Assessing walkability: index construction and application to a medium-size Greek city

Vasiliki Beltsiou[1], *Georgia* Gemenetzi[1] , and *Panayiotis* Manetos[1]

[1]School of Engineering, Department of Planning and Regional Development, University of Thessaly, 383 34, Volos, Greece

Abstract. European urban policies focus on sustainable urban mobility concept. This is linked to the constraint of motorized transport and the promotion of active-mobility modes (walking, cycling) which contribute to Green House Gas reduction targets as set in the European Union (EU) Climate Policy. Especially, walkable neighborhoods and 15-minute cities have been embraced in the post-pandemic city emphasizing the importance of walkability, which re-conciliates environmental concerns with liveable, sustainable and healthier communities. This research aims to construct a "walkability index" (WI) that may offer significant, reliable and quick results for the assessment of walkability in an urban area. The city of Larissa comprises the empirical field for its application. The index methodology is based on five main parameters: land use mix, residential density, pedestrian crossing connectivity, sidewalk condition and pedestrian-friendly areas. Then Analytic Hierarchy Process (AHP) is implemented so as to weigh the selected parameters and finally the parameters multiplied and added in an equation f(x) with the use of ArcGIS Pro software. WI detects friendly-walking and non-friendly-walking areas and assesses the factors that hinder urban mobility and vulnerable people. Therefore, it may help policy makers and urban planners to build sustainable and healthy cities and improve the quality of life.

1 Introduction

Many cities are faced up with intense and uncontrolled urbanization and the climate change risks. Under this condition, traffic congestion and use of automobiles is one of the most common problems associated with the deterioration of the quality of urban life and the environmental degradation. It contributes to air and noise pollution, increasing energy consumption, accidents and health problems (such as obesity). The car-based planning approach does not meet mobility needs due to the limited available space for new road infrastructure, leading to an inefficient transport system [1-2].

European urban policies focusing on the transport sector promote Sustainable Urban Mobility (SUM) as a one-way solution. Two of the most recent strategies are the "Strategy for Sustainable and Smart Mobility - European transport on track for the future" [3] and "The new EU urban mobility framework" [4]. Both have as main targets:

- strengthen the transport system taking into account future crises
- green, smart, affordable and healthy mobility
- the publication of plans for sustainable urban mobility
- public transport and active mobility (e.g. walking, cycling) and
- draw attention to vulnerable people of the network with reduced mobility (disabled or elderly).

In short, SUM is linked to the constraint of motorized transport and the promotion of active-mobility modes that are walking and cycling. These modes of transport contribute to meet Green House Gas targets set out in the EU Climate Policy [5].

Furthermore, walkable neighbourhoods and 15-minute cities have been embraced in the post-pandemic city emphasizing the importance of walkability, which re-conciliates environmental concerns with liveable, sustainable and healthier communities [6]. Besides, New Urbanism (NU) is an urban planning approach related to walkable neighbourhood, easily accessible by residents, promoting more environmentally friendly habits. The New Urbanism gives certain specifications for the neighbourhood, where all daily activities, such as shops, schools, hospitals, playgrounds, recreational facilities, sports are within close proximity, ten-minute walk [7]. Within this context, the idea of the 15-minute city can also work. This idea was supported by Paris, as the mayor of Paris, Anne Hidalgo [8] wanted to provide the Parisians with what they need close to home. This would lead to a reduction in pollution and stress, creating socially and economically mixed neighborhoods, improving overall quality of life for residents and visitors [9]. In 15-minute cities, most residents can meet their needs within 15 minutes by walking or cycling or using some other means of public transport [10]. This concept wants to emphasize and promote the local lifestyles in modern cities. This idea took another dimension because of the pandemic (Covid-19), as with the outbreak of the pandemic many people's daily habits changed [11]. Travel was largely restricted to a close perimeter near the areas where people lived; travel by public transport was reduced due to limited capacity, as well as reduced routes. These restrictions are an opportunity to reorganize cities in a more ecological and sustainable way [10, 12-14].

This paper emphasizes on walkable pedestrian mobility (walking). Citizens choose walking for their daily movements so as to meet their daily needs, but also needs such as work, leisure, sports, etc. However, there should be a well-developed pedestrian network in a city so that citizens will be able to move easily and safely on foot. Therefore, walking depends on the provision and the quality of mobility networks.

The above mentioned policies that concern the field of transport focus on the promotion of sustainable mobility and appropriate measures and solutions for the development of sustainable, smart, affordable, accessible cities. Cities should be able to adapt to new challenges, both negative and positive, that may have a strong economic, social and environmental effect on them. Cities should formulate policies and tools that can meet the new needs. One of these tools can be the concept of walkability in combination with other parameters such as accessibility, connectivity, and mixed-use development.

Even though there is a broad literature [15-21] regarding the concept of walkability, there is no a common approach concerning the related variables, measurement methods and tools. This study aims to construct a WI based on a new methodological framework which weights each variable in an integrated way and takes also into account the spatial properties of the built environment using GIS. The proposed WI is applied to a medium-sized city in Greece.

It is worth mentioning that within the Greek relevant literature, there is only one study that deals with the objective measurement of a combined spatial WI [22]. Most scholars dealing with walkability in small and medium-size cities evaluate the level of pedestrian satisfaction and service through questionnaires [23-25] or using statistical tools and Geographical Information Systems (GIS) [2, 26-27].

The measurement of walkability can help policy makers and urban planners to build walkable and, consequently, sustainable and health cities so as to improve the life quality.

2 The concept of walkability

The key concepts of walkability definition are:

Walking: Walking should be one of the main modes of transport in sustainable cities [28-30]. Walking has many dimensions. The first one is the practical dimension. It is easy to get somewhere through walking when the distance is short, for example, to the workplace, to shops, services or to transport stations (e.g. bus, train, etc.) [31]. The second one is the social dimension. Meeting other people increases social cohesion [32]. The third one is economical, as you can move from one point to another at no-cost or low-cost [32-34]. Finally, the health dimension is linked to outdoor exercise or a simple walk outside that can have positive effects on mental and physical health [32, 15].

Walkability: The term "walkability" is rarely found in dictionaries, but is often used in practice [33]. It has become well-known recently as it is used as an indicator to measure whether an urban area has high or low walkability [35]. It indicates the degree to which the built environment is friendly to the presence of people walking, living, shopping, visiting, enjoying or spending time in an urban area [15]. Many urban areas are characterized as problematic mainly in terms of walkability and accessibility [33]. The three main dimensions that make up the term of walkability are a) density such as pedestrian density, population density, residential density etc. depending on the target of each indicator, b) land-use mix and c) accessibility [15, 36-37]. Another dimension that completes the concept of walkability is connectivity. Connectivity refers to connections that exist between origin and destination [36,38-39]. It shows the level of “connection” between streets or sidewalks. Walking and walkability are closely related to the concept of sustainability and its three pillars: social, economic and environmental [6, 19].

Accessibility: It provides easy access to the pedestrian network, cycle paths or public transport for different members of the community. It is vital for young people, elderly, children, people with disabilities and people with low incomes [1, 15]. Convenience, comfort, safety, attractiveness and pleasure represent key spatial requirements that make measuring accessibility possible. Pedestrian accessibility is an important factor in making an area walkable. When walkability levels are increased, accessibility also increases. At the same time, the livability of community is increased, public health and economy are improved [1].

In short, specific features of the built environment have a significant influence on encouraging or discouraging walking. By identifying and quantifying these characteristics we can construct “Walkability Index” (WI) [40]. This assesses the presence of desirable features in a study area. These features include access, connectivity, land uses, pavement characteristics (blind routing guides, ramps), travel time, safety, green areas even aesthetic parameters e.g. flowers, cleanliness of public spaces etc. Walkability indexes are indicators of the quality, convenience and comfort of walking in a neighborhood through scientifically measurable parameters. According to the literature GIS is used in most cases to calculate similar walkability indicators [6].

3 Methodological framework

3.1. Methodology

Based on a thorough literature review [2, 33, 38, 18, 20-21, 41] the methodology for the index construction is based on five main parameters: land-use mix density, residential density, pedestrian crossing connectivity, sidewalk condition and pedestrian-friendly areas. Then AHP is implemented so as to weigh the selected factors and finally the parameters multiplied and added in an equation f(x) with the use of ArcGIS Pro software. Figure (1) shows the flow chart followed by the methodology for constructing and calculating the walkability index.

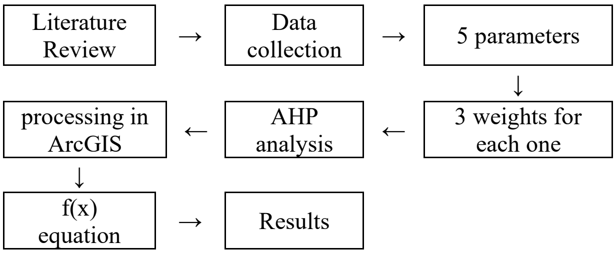

Fig. 1. Flow chart of methodology

Although the proposed index is not extensive in terms of including all the parameters that exist in the literature, it integrates the main concepts in a comprehensive way.

3.2 Study Area

Larissa is one of the largest Greek cities located in the centre in the Region of Thessaly [42]. It is a dynamic administrative, commercial, economic, university, agricultural, transport and cultural centre of the country. According to Hellenic Statistical Authority (HSA) data for 2021, its population is approximately 169,000 inhabitants [43]. Due to its geographical location, it has a strong economic activity with a dominant agricultural sector and a significant business sector with many small and large businesses, mainly in the restaurant and recreation sector [44-45]. The natural environment of the city is characterized as a high value natural environment, thanks to the Pinios River that runs through the city and the large green areas of green that create a high quality of environment. The city's identity is shaped by important cultural monuments, such as the Ancient Theatre and the Bedesten on the top of Frourio Hill.

The flatness of the terrain facilitates travel, making it easily accessible both within the city and in its surrounding area [46-47]. This encourages both pedestrian and bicycle movement. There is a connection between the existing pedestrian routes and the commercial centre, the cultural landscape of the city, the three major central squares, the districts and the cultural, administrative and social activities of the city and the Pinios River. In addition, many commercial uses are concentrated in the city centre along the sidewalks [45-47].

The walkability index is applied within the city centre area, i.e. Study Area (S.A.) 1 (delineated by the red line), as it is shown in Figure 2.

This area is one of the four areas focused on the Urban Mobility Study of the municipality which aims to make urban mobility strongly dependent on public transport, walking and cycling. At the same time, it aims to develop an integrated Sustainable Urban Mobility Plan (SUMP) with an emphasis on pedestrian movement networks through sidewalks, low-traffic streets, widened sidewalks for safe, pleasant, healthy access for all and also transforming the image of public spaces [48].

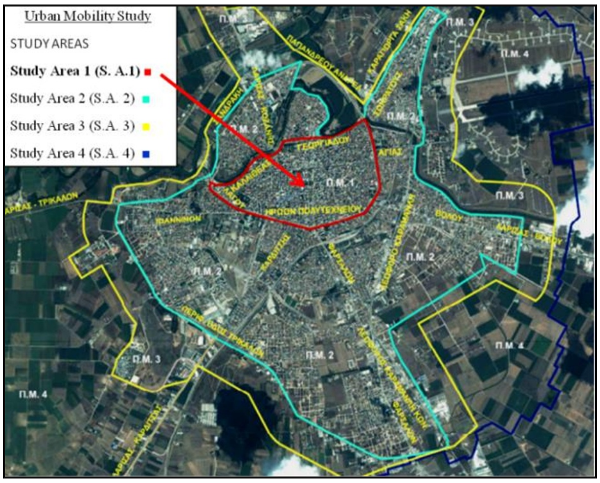

Fig. 2. The city centre area (red line): Area of walkability index application.

3.3 Data collection and analysis

In the context of this research, a methodological approach was implemented in three phases:

Phase 1: Data were collected from Open street map, Google map (Street View), Urban Atlas, HSA, the Municipality's service and in-situ monitoring concern blocks, land mix-uses, pedestrian crossings, width of sidewalks, obstacles on them, condition of sidewalks (surface), pedestrian and cycle paths, streets of low-traffic or exclusive transit, parks and squares. The basis for setting up the index was the blocks, as the area was assessed per side of the block for the entire selected parameters. Table 1 shows the variables used for each parameter.

Table 1. The five parameters and variables

Parameters	Variables
1.Residential Density	blocks
	population
2.Land-use mix Density	services
	commercial
	recreation areas
	catering fcilities
3.Connectivity	crossings
4.Sidewalk Condition	surface (good,middle, bad)
	obstacles (trees, bins, pillars)
	width(0-1,5m|1,5-2,5m | >2,5m)
5.Pedestrian Friendly Areas	green areas (parks, squares)
	blue areas (river side)
	pedestrian paths
	cycle paths
	low- traffic transit
	exclusive transit

Phase 2: Weights were collected from the literature [16-18, 21-22, 30, 40, 49-52] in order to find the percentages to be used in the AHP [53]. First of all, in Microsoft Office Excel gathered data for weight of

parameters. Three different weights were selected for each parameter. First the *average* of these weights and *the sum of the averages* (sum_ave) was calculated. Then by dividing the average of each parameter by the sum of them (ave / sum_ave) a value *num* is derived and the *sum of num* (sum_num) should equal to 1 (sum_num=1). The last column of table (2) specifies the *percentage* (Per %) of each parameter, the value of which derived from the num (of each parameter) multiplied by one hundred and the *sum of percentage* (sum_per) should be equal to 100 (sum_per=100%) [53]. The calculation process is illustrated in the Table 2.

Table 2. Calculation of weighting for each parameter based on the literature review

P	Weights	Average	Ave/ Sum_Ave	Per %
1	p_1_weight 1.1,1.2,1.3	p_1_weight/3	p_1_num_1	**p_1%**
2	p_2_weight 2.1,2.2,2.3	p_2_weight/3	p_2_num_2	**p_2%**
3	p_3_weight 3.1,3.2,3.3	p_3_weight/3	p_3_num_3	**p_3%**
4	p_4_weight 4.1,4.2,4.3	p_4_weight/3	p_4_num_4	**p_4%**
5	p_5_weight 5.1,5.2,5.3	p_5_weight/3	p_5_num_5	**p_5%**
		Sum_Ave (w_1+...+w_5)/5	Sum_num **=1**	Sum_per **=100%**

After the AHP analysis was applied, *pair wise comparison*, *hierarchy* of the parameters and finally the *consistency ratio* check for the reliability of the result [53-55].

Phase 3: Having collected all the necessary data and done the appropriate processing, parameters that will constitute the index were normalized on a scale of 1 to 3 (1 = minimum & 3 = maximum) using the *standardize field tool.* The function *f(x)* was calculated through ArcGISPro.

Table 3. The normalized weights for each parameter

Normalization ↓	p_1	p_2	p_3	p_4	p_5
Final %	***w_1* 7%**	***w_2* 50 %**	***w_3* 16 %**	***w_4* 15 %**	***w_5* 12%**

$$f_x = (p_1 \times w_1)+(p_2 \times w_2)+(p_3 \times w_3)+(p_4 \times w_4)+(p_5 \times w_5) \quad (1)$$

The final equation for the calculation of the walkability index was formulatedas shown in (1). The *p* ($p_1 ... p_5$) corresponds to each parameter and *w* ($w_1 ..... w_5$) represents the weight of each parameter. The resulting of WI value gives us information about the score of walkability of the study area.

Figure (3) shows all the parameters and their sub-variables that are calculated for the reference area. The results of the equation, in other words, the WI for the city centre of Larissa, are depicted in Figure (4).

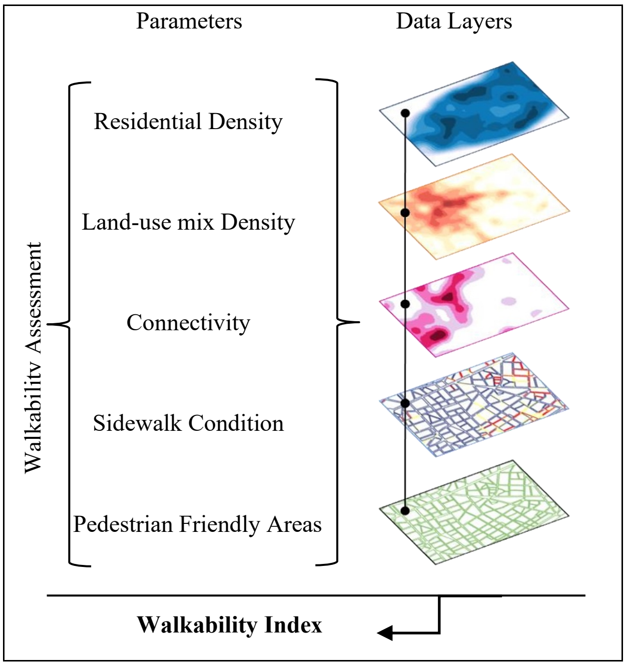

Fig 3. Steps for assessing walkability

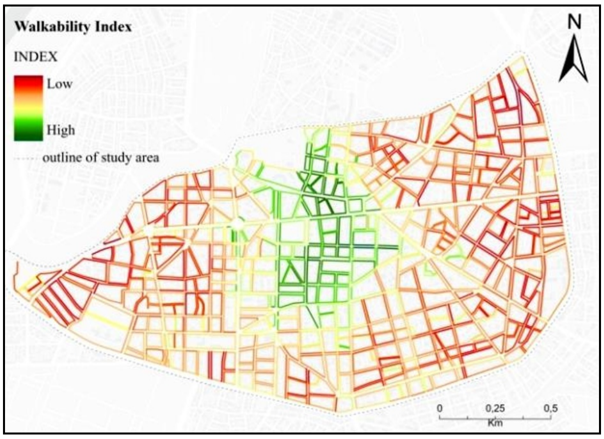

Fig. 4. The results of WI in the city centre of Larissa.

4 Results and discussion

Results indicate that the city centre has a high score of walkability. It is the most friendly-walking area. This is mainly attributed to its high residential and land-use mix density. It concentrates many services, commercial uses and activities, recreation areas, the three major central squares and important historical monuments. Besides, the pavements in the city are in a very good condition, due to their recent construction. There are widened pavements and pedestrian crossings. These are combined with low traffic roads that provide safe movement for both pedestrians and cyclists, parking spaces for the residents of the respective area and exclusive transit for buses, setting the minimum speed limit in both cases at 30km/h with priority to pedestrians [49, 56]. Therefore, the organisation and management of transport ensures higher connectivity and more pedestrian friendly areas. Besides, a special parking control system has been installed in many points of the city central, contributing to the better management of traffic and providing parking slots that encourage walkability.

As we move away from the city centre, the rest of the under-study area presents medium to low walkability. Walkability is extremely low in the periphery of the city centre. This is related to the lower residential density and lower land-use mix density that characterises the periphery of the city, in which residential use is the main land-use. Furthermore, this result is due to the change in the width of sidewalks, which enough constrained contrary to this in the centre. In particular, the width varies from 0 meters to 1.5 meters. The smaller width combined with the set of obstacles (such as signs, trees, bins) located along them makes pedestrian movement enough difficult. Even if the pavement is in a good condition, the existence of obstacles forces pedestrians to change direction, and sometimes even crossing the roads. Thus, no safe, convenient and fast access for pedestrians to and from a destination is ensured. Another parameter that plays an important role in the variation of the low index is few pedestrian crossings that imply low connectivity, therefore resulting in longer travel time [38, 57-58].

In conclusion, transport and urban policies should give emphasis on this part of the city in order to improve walkability. Making targeted urban interventions and expanding technical infrastructure may contribute to make the urban environment more friendly-walking. Simple technical solutions, such as widening pedestrian pavements and keeping them in a good condition, increasing the number of crossings, replacing the urban equipment (signs, bins etc.) in an appropriate way may encourage the pedestrian movement, even in areas where residential and land-use mixed density in not so high as in the centre.

In general, all parameters have an impact on the walkability. However, their impact, positive or negative, depends on the weight that is given to them.

5 Limitations

The limitations that concern the application of walkability index for the centre of Larissa was the collection of some spatial data. Municipal services do not always correspond and the in-situ collection is a costly and time-consuming procedure. In the next phase of data processing, there was a difficulty in defining weights for each parameter since the method may differ from study to study. Another key limitation was the difficulty of managing big data, through the ArcGIS Pro software. This software has high-standard tools, so its requirements are not covered by a common computer and make its operation difficult.

With reference to future research, the walkability index may be enriched with more variables, such as detailed sidewalk characteristics (slope, ramps, blind routes), aesthetic parameters (trees, flowers), sense of safety (crime rate, lighting) and wellness (integration of green and blue infrastructure, pleasant micro-climatic conditions), the level of cleanliness in a city. Finally, there are multitudes of parameters and indicators of walkability or even indicators that combine walkability with other sectors of the economy, public health, transport, urban planning, etc. This is also worth being studied and evaluated.

6 Conclusions

Walkability is a multidimensional and complex concept. There is a great variety of methods, tools and parameters that frame it. These may be adapted according to the characteristics of the study area and the scope of the research.

Within the current research a different methodological framework was constructed so as to calculate the WI. This was based on a process of weighting by AHP method the most representative parameters according to the literature review, along with the use of GIS. The application of the WI allows the visualisation of the walking conditions in an urban area and, therefore, the identification of the areas that are friendly-walking and non-friendly-walking. In parallel, the calculation of walkability index contributes to assess the factors that hinder urban mobility affecting especially vulnerable people groups. In short, assessing the areas that have a low and high walkability index, we can suggest which ones need immediate interventions as well as the types of intervention.

The construction and application of such a WI is used for first time in a Greek city, since until today similar attempts are based on qualitative and quantitative parameters (using questionnaires and statistical tools). Even though the required data are no always easily accessible, they are available. This enables the expansion of the usage of WI to other urban areas, providing reliable and quick results for walkability. The added value of the WI allows the comparison of walkability between different cities and reinforces insightful thinking for urban and transport planning.

To sum up, the construction of the proposed WI provides significant, reliable and quick results for evaluating walkability in an urban area. It is a useful tool for policy makers and urban planners in order to build smart, sustainable and healthy cities, set priorities for future actions and projects that aim to the improvement of urban mobility. In parallel, it is an important tool for transport planners dealing with the development of sustainable urban mobility plans, revision of existing ones or monitoring with continuous updating of the necessary data. In short, WI is a crucial tool for urban plans, since it can feedback urban planning and urban design with reference to the spatial organization of transport system, land uses planning and green infrastructure.

References

1. T.A. Litman, World Transp. Policy Pract (2018)
2. A. Sdoukopoulos, et al., Transp. Res. Procedia **24**, 337 (2017)

3. E. Commission, *Sustainable and Smart Mobility Strategy – putting European transport on track for the future*. Brussels (2020)
4. E. Commission, *The New EU Urban Mobility Framework*, Strasbourg (2021)
5. T. Philip and d.C. Andrea, UCLG, (2019)
6. A. Baobeid, M. Koç, S.G. Al-Ghamdi, Front. Built. Environ. **7** (2021)
7. A. Nghiningwa, *Application of "New Urbanism" Principles to the Revitalisation of the Swakopmund Single Quarters Supervisor: Mrs Nadine Korrubel*, N.U.S.T., (2019)
8. GIZ, *The 15-Minute city*, T.U.M.I. (2021)
9. N.S.a.E. Balázs Németh, *European Mobility Week*, Thematic Guidelines, (2021)
10. G. Pozoukidou, Z. Chatziyiannaki, Sustainability **13**, 928 (2021)
11. G. Gemenetzi, Proceedings of the International Conference on Changing Cities V: *Spatial, Design, Landscape, Heritage & Socio-economic Dimensions*, 133 (2022)
12. D. Capasso Da Silva, D.A. King, S. Lemar, Sustainability **12**, 129 (2019)
13. S. El Khateeb, I.M. Shawket, Dev. Built Environ. **9**, 100065 (2022)
14. L.A. Guzman, et al., Travel Behav. Soc. **24**, 245 (2021)
15. R. Rafiemanzelat, M.I. Emadi, A.J. Kamali, Transp. Res. Procedia **24**, 97 (2017)
16. J. Arellana, et al., Transp. Rev. **40**, 183 (2020)
17. F. Abastante, et al., Sustainability **12**, 8131 (2020)
18. F. Alves, et al., Sustainability **12**, 7360 (2020)
19. C.M. Hall, Y. Ram, Transp. Res. D: Transp. Environ. **61**, 310 (2018)
20. M. Ignaccolo, et al., Eur. Transp.- Trasp. Eur. **76**, (2020)
21. G. Lefebvre-Ropars, et al., Transp. Res. D: Transp. Environ. **57**, 378 (2017)
22. A.B. Tsiompras, *Walk and the city. Development and implementation of a combined walkability index in a GIS environment. Case study: urban complex of Volos*, School of Engineering U.Th., (M.T.) (2013)
23. A. Georgiou, A. Skoufas, S. Basbas, Case Stud. Transp. Policy **9**, 889 (2021)
24. T. Campisi, et al., Transp. Res. Procedia **60**, 124 (2022)
25. I. Boulmou, et al., Walkability Evaluation: The Case Studies of Veroia and Igoumenitsa, Greece, *Conference on Sustainable Urban Mobility* (2022)
26. G. Barmpas, et al. Evaluating Pedestrian Environments: Evidence from Small Cities in Greece, *Conference on Sustainable Urban Mobility* (2020)
27. A. Galanis, N. Eliou, WSEAS Trans. Environ. Dev. **7**, 385 (2011)
28. M.M. Cysek-Pawlak, M. Pabich, J. Urban **14**, 409 (2021)
29. P.J.M. de Cambra, I.S.T., (2012)
30. A. Shashank, N. Schuurman, Health Place **55**, 145 (2019)
31. J.A. Hirsch, et al., Am. J. Prev. Med. **45**, 158 (2013)
32. J. Burian, *Advances in Spatial Planning*. InTech. (2012)
33. R. Ceylan, J. Multidiscip. Res. **1**, (2018)
34. A. Tsakalidis, A. Sdoukopoulos, N. Gavanas, Fresenius Environ. Bull. **23**, 2819 (2014)
35. K.K. Lwin, Y. Murayama, Comput. Environ. Urban Syst. **35**, 408 (2011)
36. K. Dovey, E. Pafka, Urban Stud. **57**, 93 (2020)
37. E. Jamei, et al., Sustainability **13**, 5731 (2021)
38. R. Agampatian, *Using GIS to measure walkability: A Case study in New York City, in School of Architecture and the Built Environment*, Royal Institute of Technology (KTH). (2014)
39. Z. Dobesova, T. Krivka, *Walkability index in the urban planning: A case study in Olomouc city*, Advances in spatial planning (2012)
40. T. Al Shammas, F. Escobar, Int. J. Environ. Res. Public Health **16**, 2850 (2019)
41. G. Fancello, T. Congiu, A. Tsoukiàs, Socioecon. Plann. Sci. **72**, 100923 (2020)
42. Official Government Gazette of the Hellenic Republic, OGG 269/APP/2018 (2018)
43. H.S.A., Census Results 2023 (2023)
44. Municipality of Larissa, Operational Programme Municipality of Larissa 2015-2019 (2015)
45. Municipality of Larissa, Sustainable Urban Development Strategy. (2017)
46. Municipality of Larissa, Application for the european green power award 2016 (2013)
47. G. Kolimitras, *Exploring the physiognomy from the territory of Volos|Larissa: from the distant history of the two places to the discovery of the future reality*, School of Architecture N.T.U.A., (2019)
48. Municipality of Larissa, Urban Mobility Study for the Municipality of Larissa (2015)
49. D.P. Gaimanis, *Methodology for assessing the quality of walking in the urban environment*, School of Spatial Planning and Development A.U.Th. (M.T.) (2019)
50. A. Rebecchi, et al., Sustainability **11**, 2778 (2019)
51. D. Svoronos, *Quality of life and modern cities: geographic analysis and evaluation of the pedestrian traffic network of the municipality of Halandri in a GIS environment*, School of Rural, Surveying and Geoinformatics Engineering N.T.U.A.(M.T.) (2014)
52. A.B. Tsiompras, Y.N. Photis, Transp. Res. Procedia **24**, 523 (2017)

53. V. Beltsiou, *Calculation of Walkability Index for the Center of Larissa and Feedback on Urban Planning,* Department of Planning and Regional Development, U.Th. (M.T.) (2022)
54. T.L. Saaty, L.G. Vargas, *Models, methods, concepts & applications of the analytic hierarchy process* (ISOR **175**) (Springer, New York 2012)
55. K. Teknomo, Sci. Res. Publ. **6**, (2006)
56. M.O.U.D. Programmes, *Guide urban road redesign of municipalities* (2019)
57. P. Molaei, L. Tang, M. Hardie, World, **2**, 49 (2021)
58. F. Roozkhosh, M. Molavi, A. Salaripour, J. Archit. Urban. **44**, 1 (2020)