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

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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:

- green, smart, affordable and healthy mobility
- minute cities, most residents can meet their needs within 15 minutes by walking or cycling or using some other means of public transport

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, services, leisure facilities, schools, hospitals and sports are within close proximity, ten minutes walk or cycling distance. In the post-pandemic city the NU concept wants to emphasize and promote the local and vulnerable people of the network centres and support the decrease of public transport due to limited capacity, as well as reduce the number of vehicles per capita and road infrastructure. This aims to reduce the total travel time, increase walkability and improve air quality and noise pollution. In this context the "15-minute city" became a desire of Paris, as the mayor of Paris, Anne Hidalgo also work. This idea was supported by Paris, as the current mayor of Paris, Anne Hidalgo. The 15-minute city is a vision that aims to create a city with a structure that is accessible to all and the walkable community. It is a concept that seeks to create a city where people can live, work, play, and access services within a 15-minute radius on foot or bicycle.

In summary, walkability is an important aspect of sustainable urban development and should be considered in the planning and design of cities. It is a key factor in promoting healthy and active lifestyles, reducing traffic congestion and pollution, and improving the overall quality of life for residents. The walking index constructed in this study can provide valuable insights into the walkability of a medium-size Greek city, which can be used to inform future urban planning and development decisions.
2 The concept of walkability

Walkability: The concept of walkability is important for quality of life in cities. It is defined as the degree to which urban areas are conducive to walking. Various factors contribute to walkability, including connectivity, land uses, pavement characteristics, and the presence of pedestrian-friendly features like sidewalks and bike lanes. Walking should be one of the main modes of transport in sustainable cities.

Accessibility: It is easy to get somewhere through walking in a walkable city. It provides easy access to the workplace, schools, shops, services or transport stations (e.g., bus, train). High walkability contributes to mobility networks, quality of life and health, and economic growth.

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 to measure whether an urban area is walkable or not.
methodology for constructing and calculating the walkability index.

![Flow chart of methodology](image)

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].

### 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>
<thead>
<tr>
<th>Parameters</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Residential Density</td>
<td>Residential density</td>
</tr>
<tr>
<td>2.Land-use mix Density</td>
<td>Land-use mix density</td>
</tr>
<tr>
<td>3.Connectivity</td>
<td>Connectivity</td>
</tr>
<tr>
<td>4.Sidewalk Condition</td>
<td>Sidewalk condition</td>
</tr>
<tr>
<td>5.Pedestrian Friendly Areas</td>
<td>Pedestrian friendly areas</td>
</tr>
</tbody>
</table>

**Phase 2:**

- The walkability index is calculated and the main variables and parameters are weighted with the weight of each parameter.
- The AHP methodology is used in the calculation of the weight number and the average weight number is calculated as an average.
- The results are visualized through颜色 symbols, as shown in Figure 2.

**Phase 3:**

- The study area is divided into 4 sub-areas, and the walkability index is calculated for each sub-area using the parameters and the weight of each parameter.
- The results are visualized through color symbols, as shown in Figure 2.

![Study Area](image)
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 2. Calculation of weighting for each parameter based on the literature review

<table>
<thead>
<tr>
<th>P</th>
<th>Weights</th>
<th>Average</th>
<th>Ave/ Sum_Ave</th>
<th>Per %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>p1%</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>p2%</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>p3%</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>p4%</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>p5%</td>
</tr>
</tbody>
</table>

After collecting all the necessary data and doing 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

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W1</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W2</td>
<td>50%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>16%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W4</td>
<td>15%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W5</td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The final equation for the calculation of the walkability index was formulated as 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).
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 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.

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436 E3S Web of Conferences 436, 12003 (2023) https://doi.org/10.1051/e3sconf/202343612003