

Repositório ISCTE-IUL

Deposited in *Repositório ISCTE-IUL*:

2026-10-21

Deposited version:

Accepted Version

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

Sampaio de Almeida, D., Simões, R., Brito e Abreu, F., Lopes, A. & Boavida-Portugal, I. (2025). A carrying capacity calculator for pedestrians using OpenStreetMap data: Application to urban tourism and public spaces. In Lyndon Nixon, Aarni Tuomi, Peter O'Connor (Ed.), *Proceedings of the ENTER 2025 eTourism Conference* (pp. 79?90). Springer. https://doi.org/10.1007/978-3-031-83705-0_7

Further information on publisher's website:

[10.1007/978-3-031-83705-0_7](https://doi.org/10.1007/978-3-031-83705-0_7)

Publisher's copyright statement:

This is the peer reviewed version of the following article: Sampaio de Almeida, D., Simões, R., Brito e Abreu, F., Lopes, A. & Boavida-Portugal, I. (2025). A carrying capacity calculator for pedestrians using OpenStreetMap data: Application to urban tourism and public spaces. In Lyndon Nixon, Aarni Tuomi, Peter O'Connor (Ed.), *Proceedings of the ENTER 2025 eTourism Conference* (pp. 79?90). Springer. https://doi.org/10.1007/978-3-031-83705-0_7, which has been published in final form at https://dx.doi.org/10.1007/978-3-031-83705-0_7. This article may be used for non-commercial purposes in accordance with the Publisher's Terms and Conditions for self-archiving.

Use policy

Creative Commons CC BY 4.0

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a link is made to the metadata record in the Repository
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

A Carrying Capacity Calculator for Pedestrians Using OpenStreetMap Data: Application to Urban Tourism and Public Spaces

Duarte Sampaio de Almeida¹, Rodrigo Simões¹, Fernando Brito e Abreu¹,
Adriano Lopes¹, and Inês Boavida-Portugal²

¹ ISTAR-IUL, Instituto Universitário de Lisboa (Iscte-IUL), Lisbon, Portugal
dsbaa@iscte-iul.pt,

² University of Lisbon, Centre of Geographical Studies, Institute of Geography and
Spatial Planning, Lisbon, Portugal

Abstract. Determining the carrying capacity of urban tourism destinations and public spaces is essential for sustainable management. This paper presents an online tool that calculates pedestrian carrying capacities for user-defined areas based on OpenStreetMap (OSM) data. The tool considers physical, real, and effective carrying capacities by incorporating parameters such as area per pedestrian, rotation factor, corrective factors, and management capacity. The carrying capacity calculator helps balance environmental, economic, social, and experiential factors to prevent overcrowding and preserve the quality of life for residents and visitors. This tool can be used for tourism destination management, urban planning, and event management to ensure positive visitor experiences and sustainable infrastructure development. We detail the implementation of the calculator, its underlying algorithm, and its application to the Santa Maria Maior parish in Lisbon, highlighting its effectiveness in managing urban tourism and public spaces.

Keywords: carrying capacity, pedestrians, OpenStreetMap, overcrowding, tourism

1 Introduction

Determining carrying capacity is essential for the sustainable management of tourism destinations and public urban spaces, balancing environmental, economic, social, and experiential factors. Understanding carrying capacity helps minimize environmental impacts by limiting visitor numbers to levels that do not degrade natural resources and ecosystems, thereby preserving biodiversity and heritage sites. Capacity management enhances the visitor experience by ensuring positive experiences free from long waits, congestion, and inadequate facilities and by maintaining safety standards to prevent accidents and hazards. It also guides sustainable infrastructure development and maintenance, preventing overuse and managing the costs of repairing overused facilities. Carrying capacity informs regulatory and planning efforts, helping policymakers create

effective regulations and guidelines and assisting urban planners and event managers in designing spaces that sustainably accommodate the intended number of visitors. It also provides a feedback mechanism for ongoing monitoring and adaptive management strategies to address emerging issues, enabling data-driven decisions that improve sustainability.

Determining this capacity is especially important in tourist hotspots. While buses, trains, planes, and cruise ships can bring large groups of tourists to a destination, overcrowding occurs when these tourists congregate in pedestrian areas. For example, cruise ships regularly drop off thousands of tourists in Lisbon, Venice, Dubrovnik, and Santorini. However, the reported problems with overcrowding, especially those that cause adverse reactions from residents, occur in pedestrian areas in old neighborhoods rather than in cruise terminals or train or bus stations [1,2,3]. Therefore, a pedestrian carrying capacity calculator is an essential tool in several fields, such as tourism destination management, urban management, event management (e.g., concerts, music festivals, political rallies, fireworks, plays), and attraction management (e.g., monuments, museums, theme parks, archaeological sites). We could not find such a tool in the literature, even when looking at the many studies using the Tourism Carrying Capacity (TCC) concept.

In this paper, we present a novel tool that calculates the pedestrian carrying capacity in a user-defined area interactively defined on OpenStreetMap (OSM), an open geographic database with worldwide coverage, collaboratively updated and maintained by a large community of volunteers following a peer production model like that of Wikipedia [4]. A case study on the parish of Santa Maria Maior in Lisbon, Portugal, demonstrates the tool’s functionality and usability.

2 Background

2.1 The OpenStreetMap initiative

The OSM is a worldwide open data geographic mapping project developed since 2004 through the contribution of a large community of volunteers worldwide. The mapping elements are stored in a geographic database, which can be used without limitations as long as credit is given. Currently, OSM has a comprehensive coverage of the earth’s surface, and major cities are represented with significant accuracy. The project’s data gathered, stored, and served consists of an immense set of geographic entities characterized by tags, i.e., key-value pairs, referenced in OSM’s data model as elements of the following three main types: nodes, ways, and relations. Nodes are single points, while ways and relations can be uni- or bi-dimensional.

OSM data can be accessed mainly via the following sources: (1) The Planet.osm file, containing all mapped data; (2) Export files, containing small portions of the former; (3) Third-party providers and (4) the free, public, Overpass API.

2.2 Carrying capacity

The concept of Carrying Capacity (CC), originally from Ecology, is defined as the maximum supported population for a given environment until there are no sufficient resources to maintain its growth and degradation starts to occur. One of the first usages of this concept was in the Malthusian population theory [5], which states that the exponential growth of the human population is limited to existing resources, turning the growth model into a logistic model, being its upper limit the CC of the human population.

The concept has been applied in multiple other fields, such as Economy, Biology, and population studies [6], and has had various definition iterations according to its application. In the context of tourism, it is known as TCC. According to the [UN World Tourism Organization \(UNWTO\)](#), the TCC is defined as “the maximum number of people that may visit a tourist destination at the same time, without destroying the physical, economic, social-cultural environment and an unacceptable decrease in the quality of visitors’ satisfaction” [7].

Some authors argue that the TCC is a “magic value” [8], dependent on many realistically hard-to-model variables, which can lack stability. However, they also acknowledge the usefulness of TCC research for managing tourist sites. In other words, while the TCC is considered an imperfect measure for a touristic destination’s actual CC, it can be used as a reference value to measure overcrowding and compare scenarios. We now describe the three levels of TCC proposed in the seminal methodology of [9]: physical, real, and effective.

Physical Carrying Capacity (PCC) - This level of TCC represents the maximum number of visitors that can be physically accommodated into an area over some time. It is calculated using the following formula:

$$PCC = \frac{A}{Ap} \times Rf$$

where A is the available area for tourism activity, Ap is the area used per tourist for a specific type of tourism activity, and Rf is the rotation factor, which is the permissible visitation period, depending on the target time scale (e.g., daily open hours, weekly open days) and calculated by dividing the usable time for tourists by the meantime of a visit (in the same time scale). Examples of calculating the rotation factor can be found in [10,11,12,13].

Real Carrying Capacity (RCC) - This value is derived from the PCC, applying corrective factors with different natures (e.g., physical, ecological, socioeconomic) specific to the location. The formula to assess RCC is:

$$RCC = PCC \times (cf1 \times cf2 \times \dots \times cfn)$$

where $cf1 \dots cfn$ are the defined corrective factors. Each factor is calculated using the expression:

$$cf = 1 - \frac{Lm}{Tm}$$

where Lm is the limiting magnitude of the factor, and Tm is the total magnitude of the factor. Illustrative examples of the application of corrective factors (aka “correction factors”) can be found in [14,15,11,12,16,13].

Effective Carrying Capacity (ECC) - The final level of TCC is derived from the RCC, as

$$ECC = RCC \times Mc$$

where Mc is the management capacity of the site. The availability of infrastructure, equipment, and staff adequacy for tourism activity often determines this variable.

Regarding management capacity (a percentage), the seminal work on TCC [9] advocates that we should consider various variables such as the juridical circumstances, policies, protocols, apparatus, peoples, capital, infrastructure, and facilities. Estimation examples can be found in [10,12,13].

Although many studies use this methodology, to the best of our knowledge, there is no computer-based solution that allows their calculation on a user-defined area of a map.

3 Calculating the available area for pedestrians

Since, as discussed earlier, tourism activity occurs mainly in pedestrian areas, we need to compute the “available area” for pedestrians (aka “walkable area”) as part of the PCC. Our algorithm takes (i) a bounding polygon representing the area from which the available area is to be computed, (ii) the list of OSM geographic features in GeoJSON format within its boundary, and (iii) an options object (see section 4). It then computes the corresponding available area from the bounding polygon, also in GeoJSON format, according to the following steps:

1. The input OSM features are filtered, selecting those considered obstructions or inaccessible, “unavailable” to pedestrians, and sorted by type for specific processing using the tagging system that this data type provides. The main “unavailable” features are surface level (layer 0) buildings, water bodies, roads, railways, restricted areas (e.g., airways, military zones), urban furniture, trees, small monuments (e.g., monuments that are not polygonal buildings), and barriers. More types will be added in future releases, as OSM has many tags and feature types and some conventions for representing features that may not have been considered in this release.
2. The sorted features are then processed. Polygons require a small spatial buffer to avoid intersection errors. Zero- or one-dimensional features must be transformed into polygons (e.g., points, line strings). This is done by adding a buffer size specific to the feature type. Notable examples are roads and railroads, represented in OSM as strings of lines, although they are two-dimensional (considering the 2D aerial view). Using data available in OSM (e.g., parking spaces, number of lanes, access) and public space manuals

that provide reference values for lane widths, parking space sizes, and other relevant information, the width of these features is estimated and converted to polygonal form. Water features with bridges also require special processing to include the bridges in the available area (if applicable).

3. Using the *difference* geometric operation from the [Turf.js](#) geospatial library, it subtracts the previously selected and processed features from the bounding polygon, leaving only the pedestrian accessible area feature.

In summary, the algorithm filters and processes features inaccessible to pedestrians and subtracts them from the bounding polygon, leaving the area available for pedestrians. It is currently implemented in *JavaScript (JS)* to run locally in browsers, not needing dedicated servers, thus making the solution scalable. As the *difference* function from *Turf.js* does not support multi-polygon operations, we need to iteratively calculate the difference between the current accumulative difference and the next feature to remove all inaccessible polygons. When the complexity of the accumulative difference increases (i.e., the amount of inaccessible features subtracted from the bounding increases), the execution time of the operation also increases. The compound effect of subsequent, iterative difference operation calls makes the execution time increase more than linearly with the number of inaccessible features. The solution to this problem is to split the bounding polygons into $N = N^{CPUcores} \times 2$ sub-polygons in a grid, apply the algorithm in each sub-polygon to calculate its available area, and use the *union* operator to join the calculated sub-polygons into a single feature, obtaining the available area within the original bounding polygon.

Although JS is a single-threaded programming language, meaning there is no proper parallelization, modern browsers support the use of the [Web Workers API](#). This API allows the execution of JS scripts in the background, harnessing multi-core parallelization of execution threads that are not possible with pure JS. The application presented in this paper uses this feature to calculate available areas of sub-polygons of a bounding polygon in parallel, making algorithm running time much faster than if in single-threaded mode. Execution time will vary depending on the number of available CPU cores on the machine, core speed, background processes, etc., so a performance analysis should be conducted in future work to better assess bottlenecks and improvement paths for this tool.

4 The carrying capacity calculator tool

This tool is implemented as an extended version of the [geojson.io](#) web application, where the user can parameterize the previously described algorithm to obtain the three levels of TCC. The target areas may be selected as follows:

- user pastes the features in GeoJSON format in the right panel;
- user uses one of the available polygonal shape tools (circle, rectangle, and polygon) to draw the target area(s);

Figure 1 shows a screenshot of the tool, where we can observe a set of polygons representing Lisbon parishes, overlaying the map, its GeoJSON data in the panel to the right, and the list of available tools to draw new features.

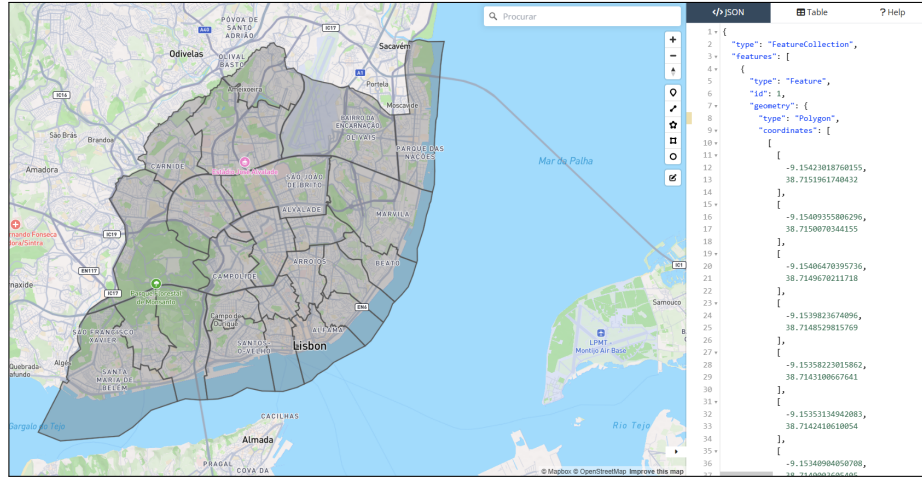


Fig. 1: Lisbon parish boundaries rendered from *Lisboa Aberta*'s GeoJSON data on the right panel (Source: authors' own)

After selecting an area of interest, the panel shown in Figure 2 offers a set of options to calculate the available walking area:

- remove inner areas within buildings that may not be publicly accessed;
- classify roads as walkable to account for road blockages during special events (e.g., festivities, marathons, parades);
- classify grass as not walkable to remove vegetation spaces possibly restricted for pedestrian stepping.

When the user presses the **“Calculate carrying capacity”** button shown in Figure 2, the tool uses the Overpass API to retrieve the features within the selected area (by clicking on it), converts them to GeoJSON format, and passes them to the algorithm described in section 3 to calculate the available area for pedestrians. The API's retrieve time is also a notable factor in the total calculation running time, and fair use is advised. An in-house dedicated private API instance could scale and mitigate this problem, requiring more computational resources or allowing the user to provide geographic data. Since the corresponding computation can take some time in the case of large areas, a completion indicator in percentage is shown after the OSM data is fetched for the user to monitor progress. When this more intensive processing is done, the available areas are rendered brown, as depicted in Figure 3.

Once the available area is calculated, a popup panel like the one shown in Figure 4 displays the statistics regarding the total available area and its overall percentage), as well as input fields where the user can enter the area per pedestrian, the rotation factor, custom correction factors, and the management capacity, and obtain the values of the various stages of TCC. The available area feature can be saved in GeoJSON format, and the TCC parameters and results can be saved in CSV format, allowing their usage in other tools.

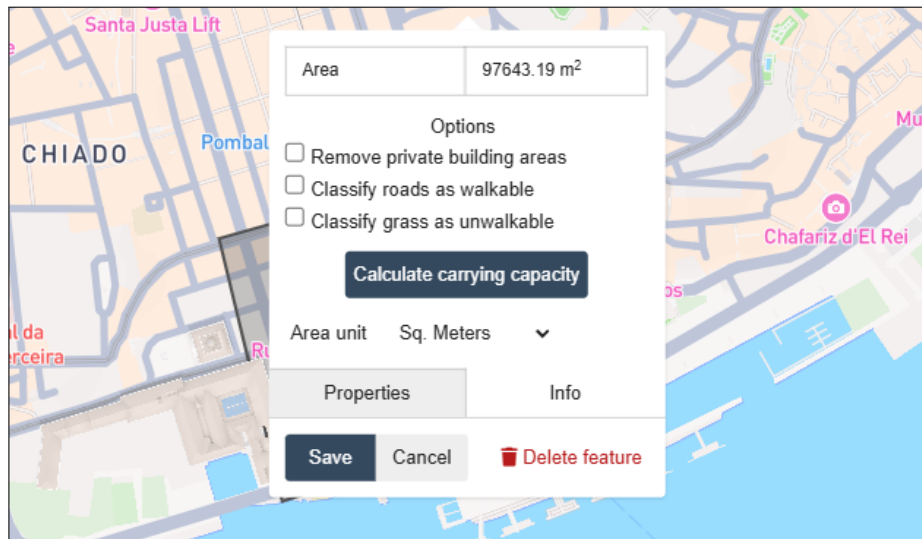


Fig. 2: Available options before triggering TCC calculation (Source: authors' own)



Fig. 3: Pedestrians available area in Santa Maria Maior parish (Source: authors' own)

5 Demonstration case study

We will now describe how the TCC parameters could be determined using the Parish of Santa Maria Maior (SMM) in Lisbon as a case study. Since determining adequate input values for these calculations requires an in-depth analysis of the tourism dynamics of the assessed space, the values were chosen based on plausibility to demonstrate the tool's usage.

Available (Walkable) Area - The available area for pedestrians is automatically calculated using the algorithm above - this area for SMM was determined as $661,585m^2$. Figure 3 shows the available area of the parish.

Area per Pedestrian - This parameter is crucial for comfortable tourism activity. We considered $5.6m^2$ per pedestrian to foster a comfortable experience where tourists can move freely. This value corresponds to the lower limit of the Level of Service A for walking pedestrians proposed in [17], providing adequate pedestrian mobility.

Rotation Factor - The time available to tourists in a day to visit the parish of SMM is about ten hours (number of commercial opening hours - from 9 a.m. to 7 p.m.), and the average duration of a visit is 4 hours. Therefore, $Rf = 10/4 = 2.5$.

Corrective Factors - Determining corrective factors is a challenging aspect of calculating TCC. This tool allows the user to add corrective factors to model the TCC of desired areas. For illustration, we have considered only two, one related to temperature and another related to precipitation. Based on data from the [Portuguese Institute for Sea and Atmosphere \(IPMA\)](#), we considered that Lisbon experiences, on average, about 290 days per year where the minimum temperature does not fall below 10 degrees Celsius. Therefore, the temperature correction factor is $290/365 = 79.45\%$.

Also, based on IPMA data, we considered that the average number of days when rainfall exceeds 3mm is 65, so the rainfall correction factor is $(365 - 65)/365 = 82.19\%$. Because of the possible correlation between these factors, a common correction factor could be derived from them (e.g. weather). Ideally, the corrective factors should be uncorrelated to avoid underestimating the TCC.

Area	3015455.16 m ²
Walkable Area	661585.20 m ² 21.94%
Area per Pedestrian	5.6 m ²
Rotation Factor	2.5
PCC	295351 visitors
Temperature Corrective Factor	0.7945 ✓
Rainfall Corrective Factor	0.8219 ✓
+ Add Corrective Factor	
RCC	192864 visitors
Management Capacity	0.7775
ECC	149952 visitors
Area unit	Sq. Meters ▼
Download GeoJSON	Download CSV
Properties	Info
Save	Cancel Delete feature

Fig. 4: TCC parameterization and results panel (Source: authors' own)

Management Capacity - Estimating this parameter (as a percentage) for the SMM parish in Lisbon would require a comprehensive analysis of several factors, as described in the seminal work on TCC [9]. Since we are concerned with presenting a plausible value, we decided to use foundational Large Language Models (LLMs) to obtain it. To this end, we presented the following prompt to *OpenAI’s ChatGPT* and *Microsoft’s Copilot*: “*The management capacity of a tourist destination (a percentage) expresses the adequacy of the available infrastructure, equipment, and personnel for the tourist activity. The seminal work on Tourism Carrying Capacity [Cifuentes1992] advocates that we should consider juridical circumstances, policies, protocols, apparatus, people, capital, infrastructure, and facilities. Please estimate the management capacity of the Santa Maria Maior parish in Lisbon.*” After some prompt engineering, ChatGPT answered 75.5% and Copilot answered 80%, so we took the average, i.e. 77.75%. This value is for demonstration purposes only, and although it seems plausible, its reliability cannot be verified and may be doubtful, as LLMs most likely do not have all the knowledge required to calculate a sound value for the management capacity.

Results - As shown in figure 4, the defined parameterization resulted in the calculation of a PCC of 295,351, a RCC of 192,864, and a ECC of 149,952 (daily) visitors. The available area for pedestrians in this scenario, whose bounding polygon covers a dense urban area of approximately $1,350,000m^2$, was computed on a low-end laptop with a quad-core AMD Ryzen 3 4300U CPU with no other foreground processes. After fetching the OSM data from the Overpass API, it took only about 91 seconds to compute the available area for pedestrians. Machines with faster CPUs and more cores should run the algorithm much faster. In addition, the test scenario is relatively complex/extensive, so the desired scenarios may be more straightforward and, therefore, even quicker to compute. Both factors confirm our belief that the performance of this tool will be sufficient for most scenarios.

An instance of this carrying capacity calculator tool can be freely explored online at <http://carryingcapacity.eu/> and its source code is available on [GitHub](#).

6 Conclusions and future work

We developed an online tool to calculate and visualize available (or walkable) outdoor space for pedestrian use and the three stages of TCC. It is a web app built as an extension of the *geojson.io* tool, allowing a user to select GeoJSON areas on a map and calculate and save the available area within those geometries using *OpenStreetMap* open georeferenced data. Given user input, the resulting available area is then used to calculate carrying capacity levels.

The core calculations are performed locally, requiring only OSM data fetches. The *Web Workers API* allows multiple CPU cores to be used in parallel for faster execution, making this tool highly scalable. To demonstrate its capabilities, we used it to calculate the TCC stages of the SMM parish in Lisbon.

This capacity calculator can help various stakeholders with its wide range of applications. Event organizers can use it to plan and manage the layout of

venues to ensure safe and comfortable occupancy levels for concerts, festivals, and rallies. Emergency response coordinators can use it to plan and manage evacuation procedures and shelter capacity effectively. Public space designers and managers can create parks, plazas, and other public spaces that accommodate visitors comfortably and safely.

This online tool is designed to calculate pedestrian carrying capacity to manage overcrowding in public spaces, which is often a source of local dissatisfaction. This tool can indirectly improve the coexistence of residents and tourists by leveraging initiatives to reduce overcrowding.

Last but not least, researchers can use this tool to determine TCC values of open spaces in scientific studies. We look forward to this tool being used in future studies/projects and to users providing feedback to help us improve it.

We plan to enhance the tool and underlying algorithm, improving available area accuracy, running speed, and customization, and allowing the usage of other free or proprietary geographical data sources (e.g., Google, Bing, Apple, governmental data, user custom data not mapped by major mappers) and adding new useful features suggested by users, such as providing corrective factor suggestions, based on the socio-economic, ecologic and geographic settings of the destination to assess, and area per pedestrian suggestions, based on values provided by studies or public space manuals. Alternative methodologies to calculate TCC can also be available for users.

The tool could impact the future of destination planning capacity, as its readiness and availability allow practitioners and researchers worldwide, without great computational power and monetary resources, to assess available areas for tourists/pedestrians of open spaces over a map, using existing polygonal areas or drawing on a map with the tool. As the tool evolves, so does its usefulness in obtaining reference values for the carrying capacity of destinations, and this data can be combined with simpler crowd monitoring technologies such as sensors, cell phone counts, or compound, more advanced technologies, such as Digital Twins (DT), to assess and manage the levels of tourism crowding in destinations, allowing practitioners to apply overcrowding mitigation measures in destinations, improving tourism activity sustainability, and limiting the degradation of the destination and the quality of life of its residents.

Acknowledgments

This tool was developed by the [Iscte-IUL team](#) on the [RESETTING project](#), funded by the [European COSME program](#), managed by [EISMEA \(European Innovation Council and SMEs Executive Agency\)](#), under the COS-TOURINN 101038190 grant. The Portuguese FCT also partially funded it under projects UIDB/04466/2020 and UIDP/04466/2020. INCD, the Portuguese National Distributed Computing Infrastructure, provided the cloud infrastructure used, funded by FCT and FEDER under project 01/SAICT/2016 #022153.

References

1. Centre of Expertise Leisure Tourism & Hospitality Sciences, NHTV Breda Univ. of Applied Sciences, and NHL Stenden Univ. of Applied Sciences, *'Overtourism'? – Understanding and Managing Urban Tourism Growth beyond Perceptions, Executive Summary*. United Nations World Tourism Organization (UNWTO), 2018.
2. K. Koens, A. Postma, and B. Papp, "Management strategies for overtourism: From adaptation to system change," in *Overtourism: Tourism Management and Solutions*, pp. 149–160, Routledge, 2019.
3. N. Camatti, D. Bertocchi, H. Carić, and J. van der Borg, "A digital response system to mitigate overtourism. the case of dubrovnik," *Journal of Travel & Tourism Marketing*, vol. 37, no. 8-9, pp. 887–901, 2020.
4. M. Haklay and P. Weber, "Openstreetmap: User-generated street maps," *IEEE Pervasive computing*, vol. 7, no. 4, pp. 12–18, 2008.
5. I. Seidl and C. A. Tisdell, "Carrying capacity reconsidered: From Malthus' population theory to cultural carrying capacity," *Ecological Economics*, vol. 31, no. 3, pp. 395–408, 1999.
6. J. Kennell, "Carrying Capacity of Tourism," in *Encyclopedia of Tourism*, pp. 1–2, Springer, 2014.
7. W. T. Organization, *Technical Handbook on the Collection and Presentation of Domestic and International Tourism Statistics*. World Tourism Organization, 1981.
8. S. F. Mc Cool and D. W. Lime, "Tourism carrying capacity: Tempting fantasy or useful reality?," *Journal of Sustainable Tourism*, vol. 9, no. 5, pp. 372–388, 2001.
9. M. Cifuentes, "Determinación de Capacidad de Carga Turística en Áreas Protegidas," 1992.
10. N. Insani, Y. Ariani, F. Arachman, and D. Wibowo, "Carrying capacity estimations to support tourism coastal management in ungapan beach indonesia," in *IOP Conference Series: Earth and Environmental Science*, vol. 485, p. 012036, IOP Publishing, 2020.
11. R. Jangra and S. P. Kaushik, "Estimating carrying capacity in a high mountainous tourist area: A destination conservation strategy," in *Global Geographical Heritage, Geoparks and Geotourism: Geoconservation and Development*, pp. 427–447, Singapore: Springer Singapore, 2021.
12. I. A. Putri and F. Ansari, "Managing nature-based tourism in protected karst area based on tourism carrying capacity analysis," *Journal of Landscape Ecology*, vol. 14, no. 2, pp. 46–64, 2021.
13. S. Bera and D. D. Majumdar, "Assessment of tourism carrying capacity for the sustainable tourism development of south andaman, india," in *Crisis on the Coast and Hinterland: Assessing India's East Coast with Geomorphological, Environmental and Remote Sensing and GIS Approaches*, pp. 367–381, Springer, 2023.
14. E. Suwarno and H. B. Widjaya, "Analysis of tourism environment carrying capacity in goa kiskendo forest tourism bkph boja kph kendal," in *E3S Web of Conferences*, vol. 73, p. 04015, EDP Sciences, 2018.
15. M. De Vera, "Localized effective tourism carrying capacity using tourist proxemics and corrective factors, the case of sabang beach in baler, aurora, philippines," in *IOP Conference Series: Earth and Environmental Science*, vol. 294, pp. 1–10, IOP Publishing, 2019.
16. A. Petronijevic, "Practical application of the tourism carrying capacity concept in cultural tourism," *Turizam*, vol. 26, no. 2, pp. 114–123, 2022.
17. M. Roupail and P. Allen, "Recommended procedures: Pedestrians," in *Highway Capacity Manual*, ch. 13, pp. 1–56, Transportation Research Board, NRC, 1998.