Journal of Infrastructure, Policy and Development 2024, 8(16), 9391.
https://doi.org/10.24294/jipd9391

Article

Temporal and mode-based accessibility to urban tourism spots: A spatial travel time analysis—Budapest

Moaaz Kabil[1,2,*], Thaib Alharethi[3], Hazem Kapil[2], Edit Ilona Pallás[1], Lóránt Dénes Dávid[1,4,5,6,*]

[1] Hungarian University of Agriculture and Life Sciences (MATE), 2100 Gödöllő, Hungary
[2] Faculty of Urban and Regional Planning, Cairo University, Giza 12613, Egypt
[3] Faculty of Tourism, King AbdulAziz University, Jeddah 21589, Kingdom of Saudi Arabia
[4] Faculty of Economics and Business, Department of Tourism and Hospitality, John von Neumann University, HU-6000 Kecskemét, Hungary
[5] Faculty of Social Sciences, Savaria University Centre, Savaria Department of Business Economics, Eötvös Loránd University, HU-9700 Szombathely, Hungary
[6] Széchenyi István University, HU-9026 Győr, Hungary
*** Corresponding authors:** Moaaz Kabil, moaazkabil@cu.edu.eg; Lóránt Dénes Dávid, david.lorant.denes@uni-mate.hu

CITATION

Kabil M, Alharethi T, Kapil H, et al. (2024). Temporal and mode-based accessibility to urban tourism spots: A spatial travel time analysis—Budapest. Journal of Infrastructure, Policy and Development. 8(16): 9391. https://doi.org/10.24294/jipd9391

ARTICLE INFO

Received: 29 September 2024
Accepted: 31 October 2024
Available online: 18 December 2024

Abstract: Efficient access to tourist spots is necessary for enhancing the overall travel experience, especially in urban environments. This study investigates the accessibility of key tourist spots in Budapest through different transportation modes (e.g., walking, cycling, and public transport) across various time intervals. Using spatial-temporal travel time maps and detailed statistical analysis, the research highlighted significant differences in how these modes connect tourists to their attractions. Cycling stands out as the most efficient transportation option, providing rapid access to a wide range of tourist spots, while public transport ranks second. However, the study also reveals disparities in accessibility, with central areas being well-served, while outer ones, especially in the northwest, remain less accessible. These findings highlight the need for targeted transportation improvements to ensure that all areas of the city are equally reachable. The results offer valuable insights for urban planners and policymakers aiming to enhance tourism infrastructure and improve the visitor experience in Budapest.

Keywords: tourism attractions; urban mobility; spatial temporal analysis; circular urban tourism; Hungary

1. Introduction

Urban tourism has become a significant component of the tourism industry, driven by the increasing attractiveness of cities as unique hubs of culture, history, and modern amenities (Edwards et al., 2008; Miller et al., 2015). Although there is not a unified definition of urban tourism, it generally refers to travel to cities and urban areas for leisure purposes, where tourists engage in activities such as sightseeing, cultural activities, and enjoying local experiences such as trying local cuisine or food (Ashworth and Page, 2011). In recent decades, the importance of the cities as tourism destinations has increased due to the concentration of attractions, ease of access, and the various unique experiences they offer. This reflects tourists' preference for cities where they can optimize their time by visiting many tourist spots and experiencing the daily life of local communities in these cities (Ashworth and Page, 2011; Edwards et al., 2008). These factors enhance the overall satisfaction of the tourist experience. Also, urban tourism faces various challenges such as overtourism, cultural heritage conservation, environmental preservation, and respecting local community values (Timur and Getz, 2008). These obstacles also make this tourism pattern a desirable research area for many scholars in the tourism academia (Pearce, 2001).

Based on the variety of factors that make cities desirable tourism destinations, the accessibility of the city tourist attractions appeared as a fundamental issue for tourists, local communities, and national governments. In this context, accessibility refers to the ease with which tourists can transfer between various attractions and services within the urban city (Dalvi and Martin, 1976; Şahin Körmeçli, 2024). This directly influences the flow of tourists and their overall experience in the city. For example, providing high levels of accessibility to tourist attractions within the city, by making them be visited within a limited and short time frame, increasing visitors' satisfaction and likelihood of return. In contrast, poor accessibility can discourage potential visitors, result in negative experiences, and eventually impact the economic vitality of the tourism industry in the city (Masiero and Hrankai, 2022; Morrison and Maxim, 2021).

The concept of accessibility of the tourist spots within the city can be discussed from two core dimensions, each playing a critical role in shaping tourist behavior and experiences. The first dimension is temporal accessibility, which is defined as the availability of transportation options to reach tourist attractions during specific time intervals. Temporal accessibility is fundamental for understanding how tourists interact with a city, as it affects the timing of visits to attractions, the flow of tourists throughout the day, and the overall itinerary planning (Kellner and Egger, 2016; Wan et al., 2019).

The second dimension of accessibility is the mode-based accessibility, also known as spatial dimension, which refers to the different transportation modes available to tourists (He et al., 2021; Hocevar and Bartol, 2021). Cities with various transportation options (e.g., buses, trams, metro, bike-sharing systems, and pedestrian pathways) offer added value to tourists (Graells-Garrido et al., 2021; Morrison and Maxim, 2021). Spatial accessibility not only facilitates the flow of tourists within the city but also influences tourists' choices regarding which attractions to visit and how to plan their day. For example, a city with a solid public transportation system, such as trains, buses, metro, or trams, allows tourists to easily visit multiple attractions in a single day (Wan et al., 2019). This not only improves their experience, but also encourages them to explore more of the city culture and the locals' daily life basics.

In general, the interaction between temporal and spatial accessibility highlights the complexity of managing urban tourism, particularly in metropolitan cities (Hocevar and Bartol, 2021; Şahin Körmeçli, 2024; Wan et al., 2019). A city that offers efficient, reliable, and diverse transportation options, connected with the attractions that are accessible at different time intervals, creates a dynamic environment that can attract different types of tourists with different plans and interests. This interaction also has implications for the spatial distribution of tourists within a city. High accessibility can encourage tourists to explore less-known neighborhoods and attractions outside of the traditional city centre, resulting in more equitable economic benefits across the city and reducing the pressure on overcrowded hotspots (Morrison and Maxim, 2021). Therefore, effective management of both temporal and spatial accessibility is essential for enhancing the overall sustainability of urban tourism.

Additionally, analyzing accessibility within the urban tourism context can contribute to mitigating some of the most critical challenges in the tourism industry such as overtourism and the leakage of tourism profits, which increase economic inequality in urban communities. Overtourism, as an example, is most noticeable in the famous urban destinations, where a small number of popular attractions receive the majority of tourists (Dodds and Butler, 2019; Nilsson, 2020). By analyzing the flow of tourists through the city and the accessibility of the various attractions, policymakers and urban planners can develop strategies that distribute tourist activity throughout different areas, mitigating the negative impacts of overtourism. This can be achieved through improved transportation links, better signage, or marketing campaigns designed to manage tourist movements and achieve a more balanced allocation of visitors throughout the city and its attractions (Aall and Koens, 2019; Bouchon and Rauscher, 2019; Hristov et al., 2021).

Furthermore, accessibility analysis can play an important role in tackling the economic leakage challenge. This leakage often happens when tourists spend money at international hotel chains, restaurants, or tour operators that do not reinvest earnings into the local community (Chaitanya and Swain, 2024; Garrigós-Simón et al., 2015). By improving accessibility these expenditures can be redirected towards local businesses, enterprises and community. For example, enhancing public transportation to reach local markets and cultural centers can make it easier for tourists to engage with and support local businesses. This, in turn, encourages a more diverse tourism economy that helps reduce economic inequality and ensures that the benefits of tourism are shared more fairly among the locals (Dalvi and Martin, 1976; Lacher and Nepal, 2010; Morrison and Maxim, 2021).

It is also worth mentioning that analyzing the accessibility of tourist spots within a city can help achieve the United Nations Sustainable Development Goals (SDGs) and play an important role in fostering sustainable and regenerative tourism practices. For example, accessibility has a direct impact on the achievement of SDG11, "Sustainable Cities and Communities", which highlights the need for cities to become more inclusive, safe, resilient, and sustainable for both locals and tourists (United Nations Development Programme, 2021). By improving public transportation and pedestrian pathways, tourist spots can become more accessible through sustainable, low-carbon transportation options, thereby reducing traffic congestion and contributing to a healthier urban environment. Also, accessibility analysis plays a significant role in achieving SDG10 "Reducing Inequalities" within urban tourism by ensuring that all locals within the city can benefit from tourism-related activities (United Nations Development Programme, 2021).

2. Literature review

From an academic perspective, the time and accessibility of locations within a city, in general, and tourist spots, in particular, by different transportation modes, has gained increasing importance in scientific research, as scholars understand its critical role in shaping urban mobility patterns and practices based on time intervals. For example, the study conducted by (Li et al., 2022) examined the spatial accessibility of urban tourism attractions using real-time travel data and a modified gravity model. In their study, the researchers highlighted the importance of the transportation infrastructure and destination attractiveness in shaping tourism accessibility, providing key insights for urban planners and policymakers (Li et al., 2022). Another study by (Zhang et al., 2020) developed a route-planning method that takes into account some factors impacting tourist behavior, including travel time, the distance between locations, time of departure, and the overall attractiveness of destinations. The study explained how transportation modes and time intervals can significantly affect spatial-temporal accessibility (Zhang et al., 2020). Additionally, (Kim et al., 2023) provided insights into how tourists see and value their time during holidays, with a focus on the implications for sustainable and environmentally friendly travel practices. The study explored the concept of the Time Use Rebound Effect (TRE), which assumes that time savings from new travel technologies could result in higher energy consumption due to changes in tourist behavior (Kim et al., 2023). By analyzing different tourist groups, the study identified how transportation modes and time savings affect the frequency of travel and leisure activities in tourist destinations. This highlights the need to include the temporal aspects in sustainable tourism strategies and policies.

Building on previous research, many other studies analyzed the concept of accessibility in urban areas generally, taking into account various factors such as transportation modes, distance, and time intervals. For example, (Fink et al., 2024) developed a travel time matrix dataset for the Helsinki metropolitan area that provides various transportation modes and time intervals, offering a detailed analysis of spatial-temporal accessibility. This study utilized a door-to-door approach, integrating walking, cycling, public transport, and driving trips at different times of the day to provide a comprehensive understanding of urban accessibility. By verifying their data through other sources such as the Google Directions API, the researchers highlighted notable differences in accessibility based on transport modes and time of travel (Fink et al., 2024). This highlights the importance of these factors in urban planning and the design of equitable and sustainable cities. Further contributing to this topic, (Tenkanen and Toivonen, 2020) presented a longitudinal spatial dataset that analyzes travel times and distances by different travel modes in Helsinki city. This dataset represents different years (e.g., 2013, 2015, and 2018), and provides comprehensive insights into spatial-temporal accessibility of various transportation modes (e.g., walking, cycling, public transportation, and private car) at different times of the day. The study employed a door-to-door research approach, which enhance the ability to compare of transportation modes, making it a valuable resource for understanding urban mobility dynamics and its implications for sustainable urban development (Tenkanen and Toivonen, 2020).

Despite these previously mentioned studies on spatial-temporal accessibility in urban areas, most of the existing studies have primarily focused on general urban accessibility rather than specifically on tourist attractions within cities. Additionally, most research has examined accessibility at a broad level, often without accounting for detailed, mode differences across various time intervals or the impact of proximity to transportation nodes in tourist-dense urban environments such as

Budapest. Also, while studies have addressed accessibility in terms of transportation modes and temporal aspects, there is limited work on systematically comparing the reachability of tourist spots based on transportation nodes and real-time travel times across different time intervals in a tourism context.

Accordingly, this study seeks to analyze the accessibility of tourist spots in Budapest based on three main transportation modes (walking, cycling, and public transportation) and across different time intervals (10 min, 20 min, and 30 min). The study will employ spatial time travel analysis using a Geographic Information System (GIS), alongside various qualitative statistical methods such as the Chi-Square Test, Survival Analysis, Random Forest Model, Analysis of Variance (ANOVA), and *T*-Test.

The findings of this research contribute both theoretically and practically to the field of urban tourism accessibility. From the theoretical perspective, it enhances the understanding of spatial-temporal accessibility within urban tourism contexts by integrating different analyses (e.g., survival analysis and random forest modeling) to measure and predict the reachability of tourist spots based on transportation modes and time intervals. Also, this study offers a unique approach compared to other studies by combining detailed temporal and mode-based accessibility data focused on tourist destinations. This adds to the theoretical understanding of how transportation infrastructure impacts tourist behavior, accessibility patterns, and the dynamics of circular communities, where accessibility fosters a greater engagement with local resources and community spaces, supporting a circular economy approach in the tourism industry. On the other side, the practical contribution, of this study provides actionable insights for urban planners, policymakers, and tourism managers in Budapest and similar cities. By identifying which transportation modes and routes are most efficient for accessing popular tourist spots within specific time intervals, the findings can guide targeted improvements in transportation infrastructure and service frequency, particularly around key tourist spots. This approach not only helps mitigate overcrowding and enhances the visitor experience but also aligns with circular economy principles by promoting local engagement and reducing the strain on central areas. Also, improved accessibility based on this study’s findings encourages visitors to explore a broader array of community-based resources and lesser-known local attractions, supporting a balanced distribution of economic benefits across urban areas.

3. Materials and methods

3.1. Study area

This research focuses on Budapest, the Hungarian capital, as the main case study for analyzing temporal and mode-based accessibility to urban tourism spots. Budapest is a metropolis with 1.78 million residents living in around 525 square kilometers. The choice of Budapest as the primary study area was based on several key reasons that directly related to the study's concept and objectives. Firstly, according to the Budapesti Közlekedési Központ (BKK), the official Hungarian government public transportation system, Budapest has a diverse transportation network that includes four metro lines, totaling around 38 kilometers, and an extensive tram network with over 30 lines covering around 156 kilometers (BKK, 2024). Additionally, Budapest has around 200 bus lines spanning almost 2500 kilometers and 15 trolleybus lines covering 67 kilometers. Moreover, the city has an extensive network of bike lanes and cycling routes totaling 200 kilometers in length (BKK, 2024).

Secondly, Budapest is an excellent study area for analyzing any topics related to tourism dynamics due to its high tourist density. For example, according to the most recent statistics from the (Hungarian Central Statistical Office—KSH, 2024), the number of tourism nights in Budapest increased by 15% in June 2024 compared to June 2023. Although the city has successfully reduced seasonal fluctuations in tourism demand by around 25% in recent years, the summertime still experiences a significant rise in the number of tourists (Hungarian Tourist Agency, 2023). This upsurge highlights the importance of this study, which focuses on how accessibility, based on transportation mode and time, can optimize tourist distribution and improve overall tourist flow management.

Thirdly, Budapest's rich historical and cultural background makes it a relevant case study for this research. For example, the city has serval United Nations Educational, Scientific and Cultural Organization (UNESCO) world heritage sites such as Buda Castle Quarter and Andrássy Avenue, which, along with of Danube banks, attract millions of tourists every year (UNESCO, 2024). In addition, the city offers a wide range of accommodation options for all tourist types and budgets (Alreahi et al., 2023). Fourthly, Budapest is a core hub for low-cost flights (Michalkó et al., 2022). In 2023, Budapest Airport offered flights to over 150 cities worldwide, enabling more tourists to visit the city and explore its rich cultural heritage and vibrant urban environment (Ferenc Liszt International Airport, 2023). This extensive network of low-cost flights and direct connections contributed to challenges such as overtourism, making Budapest a suitable case study for analyzing temporal and mode-based accessibility to urban tourism spots.

Finally, one of the key reasons for choosing Budapest is the city's strong commitment to sustainable urban development. According to the official website of Budapest, the city has developed various strategies, policies, and initiatives, along with many well-funded projects, aimed to improve the public transportation network and promoting sustainable mobility (Budapest Főváros Önkormányzata, 2024). This effort is not only limited to government action, but also many academic researchers have presented ideas and analyses to enhance the overall transportation system and mitigate the negative consequences of overtourism (Pérez Garrido et al., 2022; Pinke-Sziva et al., 2019; Smith et al., 2019). The following **Figure 1** presents the map of the Budapest study area.

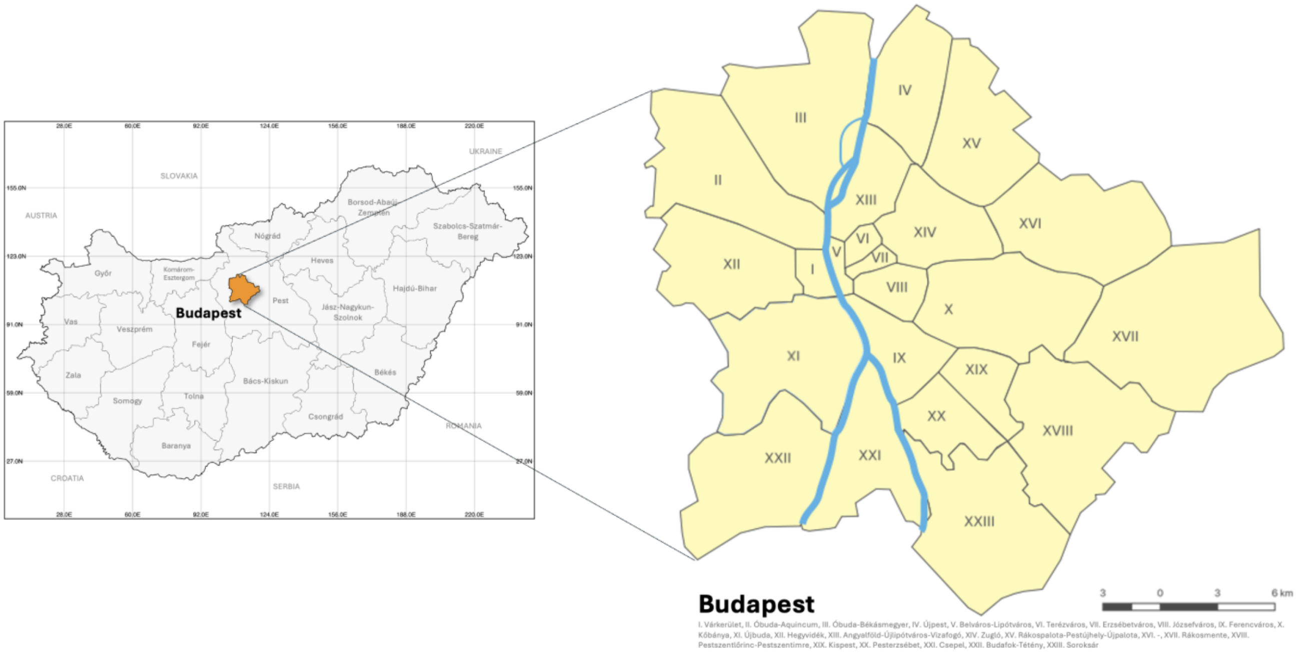

Figure 1. Budapest, Hungary (study area).

3.2. Research method and data collection

This article, as previously mentioned, focuses on presenting a practical understanding of how different transportation modes and temporal factors can affect the accessibility of tourism spots in Budapest. The main objective is to help tourists plan their visits more efficiently, as well as guide urban planners and policymakers in improving tourism development in the city. To achieve this, the article will assess the reachability of tourism spots in Budapest through two main analytical stages: spatial travel time analysis and quantitative statistical methods.

Before diving into these two analytical stages, it is important to briefly discuss the data and the collection process. The data collection process comprised three core datasets: tourist spot data, public transportation nodes data, and various transportation routes data. Firstly, the tourist spots data that comprises of 95 tourist spots within Budapest, sourced from OpenStreetMap (OpenStreetMap contributor, 2024) and validated through field observations to ensure location accuracy. Adjustments were made based on administrative boundaries, with tourist spots categorized as (Tourist_Spot_ID) and labeled according to the attraction type. It is worth mentioning that the study uses the term "tourist spots" instead of "tourist attractions" to more accurately reflect the diverse nature of the selected tourist locations. These tourist spots were allocated in the Budapest city map and by using the Quantum Geographic Information System (QGIS), spatial analysis techniques were applied to evaluate their accessibility.

The second dataset used in this study was mapping public transportation nodes, which served as the departure points for the travel time analysis. A total of 655 public transportation spots were identified, including 3 railway stations, 52 metro stations, 167 main tram and trolleybus stops, 33 main bike stations, and 400 main bus stops. The data was collected from multiple sources, including OpenStreetMap (OSM), transitfeeds.com (TransitFeeds, 2024), and BKK (2024).

The final dataset included public transportation routes, such as metro, tram, trolleybus, bus, and train lines, cycling routes, and walking paths. This data was collected from OpenStreetMap (OpenStreetMap contributor, 2024) in QGIS. This data was critical for calculating travel times and determining reachability within different time intervals. All three datasets were collected, stored, and processed in spatial maps and geodata to conduct the travel time analysis and various quantitative statistical analyses. The following **Table 1** presents the summary of the data and key variables used in this study.

Table 1. Summary of key variables and data sources.

Variable	Description	Data source	Categories/values	Example values
Tourist_Spot_ID	Identifier for each tourist location	OpenStreetMap	Numeric values (1, 2, 3, ...) (*n* = 95)	1 (Chain Bridge), 2 (Parliament Building), 3 (Buda Castle), etc.
Transport_Node_ID	Identifier for each transportation node	OpenStreetMap, TransitFeeds, and BKK*	Numeric values (1, 2, 3, ...) (*n* = 665)	1 (Kőbánya Metro Station), 2 (Nyugati Tram Stop), 3 (Margitsziget Bike Station), etc.
Public_Transportation_Route_ID	Identifier for each public transportation route	OpenStreetMap, TransitFeeds, and BKK*	Numeric values (1, 2, 3, ...)	1 (Bus E100), 2 (Metro Line M1), 3 (Tram 4 and 6), 4 (Trolleybus 72M), etc.

BKK*: Budapesti Közlekedési Központ (The Official Hungarian Government Public Transportation Site/System).

3.2.1. Travel time analysis

The first stage of the analysis is to conduct a spatial travel time analysis using QGIS (QGIS Development Team, 2024). Spatial travel time analysis is a method used to assess the accessibility of a specific location by analyzing the time required to reach it from various other locations using different transportation modes (Flügel et al., 2022; Harsha and Mulangi, 2022; Turner et al., 1998). The results of this analysis are travel time maps, also known as isochronal maps. These maps are generated based on the use of different transportation modes and different time intervals (Mokhtarian and Salomon, 2001; Nesmachnow et al., 2023; Turner et al., 1998). In this study, the spatial travel analysis focuses on three main transportation modes (e.g., walking, cycling, and public transportation) for accessing Budapest tourist spots, with time intervals of 10 min, 20 min, and 30 min. The selection of these transportation modes was based on two key reasons. Firstly, these modes are the most convenient for tourists during their trips, unlike driving, which is less commonly used in urban tourism patterns. Secondly, these transportation modes are more sustainable and present accurate insights from real-world accessibility for tourism spots in cities such as Budapest. The choice of 10-, 20-, and 30-minute time intervals reflects common tourist transportation behavior and their time constraints. Additionally, these intervals allow for the evaluation of how accessibility changes over time, which is essential for providing realistic insights for both tourists and urban planning policymakers. The following **Figure 2** illustrates the concept of travel time maps.

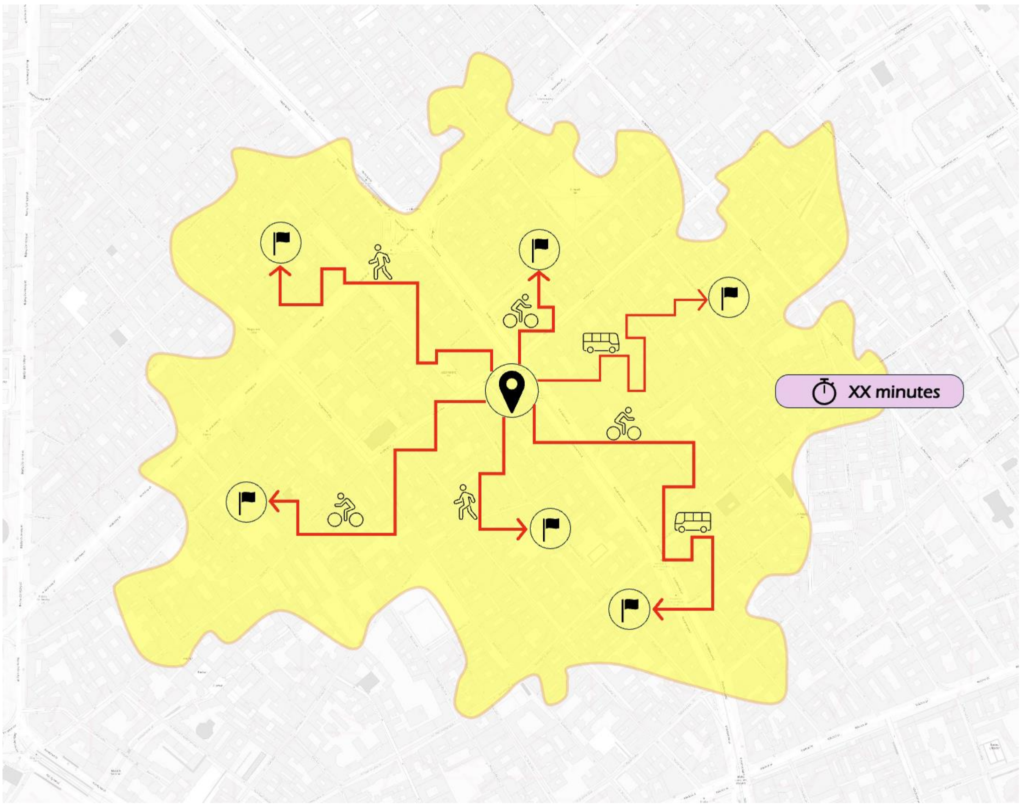

Figure 2. The idea of the spatial travel time analysis based on different transportation modes and time intervals.

3.2.2. Statistical analysis

The second stage of the analysis includes statistically analyzing the data extracted from the first stage (the travel time analysis). The quantitative statistical methods used include the Chi-Square Test, Survival Analysis (time-to-reach), Random Forest Model, ANOVA, and *T*-Test (Agresti, 2018). These statistical analyses aim to provide a comprehensive understanding of the reachability of tourism spots in Budapest, based on various factors. Each of these statistical techniques offers its own unique insights, contributing to the overall objective of enhancing our understanding of the accessibility of tourist spots in the city.

The Chi-Square Test in this study was used to assess whether there is a statistically significant relationship between the different three transportation modes (walking, cycling, and public transport) and the reachability status of the tourist spots in Budapest. The following provides the equation of the used Chi-Square Test in this study:

$$\chi^2 = \sum \frac{(O_\mathrm{i} - E_i)^2}{E_i} \quad (1)$$

where: O_i represents the observed frequency, and E_i represents the expected frequency.

Regarding the Survival Analysis (Time-to-Reach) is used in this study to analyze and interpret the time taken to reach a tourist spot using the different transportation modes (walking, cycling, and public transportation). This analysis assesses the distribution of time to reach tourist spots and identifies factors that significantly influence this time. This study employed the Kaplan-Meier estimator model for non-parametric survival analysis, as it allows us to estimate the survival function without making assumptions about the underlying distribution of travel times. This Kaplan-Meier estimator survival analysis model focus on three main variables: time to reach (the dependent variable representing the time required to reach each tourist spot), transportation mode (categorical independent variable indicating the mode of travel such as walking, cycling, and public transport), and reachability status (binary variable indicating whether the spot was reached within each time interval such as 10 min, 20 min, or 30 min). The model also calculates the median survival time for each mode of transportation, allowing for a comparative measure of efficiency in reaching tourist destinations.

This model is presented by two functions: survival function and hazard function. The survival function, $S(t)$, represents the probability that a tourist spot has not been reached by a given time interval (t). While the hazard function, $\lambda(t)$, represents the instant rate at which tourists reach a spot at a time (t), given that they have not yet reached it by that time (t). The following equations represent the survival and hazard functions, respectively:

$$S(t) = P(T > t) = 1 - F(t) \tag{2}$$

where: $S(t)$ represents the the probability that the time to reach a tourist spot exceeds time (t), T represents the random variable representing time to reach, and $F(t)$ is the cumulative distribution function (CDF) of the time to reach.

$$\lambda(t) = \frac{f(t)}{S(t)} \tag{3}$$

where: $f(t)$ represents the probability density function (PDF) of the time to reach.

In cases where certain tourist spots were unreachable within the defined time intervals, these instances were treated as “right-censored” data, meaning that the exact time to reach these spots was unknown but recorded as exceeding the observed timeframe. The survival analysis assumes non-informative censoring, meaning that the likelihood of reaching a tourist spot is independent of whether it was censored. Additionally, the analysis assumes that the travel times for each transportation mode are independent of each other.

The third statistical method is the Random Forest Model which is used to predict the reachability of tourist spots in Budapest based on the input factors that were identified in the study. In other words, this analysis focuses on identifying the most important factors that influence whether a tourist spot is reachable within a given time frame and creating a model that can predict reachability with high accuracy. The input variables (predictors) used in the Random Forest model included: “transportation mode”, a categorical variable representing the mode of travel (e.g., walking, cycling, and public transportation); “time interval”, a categorical variable indicating the time intervals analyzed, specifically 10 min, 20 min, and 30 min; “distance to spot”, a continuous variable representing the distance from the transportation node to the tourist spot in kilometers; and “day type”, a categorical variable that represents weekdays and weekends. The output variable, or target, in this Random Forest model, was “reachability status”, which is a binary variable indicating whether a tourist spot is reachable or not (coded as 1 for reachable and 0 for unreachable) within the given time interval and transportation mode.

Finally, the *T*-Test analysis was conducted to determine whether the difference in reachability for tourist spots in Budapest between weekdays and weekends (for public transportation mode) is statistically significant or not.

4. Results

The results of this study will be presented through two main sub-sections. The first subsection, spatial-temporal travel time analysis, explores the travel time map that depicts the relationship between transportation modes and time intervals on one side, and the reachability of the tourist spots in Budapest on the other side. The second subsection, isochronal map statistics, provides a detailed statistical analysis of the data extracted from the isochronal maps, highlighting key insights and patterns for understanding the reachability of tourist spots in the city.

4.1. Spatial-temporal travel time maps

The main results of the travel time analysis are the isochronal maps, that represent the reachable tourism spots in Budapest based on various transportation modes and time intervals, as depicted in **Figure 3**. By analyzing these maps, several key insights can be presented.

Cycling emerges as the most efficient transportation mode, covering most tourist spots across all time intervals. The efficiency of cycling is followed by public transportation and then walking, respectively. This efficiency of cycling in Budapest is due to many reasons such as the good bicycle infrastructure in the city. Additionally, the improvements in cycling infrastructure presented by the BKK appeared to be one of the key reasons for cycling efficiency. This development includes raising awareness of cycling through different events (e.g., Car Free Day), allowing bikes on different transportation modes (trains, buses, metro, and tram), supporting the bicycle advocacy movements (e.g., Critical Mass Movement), and provide various Bicycle Sharing Systems (BSS) with different ticket plans and types (Jaber et al., 2022).

Another insight that can be gained from the isochronal maps is that the central city area around the Danube River, which includes some of the most famous tourist attractions in the city (e.g., Chain Bridge, Parliament Building, Buda Castle, Fisherman's Bastion, St. Stephen Basilica, and Margit-Sziget), is accessible by almost all the three transportation options within the shortest time intervals. This indicates the overall efficiency of the transportation network in Budapest and how it presents a convenient environment for tourist activities.

In contrast, the outer areas of the city show lower reachability of tourist spots, which is expected due to the distance from the city center and the fewer transportation options. The Northwestern area, in particular, appeared as the least served urban area across the different transportation modes and time intervals. This area is known for its natural tourist spots related to hiking. Finally, the travel time maps revealed that there is a slight difference between weekday and weekend accessibility when it comes to public transportation, but it is not significant. This minor difference is due to the reduced frequency of public transportation services during weekends (e.g., night buses). Despite this, the public transport network remains robust enough to maintain similar levels of accessibility across both day types, ensuring that tourist spots are reachable throughout the weekdays. The following **Figure 3** presents the isochronal maps results from the temporal-spatial travel time analysis in this study.

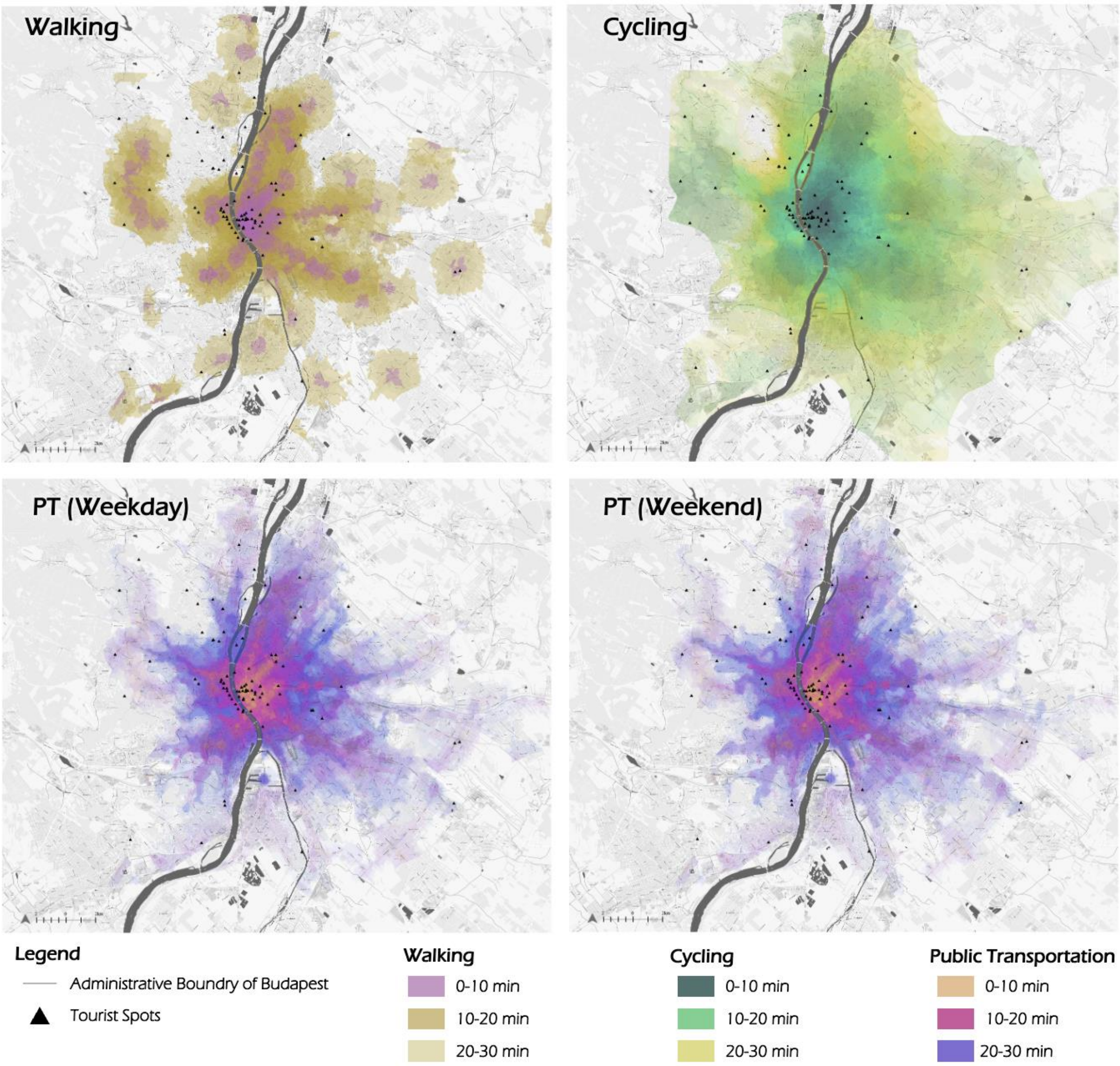

Figure 3. Comparison of tourist spots reachability in Budapest by transportation modes and time intervals.

These previously mentioned insights derived from the travel time maps are supported by the data summarized in the following **Table 2** and **Figure 4**. **Table 2** provides a detailed breakdown of the percentage of reachable and unreachable tourist spots in Budapest based on different transportation modes and time intervals. The table highlights that cycling consistently results in the highest percentage of reachable spots across all time intervals, with around 98% of spots accessible within 30 min. Public transportation, both on weekdays and weekends, also shows strong performance, particularly over longer time intervals, reaching up to 93.68% and 91.58% of tourist spots, respectively, within 30 min. In contrast, walking, while effective in shorter time intervals for central tourist spots, shows a slower increase in reachability, resulting in 80% of spots being reachable within 30 min. Additionally, **Figure 4** visually enhances these findings by illustrating the percentage of reachable tourist spots over time for each transportation mode. The significant increase in the cycling curve indicates its strong efficiency, with most tourist spots quickly becoming reachable. Public transportation follows a similar pattern, particularly after the 20-minute mark, showing minimal difference between weekdays and weekends. Walking, on the other hand, displays a steadier increase, reflecting the time constraints linked to this transportation mode.

Table 2. Summary of reachable and unreachable tourist spots in Budapest by transportation modes and time intervals.

Transportation mode		Time interval	Reachable spots	(%)	Unreachable spots	(%)
Walking		10 min	47	49.47%	48	50.53%
		20 min	63	66.32%	32	33.68%
		30 min	76	80%	19	20%
Cycling		10 min	74	78.89%	21	22.11%
		20 min	91	95.79%	4	4.21%
		30 min	93	97.89%	2	2.11%
Public transport	Weekday	10 min	48	50.53%	47	49.47%
		20 min	79	83.16%	16	16.84%
		30 min	89	93.68%	6	6.32%
	Weekend	10 min	48	50.53%	47	49.47%
		20 min	76	80%	19	20%
		30 min	87	91.58%	8	8.42%

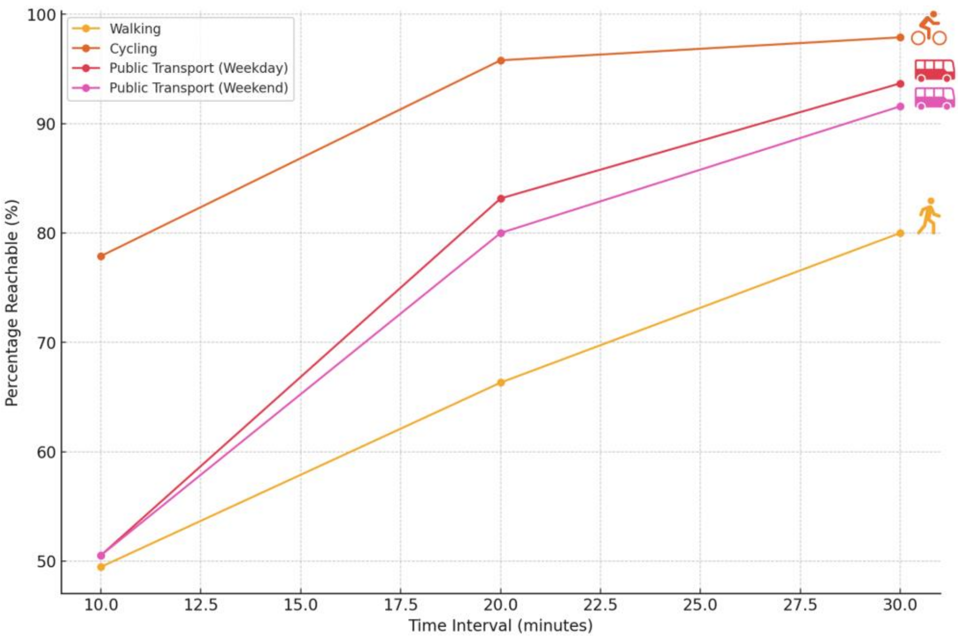

Figure 4. Percentage of reachable tourist spots in Budapest by transportation mode and time interval.

4.2. Isochronal maps statistics

In this subsection, the study presents the results of the five quantitative statistical methods (Chi-Square Test, Survival Analysis, Random Forest Model, and *T*-Test). Each method represents a theme that explains in depth the relation between the reachability status of the different tourist spots in Budapest and the various temporal-mode factors such as transportation modes, time intervals, and day category (weekday or weekend). These themes and their results are presented as follows:

a) Transportation mode vs. Reachability status: Chi-Square test

The results of the test showed a high Pearson Chi-Square value of 61.86, which indicates a significant correlation between the transportation mode and the reachability status of the tourist spots in Budapest. Also, the p-value (0.007) supported this finding, as it is less than 0.05. So, the findings of this test revealed that the choice of transportation mode significantly influences the reachability of the tourist spots in Budapest. The following **Table 3** presents the results of the Chi-Square test.

Table 3. Chi-Square test results for the relation between transportation mode and reachability status.

Test	Value (x^2)	df	Asymptotic significance
Pearson Chi-Square	61.86	2	0.007

b) Reachablity vs. Time intervals: Survival analysis (time-to-reach)

The following **Table 4** presents the results of the survival analysis which is summarized in the median time to reach, the 25th and 75th percentiles, the hazard ratio, and the survival probability for each transportation mode. Starting with walking, the median time to reach tourist spots by walking is 25 min, with a range between 15 min (25th %) and 35 min (75th %). Also, the probability of still being on route after 20 min is presented by the survival probability with 0.6 value. The hazard ratio for walking is 1.00 (the reference), meaning other transportation modes are compared against it.

Moving to cycling, the findings revealed that cycling significantly reduces the time required to reach tourist spots, with a median time of 15 min. The shorter time range, from 10 min (25th %) to 20 min (75th %), reflects the efficiency and speed of cycling. Additionally, the survival probability at 20 min is the highest among the three modes at 0.85, indicating that fewer people are still traveling after 20 min. Also, the hazard ratio of 1.5 suggests that the rate of reaching destinations is 1.5 times higher compared to walking (the reference).

Regarding public transportation, it is offered a balanced pattern with a median time of 20 min and a range from 12 min (25th percentile) to 30 min (75th percentile). The survival probability is 0.7, indicating an average level of efficiency in terms of reaching tourist spots within the time frame. The hazard ratio of 1.2 indicates that public transport users reach their destinations 1.2 times faster than walking. So, the final results of the survival analysis, presented in the following **Table 4**, indicate that cycling is the most efficient transportation mode for reaching tourist spots in

Budapest, as evidenced by the shortest median time and highest survival probability compared to walking and public transportation.

Table 4. Survival analysis results by transportation mode.

Transportation mode	Median (time to reach)	25th (%)	75th (%)	Hazard ratio	Survival probability
Walking	25 min	15 min	35 min	1.00 (ref)	0.6
Cycling	15 min	10 min	20 min	1.5	0.85
Public Transport	20 min	12 min	30 min	1.2	0.7

Additionally, these results are supported by the following **Figure 5**, which depicts the Kaplan-Meier Survival curve. This figure presented three key information: transportation mode curves, shaded area, and the number at risk table. Firstly, the curve (line) of each transportation mode represents the efficiency in reaching the tourist spots in Budapest with the different time intervals. For example, cycling (green line) appears to be the most efficient transportation mode. The survival probability drops rapidly within the first 10 min–20 min, indicating that most tourist spots are quickly reachable by cycling. The curve levels off before reaching 40 min, showing that all spots are accessible within this time frame.

Secondly, the shaded area around each curve represents the confidence intervals, which provide an indication of the degree of uncertainty in the predicted survival probability at each time point. A narrower shaded area indicates a more precise estimate and vice versa. For example, the shaded area around the green curve is relatively narrow, especially in the earlier time intervals (up to around 20 min). This suggests that the time estimates for reaching tourist spots by cycling are quite precise, with little variation among different tourist spots. For example, most spots are reached within a short time range of 10 min to 20 min, indicating consistent accessibility by cycling.

Thirdly, the number-at-risk table which shows the number of tourist spots that have not yet been reached at specific time intervals for each transportation mode. At the start (0 min), all tourist spots are at risk of not being reached, with 7 spots for each mode. As time progresses, the number decreases, indicating the increasing number of spots that have been reached. For example, by 20 min, only 4 spots remain at risk for walking, indicating that 3 have been reached, whereas, for cycling, only 1 spot remains at risk, showing its higher efficiency. This still supports the idea that cycling consistently reduces the number of spots at risk more quickly than walking and public transport, highlighting its efficiency.

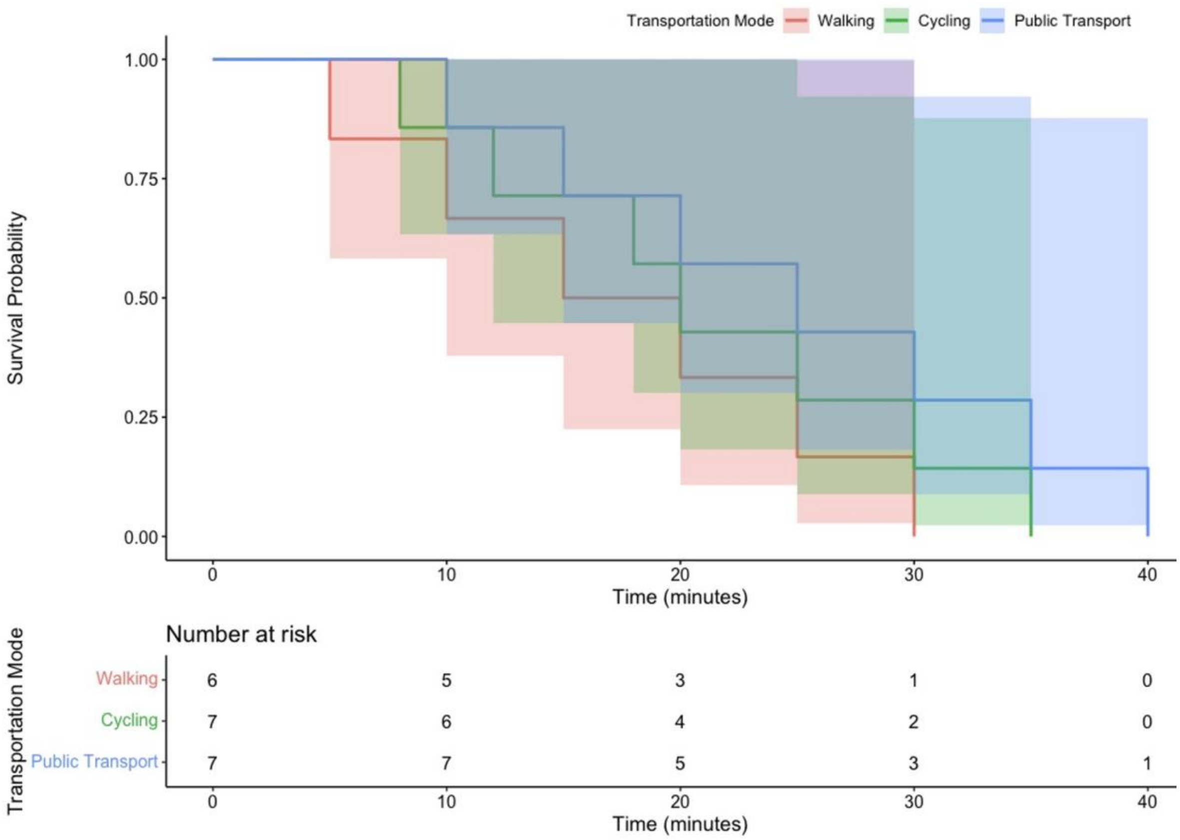

Figure 5. Kaplan-Meier Survival curve illustrating time to reach tourist spots by transportation modes in Budapest.

a) Importance of Factors Influencing Reachability: Random Forest Model

According to the results of the Random Forest analysis, presented in the following **Table 5**, transportation modes is the most influential factor in predicting the reachability of the tourist spots in Budapest, with an importance of 40% and a mean decrease in Gini of 0.45. This suggests that the choice of transportation option (e.g., walking, cycling, or public transport) plays an important role in determining reachability status. Time intervals, with an importance of 35% and a mean decrease in Gini of 0.38, is the second most important factor, indicating that the duration of travel also strongly influences the reachability status. Distance to the spot contributes 15% to the model predictive power, with a mean decrease in Gini of 0.20, highlighting that proximity to tourist spots affects reachability but with less effect. Also, the model demonstrates strong predictive performance with an overall accuracy of 85% and an out-of-bag error rate of 15%, indicating that the model is reliable.

Table 5. Feature importance in predicting the reachability of the tourists spots in Budapest.

Feature	Importance (%)	Mean decrease in Gini
Transportation mode	40%	0.45
Time interval	35%	0.38
Distance to spot	15%	0.2

Note: the model accuracy is 85% and out-of-bag error rate is 15%.

b) Weekday vs. Weekend (Public Transportation Mode): *T*-Test

The results of the *T*-test the p-value were "NaN" which indicates that there is no significant difference in the reachability of tourist spots using public transport between weekdays and weekends across the three-time intervals. The lack of significant differences highlights that the public transport system provides reliable access to tourist spots regardless of the day of the week. It is also worth mentioning that to ensure the robustness of *T*-test results, a Mann-Whitney U Test was conducted, and the results were almost identical to the *T*-Test ones, with a p-value of 1 across the three transportation modes.

5. Discussion

This study aimed to investigate the reachability of tourist spots in Budapest by analyzing the effectiveness of three transportation modes (e.g., walking, cycling, and public transport) across different time intervals (10 min, 20 min, and 30 min). The key findings of this study have important implications for urban mobility, tourism management, and the overall tourist experience in the city.

One of the main findings of this study is the notable efficiency of cycling as a transportation mode for reaching tourist spots in Budapest. The high percentage of reachable spots within the shortest time intervals highlights the efficiency of the cycling infrastructure in the city. This efficiency reflects the dedicated efforts of the Hungarian government, particularly the BKK, to enhance the cycling culture in the city. Their initiatives, such as improving cycling infrastructure, hosting cycling events, and raising public awareness, have clearly paid off, making cycling a more popular transportation option for both tourists and residents as well (Bucsky, 2020; Jaber et al., 2022; Mátrai et al., 2020). Also, this highlighted that cycling not only presents quick and easy access to tourist spots, but also supports the general aim of promoting sustainable tourism in the city. Public transport also showed a strong performance, as a second important transportation mode, making it easy for tourists to reach different tourist spots across the city.

This study also revealed significant geographic disparities in the accessibility of tourist spots, particularly between central and outer areas of Budapest. While the central areas around the Danube are well-served by almost all the transportation modes, the outer urban areas, especially in the northwest, are have some accessibility shortages. This is especially concerning because some of these less accessible areas have natural attractions that could attract different tourist types if they were easier to get. This quiet lack of accessibility is important for urban planners and policymakers to prioritize improving transportation infrastructure in these urban areas, ensuring that everyone has equal access to all parts of the city.

Regarding this research implication, the findings provide some insights that are important not only for tourists to plan their itineraries in Budapest, but also for urban planners and policymakers focusing on improving the tourism sector in the city and enhancing the overall tourist experience. Firstly, the results are highly beneficial for tourists in planning their trips. The travel time maps developed in this study provide a valuable tool for tourists to efficiently plan their itineraries, ensuring that they can make the most of their time in the city. For example, the following **Figure 6** presents the decision tree that guides tourist through the process of optimizing their transit time in Budapest, based on the travel maps resulting in this study. This decision tree takes into account key factors such as transit time, day of the week, time of day, the most efficient transportation modes, and time intervals for reaching different tourist spots. This practical application of the results of this study helps tourists make the right choices, ensuring that they can visit their preferred tourist attractions in the city in the most efficient possible way.

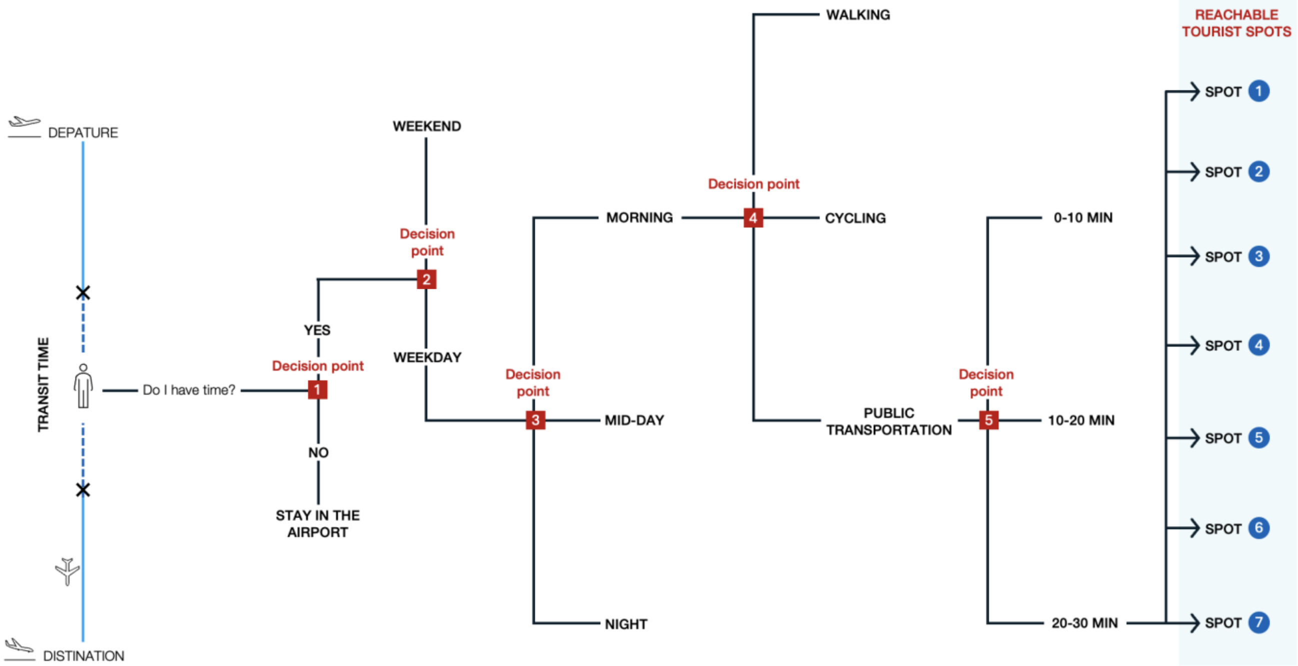

Figure 6. Tourist decision tree for optimizing transit time and accessibility of tourist spots in Budapest.

Furthermore, the research findings have a significant implication for urban planners and policymakers who are responsible for developing and enhancing the tourism sector in Budapest. The travel time maps reveal areas of the city that are well-served by transportation infrastructure, as well as those that are lacking. For example, the isochronal maps indicate that while the Budapest city centre area, particularly around the Danube, is highly accessible in terms of tourist spots, there is a noticeable shortage in reachability service in the northwestern urban areas of the city, as shown in the following **Figure 7**. This finding is particularly important for urban planners and policymakers, as it highlights the need for targeted transportation improvements in these underserved areas. By addressing these gaps, planners can ensure that all districts of the city, including those with natural attractions, are equally accessible to both tourists and residents. This not only enhances the overall tourist experience, but also enhances a more balanced flow of tourists through the city, potentially reducing congestion in more popular areas and encouraging the exploration of lesser-known sites. Furthermore, the insights from this research can inform strategic investments in transportation infrastructure, such as expanding the cycling network or improving public transport connections to these tourist natural spots, thereby supporting sustainable tourism development and economic growth in these areas.

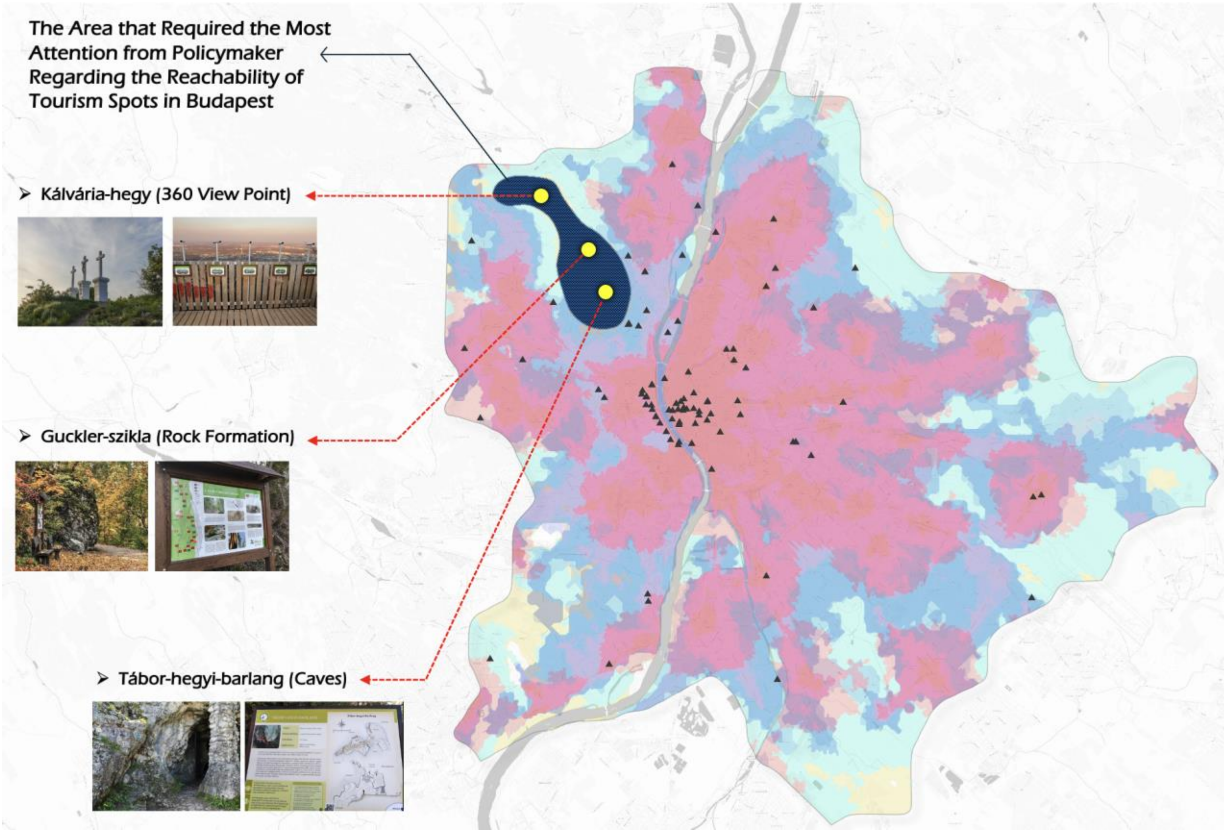

Figure 7. Less-served areas for tourist accessibility in Budapest as an important implication for this study.

While this study provides a comprehensive analysis of tourist spot reachability in Budapest, there are some limitations to be considered. The analysis is based on fixed time intervals which should consider some other factors such as the traffic conditions, seasons change, weather conditions, or shifts in the public transportation schedules. These everyday factors can affect the reachability of the tourist spots around the city, so future research could benefit from these factors to provide a more comprehensive picture of tourist spots' reachability in the city. Additionally, this study focuses only on three transportation modes (walking, cycling, and public transportation), by adding more transportation modes, such as ride-sharing services, this can enhance the results and present a new research agenda for future scholars. Also, this study is limited to a single city, Budapest; conducting comparative studies across different regions or cities could be a valuable direction for future research. Finally, including some social factors such as personal preferences and behaviors of different tourist types, could be another limitation of this study. Thus, future studies can focus on how tourist behaviors can affect the reachability of tourist spots in an urban environment, adding another layer of insight to this important topic.

6. Conclusion

Accessing tourist spots in a timely and efficient way is essential for enhancing the overall travel experience, especially in metropolitan urban areas such as Budapest. This study provided a comprehensive analysis of how different transportation modes (e.g., walking, cycling, and public transport) affect the reachability of tourist spots in Budapest across various time intervals. The findings highlighted the efficiency of cycling mode, the robust performance of public transport, and the limitations of walking, particularly in less centrally located areas in this city. These insights highlight the importance of continued investment in sustainable transportation options that not only benefit tourists, but also the residents. Furthermore, the study revealed significant geographic disparities in the reachability of tourist spots in the city, particularly between the well-served central areas and the less accessible outer urban districts, especially in the northwest. This suggests a need for targeted improvements in transportation infrastructure to ensure equal access to all parts of the city, allowing for a more balanced flow of tourists and activities.

In conclusion, this study not only contributes to a deeper understanding of urban tourism accessibility, but also offers practical recommendations for enhancing transportation infrastructure in Budapest for policymakers and urban planners. By addressing the identified gaps and building on the strengths of the existing system, Budapest can continue to improve its reputation as a top-tier tourist destination, offering a unique and enjoyable experience for all tourists.

Author contributions: Conceptualization, MK, EIP and HK; methodology, MK and TA; software, MK; validation, TA and HK; formal analysis, MK; investigation, TA and HK; resources, MK; data curation, MK; writing—original draft preparation, MK, EIP and TA; writing—review and editing, MK; visualization, MK and TA; supervision, EIP and LDD; project administration, LDD; funding acquisition, LDD. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: This work was supported by the Doctoral School of Economic and Regional Sciences, and the Flagship Research Groups Programme of the Hungarian University of Agriculture and Life Sciences (MATE).

Conflict of interest: The authors declare no conflict of interest.

References

Aall, C., & Koens, K. (2019). The Discourse on Sustainable Urban Tourism: The Need for Discussing More Than Overtourism. Sustainability, 11(15), 4228. https://doi.org/10.3390/su11154228

Agresti, A. (2018). Statistical Methods for the Social Sciences (5th Global Edition). Pearson.

Alreahi, M., Bujdosó, Z., Lakner, Z., Pataki, L., Zhu, K., Dávid, L. D., & Kabil, M. (2023). Sustainable Tourism in the Post-COVID-19 Era: Investigating the Effect of Green Practices on Hotels Attributes and Customer Preferences in Budapest, Hungary. Sustainability, 15(15), 11859. https://doi.org/10.3390/su151511859

Ashworth, G., & Page, S. J. (2011). Urban tourism research: Recent progress and current paradoxes. Tourism Management, 32(1), 1–15. https://doi.org/10.1016/j.tourman.2010.02.002

BKK. (2024). Centre for Budapest Transport (BKK) [Official government website]. Budapesti Közlekedési Központ. https://bkk.hu/

Bouchon, F., & Rauscher, M. (2019). Cities and tourism, a love and hate story; towards a conceptual framework for urban overtourism management. International Journal of Tourism Cities, 5(4), 598–619. https://doi.org/10.1108/IJTC-06-2019-0080

Bucsky, P. (2020). Modal share changes due to COVID-19: The case of Budapest. Transportation Research Interdisciplinary Perspectives, 8, 100141. https://doi.org/10.1016/j.trip.2020.100141

Budapest Főváros Önkormányzata. (2024). Buadpest [Official government website]. https://archiv.budapest.hu/sites/english/Lapok/default.aspx

Chaitanya, A. K., & Swain, S. K. (2024). Economic leakages in tourism: A comprehensive review of theoretical and empirical perspectives. Tourism Economics, 30(5), 1306–1323. https://doi.org/10.1177/13548166231204648

Dalvi, M. Q., & Martin, K. M. (1976). The measurement of accessibility: Some preliminary results. Transportation, 5(1), 17–42. https://doi.org/10.1007/BF00165245

Dodds, R., & Butler, R. (2019). The phenomena of overtourism: A review. International Journal of Tourism Cities, 5(4), 519–528. https://doi.org/10.1108/IJTC-06-2019-0090

Edwards, D., Griffin, T., & Hayllar, B. (2008). Urban Tourism Research. Annals of Tourism Research, 35(4), 1032–1052. https://doi.org/10.1016/j.annals.2008.09.002

Ferenc Liszt International Airport. (2023). Facts About bud. https://www.bud.hu/en

Fink, C., Willberg, E., Klein, R., Heikinheimo, V., & Toivonen, T. (2024). A travel time matrix data set for the Helsinki region 2023 that is sensitive to time, mode and interpersonal differences, and uses open data and novel open-source software. Scientific Data, 11(1), 858. https://doi.org/10.1038/s41597-024-03689-z

Flügel, S., Halse, A. H., Hartveit, K. J. L., & Ukkonen, A. (2022). Value of travel time by road type. European Transport Research Review, 14(1), 35. https://doi.org/10.1186/s12544-022-00554-1

Garrigós-Simón, F. J., Galdón-Salvador, J. L., & Gil-Pechuán, I. (2015). The Economic Sustainability of Tourism Growth through Leakage Calculation. Tourism Economics, 21(4), 721–739. https://doi.org/10.5367/te.2014.0372

Graells-Garrido, E., Serra-Burriel, F., Rowe, F., Cucchietti, F. M., & Reyes, P. (2021). A city of cities: Measuring how 15-minutes urban accessibility shapes human mobility in Barcelona. PLOS ONE, 16(5), e0250080. https://doi.org/10.1371/journal.pone.0250080

Harsha, M. M., & Mulangi, R. H. (2022). Probability distributions analysis of travel time variability for the public transit system. International Journal of Transportation Science and Technology, 11(4), 790–803. https://doi.org/10.1016/j.ijtst.2021.10.006

He, B., Liu, K., Xue, Z., Liu, J., Yuan, D., Yin, J., & Wu, G. (2021). Spatial and Temporal Characteristics of Urban Tourism Travel by Taxi—A Case Study of Shenzhen. ISPRS International Journal of Geo-Information, 10(7), 445. https://doi.org/10.3390/ijgi10070445

Hocevar, M., & Bartol, T. (2021). Mapping urban tourism issues: Analysis of research perspectives through the lens of network visualization. International Journal of Tourism Cities, 7(3), 818–844. https://doi.org/10.1108/IJTC-05-2020-0110

Hristov, M., Danilovic-Hristic, N., & Stefanovic, N. (2021). Impact of overtourism on urban life. Spatium, 45, 59–66. https://doi.org/10.2298/SPAT2145059H

Hungarian Central Statistical Office - KSH. (2024). Tourist arrivals at tourist accommodation establishments [Official government website]. https://www.ksh.hu/en/first-releases/tsz/etsz2406.html

Hungarian Tourist Agency. (2023). National Tourism Development Strategy 2030 – Tourism 2.0 [Official government website]. https://mtu.gov.hu/cikkek/strategia/

Jaber, A., Csonka, B., & Juhasz, J. (2022). Long Term Time Series Prediction of Bike Sharing Trips: A Cast Study of Budapest City. 2022 Smart City Symposium Prague (SCSP), 1–5. https://doi.org/10.1109/SCSP54748.2022.9792540

Kellner, L., & Egger, R. (2016). Tracking Tourist Spatial-Temporal Behavior in Urban Places, A Methodological Overview and GPS Case Study. In A. Inversini & R. Schegg (Eds.), Information and Communication Technologies in Tourism 2016 (pp. 481–494). Springer International Publishing.

Kim, S., Filimonau, V., & Dickinson, J. E. (2023). Tourist Perception of the Value of Time on Holidays: Implications for the Time Use Rebound Effect and Sustainable Travel Practice. Journal of Travel Research, 62(2), 362–381. https://doi.org/10.1177/00472875211064636

Lacher, R. G., & Nepal, S. K. (2010). From Leakages to Linkages: Local-Level Strategies for Capturing Tourism Revenue in Northern Thailand. Tourism Geographies, 12(1), 77–99. https://doi.org/10.1080/14616680903493654

Li, J., Guo, X., Lu, R., & Zhang, Y. (2022). Analysing Urban Tourism Accessibility Using Real-Time Travel Data: A Case Study in Nanjing, China. Sustainability, 14(19), 12122. https://doi.org/10.3390/su141912122

Masiero, L., & Hrankai, R. (2022). Modeling tourist accessibility to peripheral attractions. Annals of Tourism Research, 92, 103343. https://doi.org/10.1016/j.annals.2021.103343

Mátrai, T., Tóth, J., & Cruz, J. (2020). How Cycling is Perceived in Budapest Based on Household Survey Results. Periodica Polytechnica Civil Engineering. https://doi.org/10.3311/PPci.14961

Michalkó, G., Bal, D., & Erdélyi, É. (2022). Repositioning Budapest's tourism milieu for a post-Covid-19 period: Visual content analysis. European Journal of Tourism Research, 32, 3204. https://doi.org/10.54055/ejtr.v32i.2602

Miller, D., Merrilees, B., & Coghlan, A. (2015). Sustainable urban tourism: Understanding and developing visitor proenvironmental behaviours. Journal of Sustainable Tourism, 23(1), 26–46. https://doi.org/10.1080/09669582.2014.912219

Mokhtarian, P. L., & Salomon, I. (2001). How derived is the demand for travel? Some conceptual and measurement considerations. Transportation Research Part A: Policy and Practice, 35(8), 695–719. https://doi.org/10.1016/S0965-8564(00)00013-6

Morrison, A. M., & Maxim, C. (2021). World Tourism Cities: A Systematic Approach to Urban Tourism. Routledge Taylor & Francis Group.

Nesmachnow, S., Massobrio, R., Guridi, S., Olmedo, S., & Tchernykh, A. (2023). Big Data Analysis for Travel Time Characterization in Public Transportation Systems. Sustainability, 15(19), 14561. https://doi.org/10.3390/su151914561

Nilsson, J. H. (2020). Conceptualizing and contextualizing overtourism: The dynamics of accelerating urban tourism. International Journal of Tourism Cities, 6(4), 657–671. https://doi.org/10.1108/IJTC-08-2019-0117

OpenStreetMap contributor. (2024). OpenStreetMap. https://www.openstreetmap.org

Pearce, D. G. (2001). An integrative framework for urban tourism research. Annals of Tourism Research, 28(4), 926–946. https://doi.org/10.1016/S0160-7383(00)00082-7

Pérez Garrido, B., Sebrek, S. S., Semenova, V., Bal, D., & Michalkó, G. (2022). Addressing the Phenomenon of Overtourism in Budapest from Multiple Angles Using Unconventional Methodologies and Data. Sustainability, 14(4), 2268. https://doi.org/10.3390/su14042268

Pinke-Sziva, I., Smith, M., Olt, G., & Berezvai, Z. (2019). Overtourism and the night-time economy: A case study of Budapest. International Journal of Tourism Cities, 5(1), 1–16. https://doi.org/10.1108/IJTC-04-2018-0028

QGIS Development Team. (2024). QGIS Geographic Information System. https://qgis.org/

Şahin Körmeçli, P. (2024). Accessibility of Urban Tourism in Historical Areas: Analysis of UNESCO World Heritage Sites in Safranbolu. Sustainability, 16(6), 2485. https://doi.org/10.3390/su16062485

Smith, M. K., Sziva, I. P., & Olt, G. (2019). Overtourism and Resident Resistance in Budapest. Tourism Planning & Development, 16(4), 376–392. https://doi.org/10.1080/21568316.2019.1595705

Tenkanen, H., & Toivonen, T. (2020). Longitudinal spatial dataset on travel times and distances by different travel modes in Helsinki Region. Scientific Data, 7(1), 77. https://doi.org/10.1038/s41597-020-0413-y

Timur, S., & Getz, D. (2008). A network perspective on managing stakeholders for sustainable urban tourism. International Journal of Contemporary Hospitality Management, 20(4), 445–461. https://doi.org/10.1108/09596110810873543

TransitFeeds. (2024). TransitFeeds: Public Transit Data Sharing. https://transitfeeds.com/

Turner, S. M., Eisele, W. L., Benz, R. J., & Holdener, D. J. (1998). Travel Time Data Collection Handbook (FHWA-PL-98-035; p. 348). Texas Transportation Institute and The Texas A&M University System. https://www.fhwa.dot.gov/ohim/tvtw/natmec/00020.pdf

UNESCO. (2024). World Heritage List [Official UNESCO website]. https://whc.unesco.org/en/list/400/

United Nations Development Programme. (2021). What are the Sustainable Development Goals? https://www.undp.org/sustainable-development-goals?utm_source=EN&utm_medium=GSR&utm_content=US_UNDP_PaidSearch_Brand_English&utm_campaign=CENTRAL&c_src=CENTRAL&c_src2=GSR&gclid=EAIaIQobChMI7Pin2_OY9AIVSoxoCR1s8wKfEAAYAiAAEgLqy_D_BwE

Wan, J., Yan, J., Wang, X., Liu, Z., Wang, H., & Wang, T. (2019). Spatial-Temporal Pattern and Its Influencing Factors on Urban Tourism Competitiveness in City Agglomerations Across the Guanzhong Plain. Sustainability, 11(23), 6743. https://doi.org/10.3390/su11236743

Zhang, Y., Jiao, L., Yu, Z., Lin, Z., & Gan, M. (2020). A Tourism Route-Planning Approach Based on Comprehensive Attractiveness. IEEE Access, 8, 39536–39547. https://doi.org/10.1109/ACCESS.2020.2967060