Accessibility and Polarities of Pedestrian Network in University Campuses. A Space Syntax Application

Lea Jeanne Marinelli[1], Alfonso Annunziata[2], Barbara Caselli[1(✉)], Giulia Desogus[2], Vincenza Torrisi[3], and Chiara Garau[2]

[1] Department of Engineering and Architecture, University of Parma, Parco Area delle Scienze, 181/A, 43124 Parma, Italy
barbara.caselli@unipr.it

[2] Department of Civil and Environmental Engineering and Architecture, University of Cagliari, 09123 Cagliari, Italy

[3] Department of Electrical, Electronic and Computer Engineering, University of Catania, via S. Sofia 64, 95125 Catania, Italy

Abstract. This paper examines the multiple interactions between pedestrian mobility systems and land use planning within the framework of Agenda 2030's sustainability goals involving the integration of mobility networks with urban planning development (i.e., targets 11.2 and 11.3). The study focuses on suburban university campuses and science parks as significant cases. Specifically, two different campuses and science parks have been selected as case studies, i.e., Parma and Monserrato (metropolitan city of Cagliari), located in peripheral areas and built during the second half of the 20th century. The methodological approach is based on Space Syntax, to analyse the spatial configuration of the pedestrian infrastructure of each campus. First, a segment map reflecting all pedestrian routes on each campus has been created. Then, multiple measures have been calculated using the DepthmapX software, evaluating accessibility and identifying polarities. Subsequently, the strengths and weaknesses of each campus's pedestrian infrastructure network have been identified and a comparison analysis between the two case studies has been performed to identify common and efficient space conformation characteristics according to the Space Syntax analysis. The study concludes with an analysis of the limitations of the methodology and provides suggestions for further research.

Keywords: University Campuses · Accessibility · Walkability · Active mobility · Space Syntax

1 Introduction

Nowadays, sustainable land use and transport mobility are two of the foremost worldwide issues to be pursued [1]. Urban mobility, which accounts for more than 60% of the travels performed by users, is the greatest contributor to carbon dioxide emissions and

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023
O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14111, pp. 383–400, 2023.
https://doi.org/10.1007/978-3-031-37126-4_26

air pollution [2]. Since 2018, 55% of the world's population resided in urban areas, as highlighted by the 2019 U.N. report *World Urbanisation Prospects: The 2018 Revision* [3]. This report also forecasts that by 2050, this percentage will increase to 68%, having a significant impact on urban mobility.

In Italy, from 2010 to 2021, urban mobility has increased by more than 4%, accounting for 70.6% of the overall travel. In 2022, the average length and duration of urban trips have also increased, with 78% within a range of 10 kms and among those, 28% within a 2-km range. The modal shift shows a significant decrease towards active mobility, particularly walking, compared to the values of 2020, with a decline from 32.8% to 23.7% primarily due to the overcoming of Covid-19 restrictions. Moreover, private cars remaining the preferred mode of transport, with a percentage value of 64% [4]. It is common knowledge that spatial design, as well as changes in lifestyles and travel patterns, have had a substantial impact on the above outlined conditions. Indeed, several scholars have emphasised the integration of spatial planning and transport planning [5–10] and explored methodological approaches to evaluate accessibility, especially within active mobility [11]. Active mobility, together with the promotion of less polluting transport systems, constitute one of the key research concepts on sustainable mobility systems. These approaches can also provide valuable insight for planning tools aimed at urban regeneration [12, 13]. Numerous studies have been conducted to assess walkability, identifying drivers or barriers to walking [14–19] or elements in urban design and planning that positively influence pedestrian accessibility [19–22]. Several studies considered the impact of the spatial configuration of urban areas for pedestrian mobility by employing the Space Syntax approach [23–27]. The Space Syntax methodology encompasses a range of concepts and methods for defining the interrelation between the spatial configuration of urban environments and human behaviours concerning movement preferences. As a result, the Space Syntax approach has the potential to provide valuable instruments to improve planning strategies and urban regeneration initiatives.

Within this framework, limited investigations concentrate on examining walkability in suburban campuses using the Space Syntax approach. Thus, the paper investigates the level of accessibility and polarities of the pedestrian network on suburban university campuses, addressing the issue of sustainable active mobility. Case studies are conducted on university campuses as they represent an urban microcosm wherein footpaths play a critical role for students and other pedestrian users moving between different structures [28]. Therefore, it is key to examine the spatial configuration and pedestrian environments of university campuses. In particular, the research considers the campuses of Parma and Monserrato (in the metropolitan city of Cagliari), which were designed in the latter half of the 1900s in accordance with planning theories that prioritised private mobility. Thus, the aim of the research is to understand if the two analysed university campuses are able to provide a good degree of pedestrian accessibility according, to the Space Syntax methodology.

The following sections of the paper are organised as follows: Sect. 2 introduces the two case studies (Campus *Scienze e Tecnologie* of Parma's University and the *Cittadella Universitaria* of Monserrato); Sect. 3 describes the Space Syntax methodological approach; Sect. 4 presents the results of the analyses, including criticalities and potentialities; Sect. 5 compares the two case studies to identify common and efficient spatial

conformation characteristics, as revealed by the Space Syntax analysis; the research concludes with a discussion of the limitations of the methodology and a brief overview of prospective future research paths, also provided in Sect. 5.

2 Case Studies

This research focuses on suburban university campuses as an outcome of municipal expansion planning and dependence on private vehicles. The establishment of such infrastructures is closely connected to the rapid growth of the university system during the 20th century. Specifically, after the Second World War, several European universities located in historic city centres chose to construct suburban campuses in emulation of the campus model prevalent in the United States. Several factors were pivotal in prompting the design of such centres in the suburban setting, including i) scarcity of available space in urban areas; ii) the need for spacious facilities to accommodate science labs and machinery rooms; iii) the affordability of land; and iv) the conformity with the urban planning practices of the time, particularly functionalisation/zoning as stated by the Athens Charter 1933 [29].

The research analyses the pedestrian network of two specific suburban campuses, located in Italy. The first site refers to the Campus *Scienze e Tecnologie* of Parma's University, within the Emilia-Romagna region, in the northern part of the Italian peninsula. The second campus, the *Cittadella Universitaria* of Monserrato, is in the northern portion of the metropolitan city of Cagliari, within the island of Sardinia, in the southern part of Italy.

The case studies are selected among the campuses built in Italy in suburban areas. Both of the campuses in analysis have the same historical period of construction between the 1970s and 1980s. Despite having comparable facilities, Parma's campus boasts a significantly greater expanse than Monserrato's one and a discrete presence of the transport infrastructures. Additionally, they exist within two differing urban contexts, with Parma representing a medium-sized municipality and Cagliari as regional capital and metropolitan city, thus representing two interesting case studies to be compared.

2.1 Parma's Campus *Scienze e Tecnologie*

Parma's University is spatially distributed across multiple sites throughout the city. These sites can be categorised into four main areas. The first one corresponds to the historical city centre and hosts the departments of humanities, economics, and law. The second area is located outside the historical city centre and hosts the departments of medicine and surgery within the *Ospedale Maggiore* hospital complex. The third one is in the northwest suburban area of the city, characterized by the department of veterinary medical sciences. Finally, the fourth area, considered for this study, accommodates the scientific departments. Due to its territorial scattering, the Parma's University can be classified as a "diffuse" university [30]. This characteristic is also applicable to the University of Cagliari, which will be discussed in more detail in the next sub-section.

Parma's Campus *Scienze e Tecnologie* is located on the southern suburban area of the city (Fig. 1) and is delimited on the north by the southern roadway of the city's ring road. On the north-east, the site is bordered by an urbanised area characterized predominantly by local facilities. To the north-west, on the other hand, the Campus is belted by the *Cinghio* stream, while to the south and east it borders a rural area.

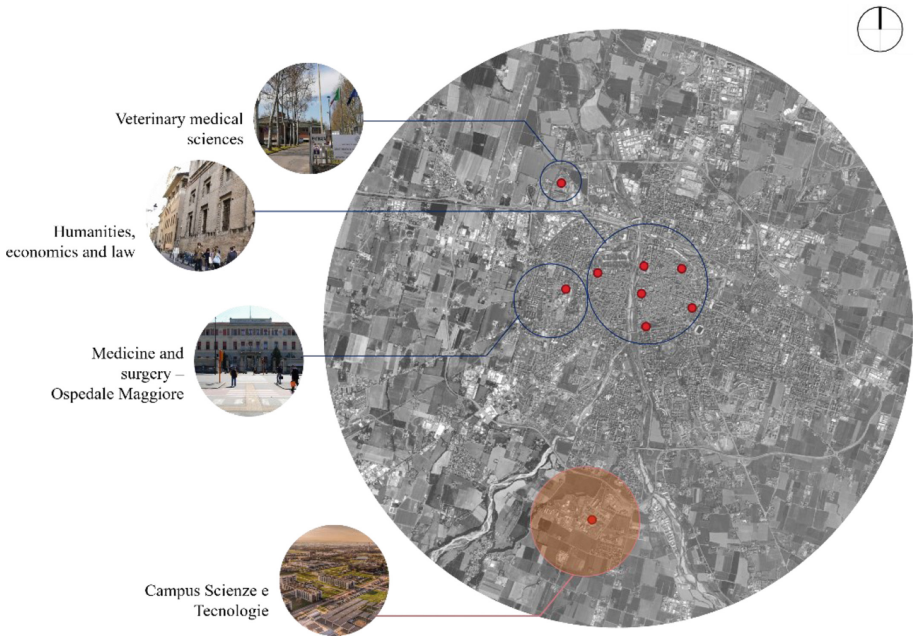

Fig. 1. Location of Parma's University main polarities. Circled in red is the Campus *Scienze e Tecnologie.* Source: elaboration from Esri Satellite. (Color figure online)

The Campus covers an area of about 77 hectares within which there are 114,000 m^2 consisting of built structures, 86,039 m^2 designated for parking and 103,328 m^2 dedicated to sports facilities. Specifically, Table 1 shows as the built facilities within Campus serve a variety of different functions.

According to the 2016 Urban Planning Implementation Plan (in Italian: Piano Urbanistico Attuativo) [31] for the Science and Technology Campus's 1997 master plan completion and functional reorganisation, it is estimated that the Campus daily users are between 6,000 and 10,000.

Table 1. Parma's campus facilities divided by functional class. Re-elaborated data from Parma's Urban Planning Implementation Plan [31].

Main functional class	N. of buildings	Usable area (m^2)
Research and teaching	17	83,772
Conference centre	2	3,055
Innovation and productive research	3	11,186
Administrative facilities	1	986
Catering facilities	3	2,520
Sports facilities	12	10,329
Other facilities	4	1,607

2.2 *Cittadella Universitaria* of Monserrato

The *Cittadella Universitaria* of Monserrato (in the metropolitan city of Cagliari) is a large university campus hosting numerous faculties of the University of Cagliari, including science, medicine, and biology. Founded at the end of the 1960s, the *Cittadella Universitaria* covers an area of approximately 48 ha (Fig. 2) between the national road SS 554 to the south, the provincial road SP8 communicating with Sestu to the west, and the Riu Saliu to the east.

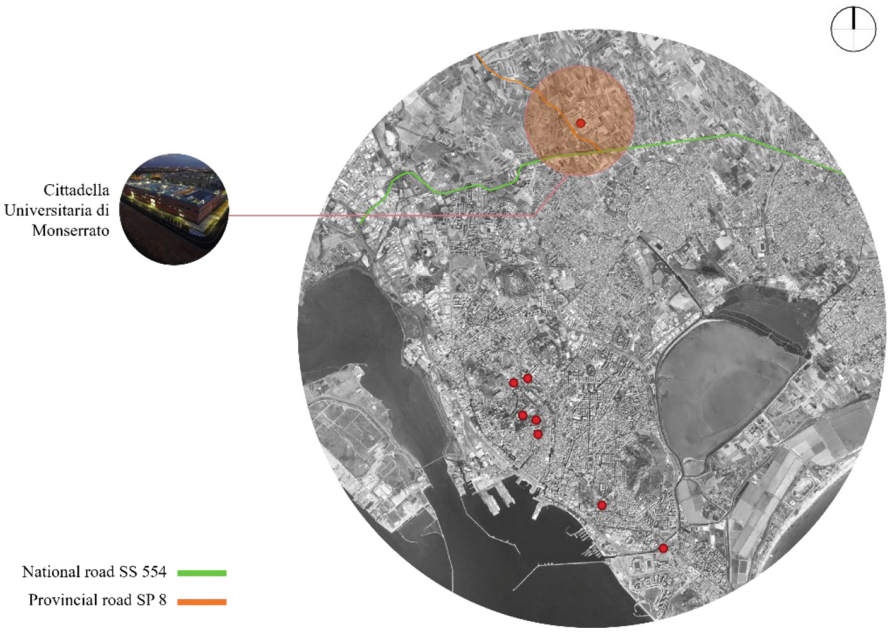

Fig. 2. Location of Cagliari's University main university buildings. The *Cittadella Universitaria* of Monserrato is encircled in red. Source: elaboration from Esri Satellite. (Color figure online)

The year of 1971 marked the beginning of the planning process for this area when the university conducted a national competition to collect proposals for an urban development plan. However, the construction plan was not drafted until 1984. The first General Variation for the Services Plan (In Italian: la prima Variante Generale per il Piano dei Servizi) was authorised between 1980 and 1983 by the Municipality of Cagliari and went into effect on April 20, 1983. After a lengthy authorization process, the foundation stone was laid on October 5, 1985, and the opening ceremony was held on August 8, 1996.

The *Cittadella Universitaria* of Monserrato is connected to the city of Cagliari by several public transport modes, including city buses (Consorzio Trasporti e Mobilità – CTM) and regional buses (Azienda Regionale Sarda Trasporti - ARST), as well as the light metro. Table 2 illustrates that, as in the case study of Parma's campus, the *Cittadella Universitaria*'s structures are distinct and serve various purposes. The project comprised the construction of a university centre with classrooms, laboratories, study areas, libraries, and service areas. In addition to university facilities, the campus hosts the Duilio Casula University Hospital (*Policlinico Universitario Duilio Casula*), which provides high-quality services in the medical and surgical fields and permits medical and surgical students to specialise in several fields.

Table 2. Monserrato's *Cittadella Universitaria* facilities divided by functional class. Re-elaborated data from Technical Implementation Standards [32].

Main functional class	Usable area (m^2)
Sports Facilities CUS CAGLIARI	1,869.00
Clinical departments	3,252.00
Building Q	2,165.00
Policlinico Universitario	9,867.00
National Research Council studies and lab and Parasitology	1,266.00
Student Secretariats	598.00
Chemistry and biology	4,925.00
Educational Axis 2 laboratory lot, classrooms, canteen	3,728.00
Animal enclosure	614.00
Neuroscience Department	907.00
Spina Departmental of Biology	4,010.00
Teaching Axis 1 lot	5,181.00
Spina Departmental Physics	6,788.00
Fourth Spina Departmental – CESAR	6,000.00
Central Library	1,839.00

3 Materials and Methods

In the proposed study, the accessibility and polarities of the pedestrian network of the two analysed case studies' pedestrian networks are determined using the Space Syntax methodology [33, 34]. The Space Syntax methodology has been originally developed in the late 1970's by Bill Hillier and his colleagues of the Bartlett School of Architecture of the College University of London. It consists of a set of theories and techniques to identify the correlation between the configuration of the street network and people's behaviour in relation to their choice of movement [35]. The set of these techniques for the configurational analysis of space, whether within structures or considering public spaces between buildings, enables the description of the relationship of a single spatial element and the system as a whole. Two software programmes are used to conduct the research: a Geographical Information System (GIS) program for generating the foundational maps and processing the data, and the DepthmapX software for performing the Space Syntax analyses. First, base maps are gathered, and employed as required within the GIS software, from the Territorial Information Systems of Cagliari and Parma municipalities incorporating topographical details about buildings location and street network. Then, a map of the footpath network (Fig. 3 and Fig. 4) is reconstructed, with each segment representing a portion of the network and is interrupted at every intersection with other paths. Upon the representation of the axial map, pedestrian pathways are not restricted to axes that have proper infrastructure, such as sidewalks or other areas specifically designated for pedestrian movement, but also include areas that are frequently used by pedestrians despite lacking supporting infrastructure. Second, the shapefile representing the footpath map is exported in dxf format and imported into the DepthmapX software, where it is converted into a segment map. In this research, the Normalised Angular Choice (NACH) and Normalised Angular Integration (NAIN) values are determined using the DepthmapX program. The NACH and NAIN indicators allow to identify within the route network the main routes for movement and the most vital and frequented spaces respectively.

The analyses are conducted for radii (r) of n, with respect to the whole system, and 400 m values, the latter corresponding to a travel distance of around 5 min for an average pedestrian [36].

Specifically, the formulas used to calculate the NACH (Eq. 1) and NAIN (Eq. 2) indicators correspond to the formulas proposed by Yamu and van Nes [37] and shown by the following equations:

$$NACH = \log(Choice(r) + 2) \tag{1}$$

$$NAIN = \log(Integration(r) + 2) \tag{2}$$

The NAIN indicator is often used to identify potential service sites in urban areas. In the cases studied, no buildings are assigned for housing, only for facilities. Thus, the NAIN indicator can be used to conduct preliminary evaluations to identify ideal locations for services with greater user flow or facilities with greater student numbers, as well as for the purpose of urban regeneration interventions.



Fig. 3. Segment map representation of the Campus *Scienze e Tecnologie* of Parma. Grey dashed line indicates the perimeter of the study areas.

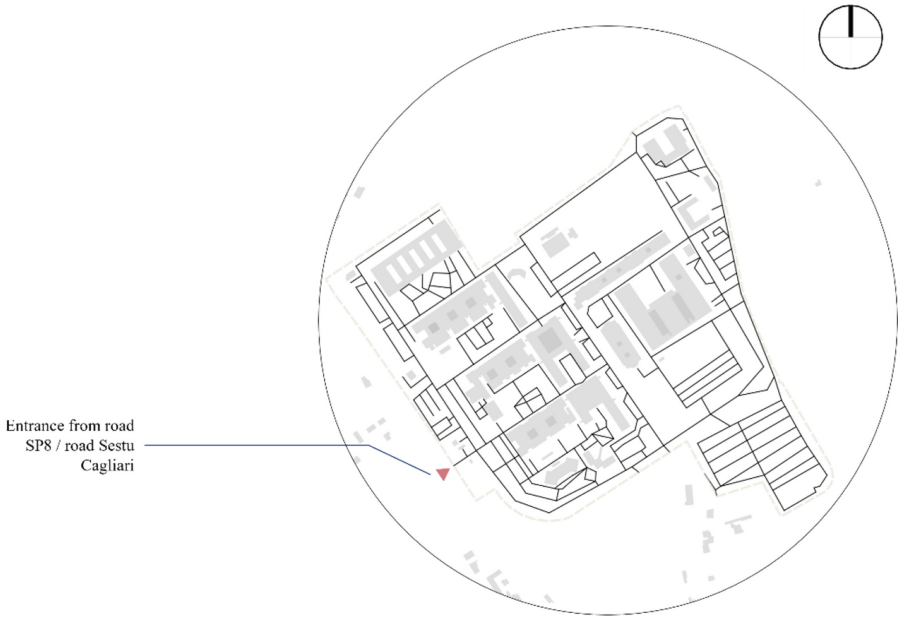

Fig. 4. Segment map representation of the *Cittadella Universitaria* of Monserrato. Grey dashed line indicates the perimeter of the study areas.

4 Results

The obtained results for the computed configurational indicators are graphically shown through axial maps, one for each performed analysis. The values are illustrated through a colour scale (from blue to red) to indicate the values. Specifically, the red and orange segments indicate high values of Integration and Choice, whereas blue segments indicate low values. The results are represented using an equal interval distribution and grouped in ten classes.

4.1 Accessibility and Polarities of Parma's Campus

Figures 5 and 6 visually display the outcomes acquired for Parma's Campus *Scienze e Tecnologie*. The evaluation of the NACH(n) indicator (Fig. 5a) indicates the sections with the highest potential of pedestrian through-movement for the entire system analysed. Even if the investigation is performed to study the pedestrian network, the analysis highlighted the primary foreground network of the infrastructure system for the conveyance of cyclists, pedestrians, and vehicles. By limiting the analysis radius to a 5-min travel time, the examination of the NACH (400) indicator (Fig. 5b) reveals that part of the sections with the highest potential of pedestrian through-movement are still included within the Campus foreground network. However, the analysis emphasizes the central and inner sections, not highlighting the perimeter network. Moreover, the remaining sections of the network with high through-movement potential, thus, high NACH (400) values, are network segments pertaining to the secondary paths, also located in the central area of the campus.

It is possible to recognise, for both examination radii, that the most critical portion of the path network is depicted by the zone situated towards the north/north-west of the examination area, which is primarily reserved for sport greenery. Moreover, concerning the NACH (400) indicator low pedestrian potential through-movement values are also depicted in the southern portion of the network. In addition to the NACH indicator, NAIN values are also represented, enabling the identification of the network segments more liable to pedestrian potential to-movement. This measure is employed to locate the most interlinked segments in the network.

The evaluation of the NAIN (N) indicator (Fig. 6a) across the whole network exposed a primary polarity located in the middle section of the campus. Moreover, the pathway originating from the Via Montanara access towards the campus is also included within this polarity. The values analysed for a 400 m radius (Fig. 6b), on the other hand, make it possible to identify a more diffuse centrality within the campus, which is however concentrated in its central portion and has slightly lower values concerning high potential to-movement rates. Nonetheless, it can be inferred that the pedestrian pathways throughout the Parma campus are effectively interconnected.

Table 3 displays the highest, lowest, and mean values determined for every indicator.



Fig. 5. Normalised values from the angular segment analysis: (a) NACH radius n, (b) NACH radius 400, (c) for Parma's Campus *Scienze e Tecnologie.*



Fig. 6. Normalised values from the angular segment analysis: (a) NAIN radius n, (b) NAIN radius 400, (c) for Parma's Campus *Scienze e Tecnologie*.

Table 3. Parma's campus main, average, and minimum values identified for the calculated indicators.

Indicator	Maximum value	Mean value	Minimum value
NACH (N)	5.277	2.908	0.301
NACH (400)	4.080	2.405	0.301
NAIN (N)	2.280	2.078	1.787
NAIN (400)	2.139	1.634	0.837

4.2 Accessibility and Polarities of Monserrato's Cittadella Universitaria

The visual representation presented in Figs. 7 and 8 illustrates the results obtained for the *Cittadella Universitaria* of Monserrato in the metropolitan city of Cagliari.

Similarly, to the campus of Parma, the NACH indicator values are computed first for the complete network and then for a radii of 400 m. Then, analysis of the normalised choice indicator for the entire network (Fig. 7a) identifies, also in this case, that the segments with the greatest pedestrian through-movement are the foreground network for vehicle and pedestrian transit. The arrangement of the grid representing the main mobility network of the campus is especially clear and easy to understand in this context. The outcomes of the NACH(400) indicator (Fig. 7b) underscore, much like before, the network that constitutes the campus foreground. Nonetheless, in this case the analysis emphasizes the horizontal components as opposed to the previous radii where the vertical ones where highlighted.

In relation to the analysis of Integration, the NAIN(N) indicator (Fig. 8a), similarly the NACH(N) analysis, emphasizes the vertical infrastructure axes of the network, also including the horizontal perimeter axis located south of the campus. Conversely, the NAIN indicator computed for a 400 m radius (Fig. 8b) reveals the significant interconnectivity of the analysed path network, indicating a near absence of segments with exceedingly low movement potential values (dark blue).

Table 4 displays the highest, lowest, and mean values determined for each indicator evaluated.

Table 4. Monserrato's campus main, average, and minimum values identified for the calculated indicators.

Indicator	Maximum value	Mean value	Minimum value
NACH (N)	4.625	2.522	0.301
NACH (400)	3.709	2.182	0.301
NAIN (N)	2.192	1.998	1.761
NAIN (400)	2.010	1.721	1.183



Fig. 7. Normalised values from the angular segment analysis: (a) NACH radius n, (b) NACH radius 400, (c) for the metropolitan city of Cagliari's *Cittadella Universitaria* of Monserrato.



Fig. 8. Normalised values from the angular segment analysis: (a) NAIN radius n, (b) NAIN radius 400, (c) for Cagliari's *Cittadella Universitaria* of Monserrato.

5 Discussion and Conclusions

The achievement of climate change targets is strongly dependent on sustainable mobility, especially active mobility. To accomplish these objectives, it is crucial to plan infrastructures that are suitable and well-coordinated with appropriate land-use and transport planning. In specific urban enclaves, such as campuses and science parks, where pedestrian mobility ought to be the primary transport mode for users, this becomes even more important [28]. In this respect, the Space Syntax methodology can therefore provide useful tools for the configurational analysis of space to comprehend its impact on individuals' path choices, and thus as a tool to support planning tools and urban regeneration practices [34].

Within this context, the contribution proposed the study of two spatial configuration indicators, using the Space Syntax methodology, on two campuses (Parma and Monserrato), with the objective of assessing the degree of pedestrian accessibility. The performed analyses provided values demonstrating that the analysed campuses have a good degree of pedestrian accessibility, particularly as regards the *Cittadella Universitaria* of Monserrato. In fact, according to the NAIN indicator assessment, segments with very low values, and thus poorly integrated with the overall network of pedestrian routes, are almost absent.

Comparing the mean values of both case studies reveal that, with the exception of the NAIN(400) indicator, Parma's campus has slightly higher values than the *Cittadella Universitaria* of Monserrato. Therefore, it is possible to assume that this characteristic is mainly influenced by the campus' smaller size, as well as its higher building concentration. Additionally, the indicator could be affected by more systematic arrangement of footpaths and consequently, of structures / facilities. In both campuses, the analyses performed reveal that the parking areas are the most problematic zones for both campuses. These areas hold particular significance as they constitute a substantial portion of the total area of both campuses.

The evaluations conducted through the Space Syntax approach have certain constraints that impact the genuine pedestrian accessibility perceived by individuals. These include the impossibility of considering the quality of the analysed pedestrian routes and their urban context [38]. In fact, a portion of the segments of the pedestrian network analysed did not have sidewalks, especially regarding the Parma case study. Additionally, these analyses do not consider some key elements to be considered when assessing the degree of pedestrian accessibility to be evaluated through an inclusive design perspective such as the presence of elements to support vulnerable users (such as people with disabilities).

In conclusion, despite their limits, the analyses performed identify a considerable degree of pedestrian accessibility in the two case studies considered. To enhance the precision of these assessments, a prospective research advancement can merge spatial configurational analysis with the application of criteria to assess the standard of pedestrian walkways, such as the Synthetic Indicator of Perceived Road Quality or the Composite Indicator by Universal Design [39]. A subsequent phase instead involves scrutinizing the NACH indicator with the localisation of public transportation stations or other amenities (e.g., dining halls) to assess their appropriate placement.

Finally, an ultimate progression of the study involves theorising potential adaptations of the spaces designated for parking purposes to accommodate new uses in a perspective of urban regeneration and sustainable mobility, recurring once more to the Space Syntax methodology to assess optimal scenarios for pedestrian accessibility.

Attributions This paper is the result of the joint work of the authors. 'Abstract', and 'Discussion and Conclusions' were written jointly by the authors. BC wrote the 'Introduction'. LJM wrote the 'Introduction', 'Materials and Methods', 'Case studies' (Sect. 2 and 2.1) and 'Results' (Sect. 4 and 4.1). AA and GD wrote the 'Case studies' (Sect. 2.2) and 'Results' (Sect. 4.2). BC, CG and VT coordinated and supervised the paper.

Acknowledgements. This work is the result of a project proposal developed within the doctoral course Smart and Sustainable Cities (3rd edition) held at the University of Cagliari and coordinated by C. Garau (https://dottorati.unica.it/dotticar/smart-and-sustainable-cities-3-edizione/). The course was attended by LJM to refine theoretical and methodological tools with reference to the topics researched in the framework of the Sustainable Mobility Centre (CNMS) Spoke 9, WP3. Funder: Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3138 of 16/12/2021 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU. Award Number: Project code CN00000023, Concession Decree No. 1033 of 17/06/2022 adopted by the Italian Ministry of University and Research, CUP D93C22000400001, "Sustainable Mobility Center" (CNMS). The work of V. Torrisi was supported by European Union (NextGeneration EU), through the MUR-PNRR project SAMOTHRACE (ECS00000022).

References

1. United Nations, The 2030 Agenda for Sustainable Development, New York (2015)
2. Rode, P., et al.: Accessibility in Cities: Transport and Urban Form. NCE Cities Paper (03). LSE Cities. London School of Economics and Political Science (2014)
3. United Nations Department of Economic and Social Affairs (UN DESA), World Urbanization Prospects: The 2018 Revision, New York (2019)
4. Istituto Superiore di Formazione e Ricerca per i Trasporti (ISFORT), 19° Rapporto sulla mobilità degli italiani. https://www.isfort.it/wp-content/uploads/2022/12/19-Rapporto_mobilita_italiani_Sintesi.pdf. Accessed 30 Mar 2023
5. Kenworthy, J.R., Laube, F.B.: Automobile dependence in cities: an international comparison of urban transport and land use patterns with implications for sustainability. Environ. Impact Assess. Rev. **16**(4–6), 279–308 (1996)
6. Newman, P., Kenworthy, J.: Sustainability and Cities: Overcoming Automobile Dependence. Island Press, Washington DC (1999)
7. Boarnet, M., Crane, R.: Travel by Design: The Influence of Urban Form on Travel. Oxford University Press, New York (2001)
8. Tira, M., Tiboni, M., Rossetti, S., De Robertis, M.: "Smart" planning to enhance nonmotorised and safe mobility in today's cities. In: Papa, R., Fistola, R., Gargiulo, C. (eds.) Smart Planning: Sustainability and Mobility in the Age of Change. GET, pp. 201–213. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-77682-8_12
9. Tiboni, M., Rossetti, S., Vetturi, D., Torrisi, V., Botticini, F., Schaefer, M.D.: Urban policies and planning approaches for a safer and climate friendlier mobility in cities: strategies initiatives and some analysis. Sustainability **13**, 1778 (2021). https://doi.org/10.3390/su1304

10. Carpentieri, G., Guida, C., Chorus, P.: Land-Use and Transport integration polices and real estate values. the development of a GIS methodology and the application to Naples (Italy). TeMA – J. Land Use, Mobility Environ. **12**(3), pp. 313–330 (2019). https://doi.org/10.6092/1970-9870/6273
11. Pellicelli, G., Caselli, B., Garau, C., Torrisi, V., Rossetti, S.: Sustainable mobility and accessibility to essential services. an assessment of the san benedetto neighbourhood in Cagliari (Italy). In: Gervasi, O., Murgante, B., Misra, S., Rocha, A.M.A.C., Garau, C. (eds) Computational Science and Its Applications – ICCSA 2022 Workshops, ICCSA 2022, Lecture Notes in Computer Science (13382), Springer, Cham (2022). https://doi.org/10.1007/978-3-031-10592-0_31
12. Gallo, M., Marinelli, M.: Sustainable mobility: a review of possible actions and policies. Sustainability **12**(8) (2020). https://doi.org/10.3390/su12187499
13. Pellicelli, G., Rossetti, S., Caselli, B., Zazzi, M.: Urban regeneration to enhance sustainable mobility. TEMA – J. Land Use, Mobility and Environ., pp. 57–70 (2022). https://doi.org/10.6093/1970-9870/8646
14. Ewing, R., Handy, S.: Measuring the unmeasurable: urban design qualities related to walkability. J. Urban Des. **14**(1), 65–84 (2009). https://doi.org/10.1080/13574800802451155
15. Mrak, I., Campisi, T., Tesoriere, G., Canale, A., Cindrić, M.: The role of urban and social factors in the accessibility of urban areas for people with motor and visual disabilities, In: AIP Conference Proceedings, **2186**(1), p. 160008, AIP Publishing LLC (2019). https://doi.org/10.1063/1.5138076
16. Ignaccolo, M., Inturri, G., Giuffrida, N., Le Pira, M., Torrisi, V., Calabrò, G.: A step towards walkable environments: spatial analysis of pedestrian compatibility in an urban context. European Transport **76**(6) (2020)
17. Annunziata, A., Garau, C.: A literature review on walkability and its theoretical framework. emerging perspectives for research developments. In: Gervasi, O., et al. (eds.) ICCSA 2020. LNCS, vol. 12255, pp. 422–437. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58820-5_32
18. Caselli, B., Rossetti, S., Ignaccolo, M., Zazzi, M., Torrisi, V.: Towards the definition of a comprehensive walkability index for historical centres. In: Gervasi, O., et al. (eds.) ICCSA 2021. LNCS, vol. 12958, pp. 493–508. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-87016-4_36
19. Blečić, I., Cecchini, A., Congiu, T., Fancello, G., Triunfo, G.A.: Evaluating walkability: a capability-wise planning and design support system. Int. J. Geogr. Inf. Sci. **29**(8), 1350–1374 (2015)
20. Talen, E.: Pedestrian access as a measure of urban quality. Plan. Pract. Res. **17**(3), 257–278 (2002). https://doi.org/10.1080/026974502200005634
21. Rossetti, S.: Planning for Accessibility and Safety: theoretical framework and research methodologies to address people friendly mobility. Maggioli Editore, Sant'Arcangelo di Romagna (2020)
22. Caselli, B., Carra, M., Rossetti, S., Zazzi, M.: Exploring the 15-minute neighbourhoods: an evaluation based on the walkability performance to public facilities. Transp. Res. Procedia **60**, 346–353 (2022)
23. Tsigdinos, S., Latinopoulou, M., Paraskevopoulos, Y.: Network configuration as tool for improving pedestrian accessibility: Implementing a street design methodology in an Athenian neighbourhood. In: Proceedings of the 12thSpace Syntax Symposium, SSS2019, (2019)
24. Lamíquiz, P.J., López-Domínguez, J.: Effects of built environment on walking at the neighbourhood scale. a new role for street networks by modelling their configurational accessibility?. Transportation Research Part A: Policy and Practice, **74**(2015), 148–163 (2015). https://doi.org/10.1016/j.tra.2015.02.003

25. Lerman, Y., Rofè, Y., Omer, I.: Using space syntax to model pedestrian movement in urban transportation planning. Geogr. Anal. **46**(4), 392–410 (2014). https://doi.org/10.1111/gean.12063
26. Garau, C., Annunziata, A., Yamu, C.: A walkability assessment tool coupling multicriteria analysis and space syntax: the case study of Iglesias, Italy, European Planning Studies, pp. 1–23 (2020). https://doi.org/10.1080/09654313.2020.1761947
27. Soares, I., Yamu, C., Weitkamp, G.: The relationship between the spatial configuration and the fourth sustainable dimension creativity in university campuses: the case study of Zernike Campus, Groningen, The Netherlands, Sustainability **12**, 9263 (2020). https://doi.org/10.3390/su12219263
28. Salingaros, N.: Planning, complexity, and welcoming spaces: the case of campus design, Chapter 18. In: Gert, R., Claudia, Y., Christian, Z. (eds.): Handbook on Planning and Complexity, pp. 353–372 (2020)
29. Bott, H.: City and university: an architect's notes on an intriguing spatial relationship. In: Meusburger, P., Heffernan, M., Suarsana, L.: Geographies of the University, Knowledge and Space 12, Springer International Publishing, pp. 375- 437 (2018)
30. Università degli Studi di Parma, Unipr sostenibile, Mobilità. https://ateneosostenibile.unipr.it/mobilita/. Accessed 30 Mar 2023
31. Università degli Studi di Parma, Piano Urbanistico Attuativo: completamento e riorganizzazione funzionale del piano particolareggiato 1997 per il Campus Scienze e Tecnologie, Relazione introduttiva: il progetto MASTERCAMPUS e relazione tecnica (2016)
32. SPA srl., Complesso Universitario di Monserrato. Proposta di riordino e assestamento del piano Italposte. Relazione paesaggistica ai sensi del DPCM 12/12/200 (2018)
33. Hillier, B., Hanson, J.: The Social Logic of Space. Cambridge University Press (1984). https://doi.org/10.1017/CBO9780511597237
34. Hillier, B.: Space is the Machine: A Configurational Theory of Architecture. Cambridge University Press (1996)
35. Cutini, V.: La rivincita dello spazio urbano. L'approccio configurazionale all'analisi e allo studio dei centri abitati. Pisa University Press, Pisa (2010)
36. Yamu, C., van Nes, A., Garau, C.: Bill Hillier's legacy: space syntax—a synopsis of basic concepts, measures, and empirical application. Sustainability **13**(6), 3394 (2021). https://doi.org/10.3390/su13063394
37. Yamu, C., van Nes, A.: Analysing linear spatial relationships: the measures of connectivity, integration, and choice. In: Introduction to Space Syntax in Urban Studies **78** (2021)
38. Ratti, C.: Space syntax: some inconsistencies. Environ. Plann. B. Plann. Des. **31**(4), 487–499 (2004). https://doi.org/10.1068/b3019
39. Pinna, F., Garau, C., Maltinti, F., Coni, M.: Beyond architectural barriers: building a bridge between disability and universal design. In: Gervasi, O., et al. (eds.) ICCSA 2020. LNCS, vol. 12255, pp. 706–721. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58820-5_51