Post-Occupancy Evaluation (POE) Using Space Syntax: A Case Study of Urban Parks in the South of Brazil

Alcindo Neckel¹, Laércio Stolfo Maculan¹, Anaise Breda¹, Daniela Maroni¹, Edilaine Cristina Becker¹, Isabelle Risson¹, Laura Pasa Cambrussi¹, Michele Bianchini¹ and Julian Grub²

1. Postgraduate Program in Architecture and Urbanism (PPGArq-IMED), Group of Studies and Research on Urban Mobility (NEPMOUR), Passo Fundo/RS, 99070-220, Brazil
2. Postgraduate Program in Architecture and Urbanism (PPG Arq e Urb—UNISINOS), São Leopoldo/RS, 93022-750, Brazil

Abstract: This study is based on strategies for reading and representing the environment, associated with the theory of social logic of space (space syntax). The general objective of this study is to understand and compare the use of space syntax in relation to connectivity, integration and choice of axial routes of the urban parks of Porto Alegre, in the state of Rio Grande do Sul, south of Brazil. The method applied was the capture of georeferenced images for data analysis by using the Theory of Space Syntax (TSE). Thus, three variables were considered for interpretation: choice, connectivity and integration, and they were correlated to statistical data on urban morphology. The results demonstrated the possibility of obtaining significant improvements in the studied urban parks due to the need to create guidelines related to connection and integration that directly impact users' choice strategies when they move around the city.

Key words: Walkability, choice, connectivity, integration, urban parks, space syntax.

1. Introduction

The importance of understanding the dynamics of the environment related to factors that influence the relationships of individuals in urban settings [1] is perceived through field research. Data on a global scale show that more than half of the population lives in urban areas, with an increase estimated at 66% by 2050 [2]. Due to this population growth, there will be a need for more urban parks for leisure activities, maintenance of urban biodiversity, mitigation of the increase in urban temperature as an effect of climate change, and stimulation of quality of life of the population who live in the cities [2].

First, it is important to understand that an urban park consists of a space for public use intended for the population’s recreation, capable of incorporating forms of conservation [3]. In Brazil, urban parks are understood as green areas with an ecological, aesthetic and leisure function [4].

Parks offer the population passive and active forms of connection and recreation, making them more livable spaces, suitable for the health of the urban population [5]. They act as regulating agents of the microclimate, becoming an indispensable element of the urban landscape [6].

The search for hikes and walks through urban wooded areas, in addition to benefiting life quality of the population, reduces the environmental impacts caused by the use of vehicles. The positive factors to the development of urban spaces, which generate factors of urban sustainability, are challenged by the premise of using urban spaces properly [7, 8]. Thus, it is considered that urban parks need to be analyzed through walkability in order to design urban projects aimed at their maintenance and conservation [6, 9-12].

Thus, the relationship between access to a green area and environmental quality is discussed in an intrinsic manner, where walks are vital elements for
the sustainable development of urban spaces, significantly improving the quality of life and decreasing transportation costs [13-15]. It is known that the urban environment can influence the walking behavior due to the presence of green areas in these routes, which have the purpose of meeting the multiple needs of the population [16, 17].

The general objective of this study is to understand and compare the functionality of space syntax in relation to connectivity, integration and choice of axial routes of urban parks in the city of Porto Alegre, in the state of Rio Grande do Sul, south of Brazil. More specifically, mappings, definition of axial traces and analysis of routes used by park users were carried out.

2. Method and Materials

The city of Porto Alegre is located in the northern region of the state of Rio Grande do Sul (Fig. 1), with a coverage area of 495,390 km² and an estimated population of 1,488,252 inhabitants (2020) [18, 19].

Eight urban parks in Porto Alegre were chosen to be studied, as follows: Farroupilha (Redenção); Chico Mendes; Gabriel Knjnk; Germania; Mauricio Sirotsky Sobrinho (Harmonia); Marinha do Brasil; Marechal Mascarenhas de Moraes; and Moinhos de Ventos (Parcão).

Marinha do Brasil Park was opened in 1978 and is located in Praia de Belas neighborhood. It is known as a sports park, with a total area of 70.70 hectares, and several sports courts, a variety of native trees and the presence of fauna with different species.

Chico Mendes Park was opened in 1992 and is located in Mário Quintana neighborhood. It has an area of 25.29 hectares and offers its users squares, courts,
and barbecue places as an option of leisure and relaxation. It stands out for the presence of vegetation and diversity of fauna.

Maurício Sirotsky Sobrinho Park (Harmonia), initially known as “the couples’ harbor”, is recognized for highlighting the population’s cultural traditions. It was opened in 1981, has a total area of 17 hectares, and is located in Praia de Belas neighborhood, close to Arroio Dilúvio.

Farroupilha Park (Redenção) was opened in 1935 and is located in Bom Fim neighborhood. It offers its visitors with a total area of 37.51 hectares. It stands out for having water resources, numerous cultural monuments at a dense strip of vegetation, and a great variety of outdoor spaces and activities.

Gabriel Knijnik Park, located in Vila Nova neighborhood, has an area of 11.95 hectares. The park has a wetland and several fruit trees.

Marechal Mascarenhas de Moraes Park, located in Humaitá neighborhood, has an area of 18.3 hectares. The wetland and planted native vegetation make up paths and nooks of natural beauty and offer a recreational area.

Moinhos de Vento Park, located in Moinhos de Vento neighborhood and well-known as Parcão, was opened in 1972. It covers an area of 11 hectares and houses more than 100 different species of trees.

Germânia Park, located in Jardim Europa neighborhood, was opened in 2006. It has approximately 15.11 hectares of extension, and offers a leisure and vegetation protection area.

2.1 Procedures of This Study

Urban parks need to be studied as their presence in urban areas directly impacts the population’s quality of life. They help mitigate climate change provided by trees, are a place for doing physical activities outdoors and having social interaction [6]. Thus, this study applied four methodological stages:

Stage I—Mapping of the perimeters of the studied parks was carried out, using QGIS software. Paths were drawn through the use of polygons based on Google Maps satellite images, and projected coordinate reference system (SRC) SIRGAS 2000/UTM zone 22S. From the delimited area, paths were drawn; trails were inserted in the inner perimeter of the parks, forming a set of maps with movement patterns, represented by axial lines [21].

Stage II—After mapping the demarcation of the studied areas and insertion of axial lines of the paths existing in the parks for the routes inside the parks, the information was exported in Drawing Exchange Format (DXF), in Computer Aided Design software (CAD) for checking the intersection of axial lines. Through the Theory of Space Syntax (TSE), also known as Theory of Social Logic of Space, developed by Bill Hillier in London in 1954 at the University of College London [22], axial lines represented the paths established to track the movement of their users in urban parks in Porto Alegre. To obtain these quantitative data from the Space Syntax analysis, DephmapX software was used, followed by the application of axial analysis through the analysis radius variables, namely “radius N”, aiming to cover all axes of the system, thus finding the factors of global interaction [23]. DephmapX, an open-source and multi-platform software, was used to perform a set of spatial network analyses designed to understand social processes within the built environment [24].

Stage III—From DephmapX, the integration values were calculated from the straight line segment, which was calculated from the integration index for each road axis, and numerically indicates its relative accessibility in relation to the entire system [24, 25]. Based on this calculation, the most integrated axes within each park were identified. Among these values, the integration index was obtained, which can be converted to a color scale that goes from red (most integrated axes of the system), orange, green, light blue, to dark blue (least integrated axes) [26]. Based on the analysis of the maps, the integration nuclei were identified. The average depth (AD), which is obtained by adding the depths in
relation to other axial segments, dividing by the number of spaces in the system, minus 1 (one), as shown in Eq. (1):

\[ MD = \frac{TD}{(n-1)} \]  

where:
- \( MD \) = mean depth;
- \( TD \) = total depth;
- \( n \) = number of spaces in the system.

Based on this calculus, one can find the relative asymmetry (RA):

\[ RA = \frac{2x(MD-1)}{(n-2)} \]  

Stage IV—From the axial analysis of the parks, these 3 (three) variables were selected to be analyzed and compared, thus allowing to highlight the differences between the parks, their strengths and their weaknesses. The space syntax variables highlighted choice, integration (HH) and connectivity. In this context, choice can be defined as the dynamic local measure, which analyzes the degree of choice of a given space [27].

Within an urban line, routes are analyzed, where different paths are connected, following the same flow for shorter paths, and considering this space as a place with a greater degree of choice [28]. Choice helps analyze parallels with travel allocation parameters [29].

Regarding connectivity, it corresponds to the number of lines/or segments that are integrated. The average connectivity of all park spaces means an analysis of connections between spaces, loops, corridors and paths, and movement routes [30]. Connectivity is a local spatial property based on how many immediate neighbors intersect each axial line by the degree of direct visual connection [31].

Integration consists of the variable that analyzes proximities that form centrality. Sometimes the spatial accessibility index is also considered the best way to move between spaces [32]. Integration can be defined as the degree of integrated or segregated intersections [26, 33].

3. Results and Discussions

When analyzing and comparing the Axial Maps of the parks, some clear differences between them, from their dimensions to the number of existing paths were observed. Some factors within the parks make these differences more evident, such as their green areas (vegetation), their uses, and buildings in the same parks, but with different uses.

In the construction of the axial maps, several line segments were drawn, which illustrate the routes on the paths existing in the studied urban parks, highlighting the different configurations in the drawings of the park path lines. The largest number of segments is found in Farroupilha Park (Redenção), with a total of 408 segments, followed by Moinhos de Ventos Park (Parcão) with 296 segments, Marinha do Brasil Park with 282 segments, Harmonia Park with 234 segments, Chico Mendes Park with 78 segments, Marechal Mascarenhas de Moraes Park with 67 segments and, finally, Gabriel Knjnj Park with 49 segments. The parks analyzed have a total of 1,658 segments. Farroupilha Park represents 25% of the segments, followed by Parcão, which represents 18% of the segments, and Marinha do Brasil, 17%. The other parks account for 41% of the segments.

In relation to the number of segments, the parks can be divided into 2 groups, one with fewer segments (> 100) and the other with more segments (< 100). Fewer segments represent more fluid paths. The more fluid, the faster the movement can be, which decreases the possibility of encounter [33].

Visually, the morphological analysis of the map of Moinhos de Ventos Park-Parcão (Fig. 2d) and the Marinha do Brasil Park (Fig. 2a), shows a very different path drawing between them. However, in relation to the number of segments, they are very similar, Parcão with 296 segments and Marinha do Brasil with 282 segments.

When the segment denominator is lower, as well as its average, it is possible that the park is more linear and has fewer choices, as Mascarenhas, Gabriel and Mendes parks, which indicate the creation of new paths with the potential to generate more choices/segments. From the point of view of accessibility, choice reveals
that the most walkability paths have the potential for greater pedestrian flow [34].

Choice analysis, as shown in Fig. 2d, demonstrates that Moinhos de Vento Park (Parcão) has the greatest choice and concentration of red lines. The second park with the greatest choice is Germânia Park, as shown in Fig. 2c. The other studied parks present a higher concentration of blue and green lines.

Connectivity becomes an important parameter in syntax analysis. It basically consists of the number of axial lines that intersect other lines [35]. This measure is interesting as it gives a clearer view of the role that an axial line plays within the system. Lines with high connectivity tend to play an important role, as they potentially promote access to a large number of other axial lines [36]. Connectivity measures the accessibility potential of each line, so the more lines that intercept a given segment, the greater the connectivity that this line represents [37].

Referring to the connectivity variable analyzed through maps, Marinha do Brasil Park is listed (Fig. 3a) as the park with the largest extension of red lines, but this does not represent it has the largest connectivity. However, Farroupilha Park shows the best connectivity because it presents the largest number of interconnecting lines, shown by the red and yellow lines (Fig. 4c).

Farroupilha Park (Redenção) (Fig. 4c), which shows predominantly blue lines, has a regular network that represents greater connectivity with straight lines. Regarding this park, Fig. 4c shows two yellow lines in its boundaries that demonstrate the number of accesses which form a direct connection with the city.

The park that presents the least connectivity is Gabriel Knijnik with predominance of blue lines. This is due to being more distant from the urban mesh, not having enough paths to provide interconnection and having a concentrated green is which limits visibility, and thus increases insecurity.

Integration is considered the main variable to analyze when dealing with space syntax, which in turn, considers proximity that forms centralities, interconnecting the spaces of the studied urban parks. This analysis can observe details, such as flows, land occupations and their uses. For instance, areas with less flow of people tend to be more dangerous.

Of all the urban parks studied, Farroupilha Park (Redenção) is the one with the greatest integration. This is due to the number of central points, with different uses for each drawn path, resulting in a greater flow of users daily. The location in which the urban mesh is inserted intensifies this integration, as it is circumscribed by high flow avenues. However, Moinhos de Vento Park has the least integration due to the smaller number of interconnected paths and few internal attractions, when compared to Farroupilha Park.

The lived experience through a landscape can be measured by perception of the components and resources of the trails. In addition, the experiential
landscape place concept uses the argument that human perception measures and affects users’ behavior [38, 39].

4. Conclusions

The idea of insertion of the park in the urban mesh is the most relevant factor when discussing the flow of people who enjoy spaces. The parks located in urban centrality are more attractive to the public, as they have better accessibility conditions regarding urban mobility and a greater flow in relation to the parks that are further away from downtown.

From the analysis determined by the methodological procedure for the collection and design of the analyses, it is perceived that the method offers a range of possibilities in relation to its applicability in studies related to walkability.

The methodology based on the theory of space syntax, with the use of software, proved to be efficient. Data were obtained in relation to the applied variables that with correct analysis, generated discussions related to the theory of movement. These data may contribute to the construction of future management models to be applied by managers of these urban parks.

In recent years, the importance of designing qualitative spaces in terms of accessibility and walkability has been discussed, making these spaces more attractive for people to enjoy, to do physical activities and to integrate with the park.

Regarding the assessment of walkability conditions in these eight parks studied, results obtained are related to connection and integration directly and interfere in individuals’ choice strategies. Thus, this study shows that the strength of integration identified by axiality is intensified according to the centrality and the historical load within the urban mesh.

It was observed that some parks, especially those that are the furthest from the urban mesh, need improvements, which directly impacts use and attendance. Through the use of these data, it is possible to turn these studied parks, as well as other parks, into
safer and more attractive spaces, thus generating a positive impact on their users’ quality of social life.

Acknowledgements

We wish to thank IMED; PPGArq/IMED; DepthMap/University College London (UCL); and Quantum GIS Software (QGIS).

References

[1] Bailey, M., Farrell, P., Kuchler, T., and Stroebel, J. 2020. “Social Connectedness in Urban Areas.” *Journal of Urban Economics* (1-2): 103264. doi: 10.1016/j.jue.2020.103264. Accessed Sep. 2020.

[2] Li, C. 2020. “Quality of Life: The Perspective of Urban Park Recreation in Three Asian Cities.” *Journal of Outdoor Recreation and Tourism* 29: doi: 10.1016/j.jort.2019.100260. Accessed Sep. 2020.

[3] Macedo, S. S., and Sakata, F. G. 2002. *Parques urbanos no Brasil*. São Paulo: Editora da Universidade de São Paulo, 14-5.

[4] Ambiente, M. M. A. 2020. “Areas Verdes Urbanas.” Accessed Oct. 2020. https://www.mma.gov.br/cidades-sustentaveis/areas-verdes-urbanas/item/8051.html.

[5] Miana, A. C. 2010. “Adensamento e forma Urbana: Inserção de Parâmetros Ambientais no Processo de Projeto.” *Social Indicators Research*, 79-80.

[6] Neckel, A., Da Silva, J. L., Saraiva, P. P., Kujawa, H. A., Araldi, J., and Paladini, E. P. 2020. “Estimation of the Economic Value of Urban Parks in Brazil, the Case of the City of Porto Alegre.” *Journal of Cleaner Production* 264. https://doi.org/10.1016/j.jclepro.2020.121369.

[7] Ruiz Padillo, A., Pasqual, F. M., Larranaga Uriarte, A. M., and Cybis, H. B. B. 2018. “Application of Multi-criteria Decision Analysis Methods for Assessing Walkability: A Case Study in Porto Alegre, Brazil.” *Transportation Research Part D: Transport and Environment* 63: 855-71. doi: 10.1016/j.trd.2018.07.016.

[8] Alalouch, C., Al-Hajri, S., Naser, A., and Hinai, A. A. 2019. “The Impact of Space Syntax Spatial Attributes on Urban Land Use in Muscat: Implications for Urban Sustainability.” *Sustainable Cities and Society* 46. https://doi.org/10.1016/j.scs.2019.01.002.

[9] Zhai, Y., Baran, P. K., and Wu, C. 2018. “Spatial Distributions and Use Patterns of User Groups in Urban Forest Parks: An Examination Utilizing GPS Tracker.” *Urban Forestry & Urban Greening* 35: 32-44.

[10] Nicese, F. P., Colangelo, G., Comolli, R., Azzini, L., Lucchetti, S., Marziliano, P. A., and Sanesi, G. 2020. “Estimating CO2 Balance through the Life Cycle Assessment Prism: A Case-Study in an Urban Park.” *Urban Forestry & Urban Greening*, http://dx.doi.org/10.1016/j.ufug.2020.126869.

[11] Han, X., Sun, T., and Cao, T. 2021. “Study on Landscape Quality Assessment of Urban Forest Parks: Take Nanjing Zijinshan National Forest Park as an Example.” *Ecological Indicators* 120: 106902. http://dx.doi.org/10.1016/j.ecolind.2020.106902.

[12] Abdelhamid, M. M., and ElFakaharany, M. M. 2020. “Improving Urban Park Usability in Developing Countries: Case Study of Al-shalatat Park in Alexandria.” *Alexandria Engineering Journal* 59 (1): 311-21. http://dx.doi.org/10.1016/j.aeij.2019.12.042.

[13] Brownson, R. C., Royer, C., Ewing, R., and McBride, T. D. 2006. “Researchers and Policymakers: Travelers in Parallel Universes.” *Am J Prev Med.*, 30: 164-72.

[14] Tribby, C. P., Miller, H. J., Werner, C. M., Smith, K. R., and Brown, B. B. 2015 “Licensed under the Creative Commons Attribution—Noncommercial License 3.0 Assessing Built Environment Walkability Using Activity-Space Summary Measures.” *Journal of Transport and Land Use* 9: 187-207. http://dx.doi.org/10.5198/jtlu.2015.625.

[15] Ruiz Padillo, A., Pasqual, F. M., Larranaga Uriarte, A. M., and Cybis, H. B. B. 2018. “Application of Multi-criteria Decision Analysis Methods for Assessing Walkability: A Case Study in Porto Alegre, Brazil.” *Transportation Research Part D: Transport and Environment* 63: 855-71. doi: 10.1016/j.trd.2018.07.016.

[16] Torabi, N., Lindsay, J., Smith, J., Khor, L. A., and Sainsbury, O. 2020. “Widening the Lens: Understanding Urban Parks as a Network.” *Cities* 98: 102527. https://doi.org/10.1016/j.cities.2019.102527.

[17] Wu, S., and Chen, H. 2020. “Smart City Oriented Remote Sensing Image Fusion Methods Based on Convolution Sampling and Spatial Transformation.” *Computer Communications* 157: 444-50.

[18] Zhang, S., and Ramirez, M. F. 2019. “Assessing and Mapping Ecosystem Services to Support Urban Green Infrastructure: The Case of Barcelona, Spain.” *Cities* 92: 59-70. https://doi.org/10.1016/j.cities.2019.03.016.

[19] IBGE. 2020. “Diretoria de Pesquisas, Coordenação de População e Indicadores Sociais.” Accessed Nov. 2020. https://cidades.ibge.gov.br/brasil/rs/porto-alegre/panorama.

[20] “MICHELI Localização dos parques urbanos na cidade de Porto Alegre/RS.” https://blogdapaisagem.wordpress.com/2018/06/18/parkes-de-porto-alegre/03-11-20.

[21] Hillier, B., et al. 1993. “Natural Movement: Or, Configuration and Attraction in Urban Pedestrian
Post-Occupancy Evaluation (POE) Using Space Syntax: A Case Study of Urban Parks in the South of Brazil

Movement.” Environment and Planning B 20 (1): 29-66.

Andrade, C. G. G. 2014. “Crenças, Percepção e Atitudes Linguísticas de Falantes Madeirenses.” Accessed Nov. 2020. https://www.researchgate.net/publication/310604985_Sintaxe_Dicionario_Enciclopedico_da_Madeira.

ZECHIN, Patrick di Almeida Vieira, et al. 2014. “Sobre a Dimensão Espacial da Desigualdade Socioeconômica Urbana. Um estudo sobre cinco cidades brasileiras.” Tese doutorado, Universidade de Brasília, Brasília. http://fredericodeholanda.com.br/orientacoes/doutorado/2014_ZechinPatrickDiAlmeidaVieira_sobre_a_dimensao_espacial_da_desigualdade_social_urbana.pdf.

Rego, G., and Bezerra, M. 2016. “Análise de sintaxe espacial sobre o sistema de espaços livres urbanos do bairro de Águas Claras no Distrito Federal.” Revista de Arquitetura IMED 5 (2): 42-52. doi: https://doi.org/10.18256/2318-1109/argimed.v5n2p42-52.

Ribeiro, R. J. da C. 2008. “Índice Composto de Qualidade de Vida Urbana—Aspectos de Configuração Espacial, Socioeconômico e Ambientais Urbanos. 102.

Mustafa, F. A., and Rafeeq, D. A. 2019. “Assessment of Elementary School Buildings in Erbil City Using Space Syntax Analysis and School Teachers’ Feedback.” Alexandria Engineering Journal 58 (3): 1039-52. http://dx.doi.org/10.1016/j.aej.2019.09.007.

BHERING, and Iracema Generoso de Abreu. 2019. “O Urbanismo E A Paisagem Desejada.” Tese doutorado, Universidade Federal de Minas Gerais.

Francisco, A., and Oliveira, V. 2020. “Explorando as relações entre forma Urbana e tecido social: o caso de Azevedo, Porto.” Accessed Nov. 2020. https://www.researchgate.net/publication/345734116_Explorando_as_relacoes_entre_forma_urbana_e_tecido_social_o_caso_de_Azevedo_Porto.

Hillier, B., and Hanson, J. 1984. The Social Logic of Space. Cambridge University Press.

Peponis, J., Ross, C., and Rashid, M. 1997. “The Structure of Urban Space, Movement and Co-presence: The Case of Atlanta.” Geoforum 28: 341-58.

Vaughan, D. G., Corr, H. F. J., Ferraccioli, F., Frewson, N., O’Hare, A., Mach, D., Holt, J. W., Blankenship, D. D., Morse, D. L., and Young, D. A. 2006. “New Boundary Conditions for the West Antarctic Ice Sheet: Subglacial Topography beneath Pine Island Glacier.” Geophys. Res. Lett. 33 (9).

Martins, L. F. V. 2014. “Monitoramento de Parques Urbanos em fundos de Vales: análise das funções de conservação e uso público—estudos de casos múltiplos em Curitiba, Paraná.” Tese doutorado, Universidade de São Paulo.

Gehl, J. 2010. Cities for People. Island Press.

Cavalcante, A. P. de H. 2009. “A Arquitetura da Cidade e os Transportes: O Caso dos Congestionamentos em Fortaleza, Ceará.” PPG/FAU/UnB 347: 118.

Silva, R. C. da. 2009. “Urbanismo Paramétrico: Parametrizando Urbanidade.” Dissertação mestrado, Universidade Federal de Pernambuco. https://repositorio.ufpe.br/bitstream/123456789/2916/1/arquivo163_1.pdf.

Carmo, C. L., et al. 2013. “Aplicações da Sintaxe Espacial No Planejamento da Mobilidade Urbana.” Ciência & Engenharia 22 (1): 29-38.

Lima-Guimarães, S. T. 2010. “Trilhas Interpretativas e Vivências na Natureza: Aspectos relacionados à percepção e interpretação da paisagem.” Caderno de Geografia 20 (33): 8-19.

Thwaites, K., and Simkins, I. M. 2007. “Are You Experienced?” Landscape, 26-31.

Zhai, Y., Korça Baran, P., and Wu, C. 2018. “Can Trail Spatial Attributes Predict Trail Use Level in Urban Forest Park? An Examination Integrating GPS Data and Space Syntax Theory.” Urban Forestry and Urban Greening 29: 171-82. https://doi.org/10.1016/j.ufug.2017.10.008.