of Planning for Health and Well-Being (New York: Routledge)
[5] Brownson et al 2009 Am. J. Prev. Med. 36 pp 99-123.
[6] Burton L 2015 Mental well-being and the influence of place (The Routledge Handbook of Planning for Health and Well-Being) ed Barton et al (New York: Routledge) Chapter 11 pp
150-161.

[7] Cerin et al 2006 Medicine & Science in Sport & Exercise 38 pp 1682-1691.
[8] Cervero R 2013 J. Transp. Land Use. 6 pp 7-24
[9] Dempsey N et al 2010 Elements of Urban Form (Dimensions of the Sustainable City 2) ed M Jenks and C Jones (Dordrecht: Springer) chapter 2 pp 21-52.
[10] Dempsey N et al 2011 Sust. Dev. 19 pp 289-300.
[11] Espinoza D and Zumelzu A 2016 Urbano 19 pp 14-29.
[12] Ewing R and Cervero R 2010 J. Am Plann Assoc. 76 pp 265-294.
[13] Ewing R and Handy S 2009 J. Urban Des. 14 pp 65-84.
[14] Frank et al 2010 Brit J Sport Med 44 pp 924-933
[15] Frey H 1999 Designing the city: Towards a More Sustainable Urban Form (London: Spon Press)
[16] Frey H and Bagaeen S 2010 Adapting the City (Dimensions of the Sustainable City 2) ed M Jenks and C Jones (Dordrecht: Springer) chapter 8 pp 163-182.
[17] Gehl J 2010 Cities for People (Washington DC: Island Press).
[18] Hérnandez-Mercado et al 2013 Bitácora Urbano Territorial 2 pp 28-41.
[19] Herrmann G and Mora R 2017 J. Urban Des. 23 pp 336-353.
[20] Hillier B 1996 Space is the Machine (London: Univesity College London)
[21] Hosni J and Zumelzu A 2019 Sust. Dev. 27 pp 21-52.
[22] Iacono et al 2010 J Transport Geography 18 pp 133-140.
[23] Jackson R et al 2013 Am. J. Public Health 103 pp 1542-1544
[24] Jacobs J 1961 The Death and Life of Great American Cities (New York: Vintage Books).
[25] Jacobs AB 1993 Great Streets (Cambridge: MIT Press).
[26] Jun H and Hur M 2015 Appl. Geogr. 62 pp 115-124
[27] Kowaleski-Jones L et al 2018 Popul. Health. 6 pp 9-15
[28] Leyden K 2003 Am. J. Public Health 93 pp 1546-1551.
[29] Lynch K 1981 Good City Form (Cambridge: MIT Press).
[30] MINVU 2017 La Dimensión Humana en el Espacio Público. Recomendaciones para el Análisis y el Diseño (Santiago: Ministerio de Vivienda y Urbanismo).
[31] Mortland et al 2002 Am. J. Prev. Med 22 pp 23-29.
[32] Nieuwenhuijsen M and Khries H 2019 Integrating Human Health into Urban and Transport Planning (Dordrecht: Springer).
[33] Oliveira V 2013 Urban. Morph 17 pp 21-33-
[34] Sevtssuk A et al 2016 Urban. Morpho. 20 pp 89-106
[35] Siksn A 1997 Urban. Morpho. 1 pp 19-33.
[36] Sternberg E 2000 J. Am. Plan.Assoc. 66 pp 265-278
[37] Talen E 2002 J. Plan. Educ. Res 17 pp 257-278.
[38] Talen E 2011. Environ. Plan. B- Plan. Des 38 pp 952-978.
[39] Talen E and Koschinsky J 2013 Int. J. Sust. Land Use. Urban. Plan. 1 pp 42-63.
[40] Vaughan L 2001 Space Syntax Observation Manual (London: UCL)
[41] Whyte W 1980 The Social Life of Small Urban Spaces (New York: Project for Public Spaces).
[42] Zumelzu A 2015 Sustainable transformation of cities: urban design pragmatics to achieve a sustainable city (Eindhoven: Bouwstenen series)
[43] Zumelzu et al 2018 Sostenibilidad de la forma urbana en un barrio CORVI: El caso de la Villa Llaima, Temuco (Patrimonio Moderno y Sustentabilidad: De la Ciudad al Territorio) ed H Torrent et al (Valdivia: Docomomo Chile) Capítulo 5 pp 170-174.
[44] Zumelzu A and Barrientos-Trinanes M 2019 J Hous and the Built Environ https://doi.org/10.1007/s10901-019-09694-8