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Mapping the Distance: An Analysis of Visitor Travel Distance to German National Parks and Biosphere Reserves

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Abstract

The ecologically valuable and unique natural and cultural landscapes of protected areas are popular nature tourism destinations. From a spatial perspective, travellers visit protected areas by moving from their place of origin to the destination for a temporary stay. This paper analyses the travel distances of day visitors and overnight guests to German national parks and biosphere reserves. National parks position themselves as both regional and national destinations. In contrast, biosphere reserve tourism is more regionally concentrated due to the proximity of biosphere reserves to urban centres, which are the primary places of origin for visitors. On average, visitors travel 278.6 km by car to visit a national park, taking 172.1 min-

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Keywords: Automated distance analysis - Biosphere reserves - Mode of transport - National parks - Nature tourism - Travel distance

Kartierung der Entfernungen: Eine Analyse der Reisedistanz von Besucherinnen und Besuchern zu deutschen Nationalparks und Biosphärenreservaten

Zusammenfassung

Die ökologisch wertvollen und einzigartigen Natur- und Kulturlandschaften von Großschutzgebieten sind beliebte Ziele des Naturtourismus. Aus räumlicher Sicht bewegen sich Reisende von ihrem Herkunftsort zu einem bestimmten Großschutzgebiet für einen vorübergehenden Aufenthalt. Dieser Beitrag analysiert die zurückgelegten Reisedistanzen von Tages- und Übernachtungsgästen für die Anreise in deutsche Nationalparks und Biosphärenreservate. Nationalparks positionieren sich sowohl als regionale als auch als nationale Destinationen in Deutschland. Im Gegensatz dazu ist der Tourismus in Biosphärenreservaten durch ihre nähere Lage an den als Quellgebieten der Reisen fungierenden Verdichtungsräumen stärker regional konzentriert. Im Durchschnitt legen Nationalparkgäste 278,6 km bei einer Fahrzeit von 172,1 Minuten (02:52 Stunden) mit dem Auto zurück. Mit öffentlichen Verkehrsmitteln erhöht sich die durchschnittliche Entfernung auf 312,5 km bei 284,5 Minuten (04:43 Stunden). Besucherinnen und Besucher deutscher Biosphärenreservate legen 208,7 km bei 134,7 Minuten (02:15 Stunden) mit dem Auto zurück. Bei der Nutzung öffentlicher Verkehrsmittel für den Besuch von Biosphärenreservaten erhöht sich die durchschnittliche Entfernung auf 234,0 km bei einer Fahrzeit von 239,1 Minuten (03:59 Stunden). Die automatisierten, GIS-gestützten Distanzanalysen bieten einen innovativen Ansatz zur Bewertung von naturtouristischen Einzugsgebieten sowie zur Zugänglichkeit von Großschutzgebieten als Informationsbasis für eine effektive räumliche Planung, Entwicklung und regionales Marketing.

Schlüsselwörter: Automatisierte Distanzanalyse = Biosphärenreservate = Transportmittel = Nationalparks = Naturtourismus = Reisedistanz

1 Introduction

Protected areas are attractions for tourists seeking experiences of nature (Balmford/Green/Anderson et al. 2015; Job/ Becken/Lane 2017). Designated for nature protection and landscape conservation, protected areas play a vital role in preserving valuable ecosystems and their services for humans, including outdoor recreation and tourism (CBD 2022). In Germany, large-scale protected areas are managed and therefore act as both formal and informal instruments of spatial planning and development. The aim is to guide nature tourism use and other human impacts on nature and the landscape by implementing strategies and action plans for visitor experiences, guidance, and education (Eagles/McCool/Haynes 2002: 13-14; Hammer/Mose/ Siegrist et al. 2018: 228). In Germany, these areas include 16 national parks (NLP; IUCN category¹ II), 18 biosphere reserves (BR; no separate IUCN category, I to IV for natural areas and V to VI for landscapes), and 104 nature parks (IUCN category V).

Understanding visitors' travel patterns within these sensitive areas is crucial for implementing and optimizing spatial planning and development strategies and for broader tourism marketing (Leung/Spenceley/Hvenegaard et al. 2018: 1–5; Arnberger/Eder/Allex et al. 2019). For this reason, it is worthwhile investigating nature tourism in protected areas to identify local factors and trends affecting

¹ Classification in the protected area category system of the International Union for Conservation of Nature. the planning and management of tourism in such areas. Measuring the role of nature in protected areas in the context of tourism presents challenges, but there are various approaches to operationalize assessments of this kind (Zulian/La Notte 2022). One such approach is the concept of ecosystem services provided by protected areas for human well-being. In this framework, nature tourism and outdoor recreation are considered quantifiable units for evaluating the volume of these services (Milcu/Hanspach/Abson et al. 2013; Albert/Henke/Iwanowski et al. 2022: 34). Economic impact analyses, for example, typically include tangible factors such as the number of day and overnight visitors to a region and the economic impact of their expenditures in terms of value added and job creation (Mayer/Müller/ Woltering et al. 2010; Job/Merlin/Metzler et al. 2016; Job/ Majewski/Woltering et al. 2024; Majewski 2024).

Travel cost analyses are a sophisticated approach to measure the recreational value of protected areas. These analyses assume people are willing to incur certain travel costs to visit specific destinations. These travel costs can serve as a proxy for the destinations' recreational value, estimated using regression models that examine the relationship between visitation rates and travel costs (Hanley/ Barbier 2009: 79–97). For example, Mayer and Woltering (2018) conducted a travel cost analysis to assess the recreational ecosystem services provided by national parks in Germany, utilizing data on visitation and visitor spending from previous economic impact studies (Job/Merlin/ Metzler et al. 2016).

While these approaches focus on the monetary aspects of measuring the economic impact or value of nature tourism, this paper takes a geographical perspective to examine the spatial dimensions of nature tourism to German national parks and biosphere reserves. The key parameter under examination is the distance travelled by visitors, which is a fundamental spatial feature of their journeys. This factor is also employed in travel cost analyses to determine recreational values; thus, the approach in this paper is conceptually related to such analyses. The analysis compares travel linkages, distances and travel times between the two major protected area categories, each of which has different conceptual frameworks and spatial structures. National parks focus on nature protection and tourism, while biosphere reserves manage cultural landscapes for sustainable human use. This paper displays a nationwide analysis of the travel distance to German national parks and biosphere reserves, answering the following questions:

- What are the spatial linkages between visitors' places of origin as the source region and the national park or biosphere reserve as the nature tourism destination?

- What distances are day visitors and overnight guests willing to travel to national parks and biosphere reserves?
- What are the differences in travel linkages and distances between national parks and biosphere reserves?
- What are the differences in distances between private and public modes of transport?

Understanding the spatial linkages between visitors' origins and destinations aids planners in identifying nature tourism catchment areas and travel patterns, informing marketing strategies for appropriate targeting, and improving accessibility to protected areas. These aspects are crucial for mobility planning of a socio-ecological transformation in transportation (Mark/Holec/Escher 2024: 249), which is particularly important in ecologically sensitive protected areas to alleviate negative impacts on nature, landscape, local communities, and visitors. We utilize an innovative methodological approach to track visitor movements, providing inspiration for spatial analyses in planning. Our approach employs an automated, GIS-based framework to assess the spatial dimensions of tourism in natural areas. Analyses of spatial linkages are familiar from the classic commuter traffic maps, which illustrate the commuting distances of employees based on labour market statistics. These maps show a concentration of commuters in the labour market centres of Germany's major cities, and longer distances in rural areas.² We adapt this spatial analysis of commuters to analyse the attraction of nature in protected areas from the perspectives of outdoor recreation and tourism. Consequently, our approach primarily targets rural areas due to the location of protected areas, in contrast to commuter traffic maps, which reveal urban concentrations.

Aiming to further general understanding, Section 2 explains spatial aspects of nature tourism. Subsequently, Section 3 outlines the roles of protected areas for nature tourism and provides empirical statistics on visitor use in German protected areas, which serve as the basis for the subsequent data analysis. Section 4 explains the methodology, while Section 5 presents the results, which are thoroughly examined and discussed in Section 6. Finally, Section 7 offers a conclusion.

2 Spatial aspects of nature tourism

The key features of tourism are, first, the temporary movements of people using various modes of transport. This feature distinguishes tourism from leisure activities within residential areas. Second, the purpose of these journeys is touristic, including amusement, business, and health tourism (Kaspar 1991: 18; Freyer 2015: 3). Consequently, tourism shows both a dynamic component (the journey) and a static component (the stay) (Kaspar 1991: 18; Freyer 2015: 3). Generally, a distinction is made between day visitors and overnight guests who stay for at least one night (Spenceley/Schägner/Engels et al. 2021: 10–13).

Definitions of nature(-based) tourism typically allude to regions characterized by relatively undisturbed near-natural landscapes (Valentine 1992: 108; Rein/Strasdas 2017: 114–120). Landscape, in a broader sense, is defined by human impacts on space (Aschenbrand 2017: 37), yet nature tourism also reflects socially constructed perceptions of landscapes, as travellers may perceive these areas as natural spaces (Kühne 2013: 31–35; Frieser/Bittlingmaier/Piana et al. 2023: 197–198).

A system-theory definition of visitor movements presented by Leiper (1979: 403–404) outlines five key elements of a tourism system: the tourist, the tourism industry, the source region, the transit region, and the destination region. These elements are spatially and functionally interconnected within a broader environmental context, which includes physical, cultural, social, economic, political, and technological factors. In spatial analysis, the geographical elements are of interest. The source region, typically the tourist's home region, is regarded as the origin and endpoint of the journey. The transit region functions as the travel corridor connecting the source region with the destination, facilitating tourist movement (Leiper 1979: 369).

Later, Leiper (1990: 370–381) introduced the concept of the 'tourist attraction system', consisting of three key elements: the tourist, the nucleus as the geographical point of interest or attraction, and the marker as the information channel which fulfils the brand function of the nucleus. The nucleus functions as the tourism destination, encompassing the area where tourists choose to stay temporarily. This area is equipped with essential infrastructure like accommodation, restaurants, and entertainment facilities (Bieger 2005: 56; Letzner 2014: 5; Freyer 2015: 148; UNWTO 2019: 14).

3 Nature tourism in German national parks and biosphere reserves

Protected areas are popular destinations for nature tourism, offering landscapes for nature-based activities like hiking, cycling, or nature photography. Visitors' travel motivations range from nature preservation to hedonistic pursuits, while the services offered on the supply side can vary from independent to standardized options (e.g., scientific expeditions vs. organized tours or individual backpacking trips vs.

² Pendleratlas der Statistischen Ämter der Länder; https:// pendleratlas.statistikportal.de/ (20.07.2024).



Figure 1 Visitor days in German national parks and biosphere reserves; Source: Steingrube/Jeschke (2011); Rein/Baláš (2015); Job/Merlin/Metzler et al. (2016); Nationalpark-Verwaltung Hainich (2019); Job/Majewski/Engelbauer et al. (2021); Job/Majewski/Woltering et al. (2024); Area size: Bundesamt für Naturschutz

volunteering) (Butzmann/Job 2017: 1741; Marques/Reis/ Menezes 2010: 982). These areas provide infrastructure and visitor management to meet this demand while safeguarding ecologically sensitive areas through visitor guidance (Buckley/Robinson/Carmody et al. 2008: 3593–3598; Leung/Spenceley/Hvenegaard et al. 2018: 27–39).

National parks serve to protect ecological processes, species, and ecosystems in natural regions. This, in turn, forms the basis for recreational activities, environmental education, and nature tourism (Dudley 2008: 16; see also § 24 BNatSchG).³ In Germany, the 16 national parks collectively cover 1.05 million hectares (including marine areas; 208,238 ha terrestrial area).⁴ Visitation to German national parks amount to a total of 57 million visitor days⁵

⁵ Number of days that visitors spend within the protected area.

³ Bundesnaturschutzgesetz (Federal Nature Conservation Act) in the version promulgated on 29. Juli 2009 (BGBl. I S. 2542), last amended by Article 5 of the Act on 3 July 2024 (BGBl. 2024 | Nr. 225). ⁴ https://www.bfn.de/nationalparke (21.07.2024).

https://www.bhi.de/hatiohatparke (21.07.2024).



Day visitor and overnight guest shares in national parks



Figure 2 Overnight guest and day visitor shares in German national parks (NLPs) and biosphere reserves; Source: Steingrube/Jeschke (2011); Rein/Baláš (2015); Job/Merlin/Metzler et al. (2016); Nationalpark-Verwaltung Hainich (2019); Job/Majewski/Engelbauer et al. (2021); Job/Majewski/Woltering et al. (2024)

each year (Mayer/Müller/Woltering et al. 2010; Job/Merlin/ Metzler et al. 2016; Job/Majewski/Engelbauer 2021). The important coastal national park destinations in Germany attract the highest annual visitor numbers, with 21.7 million visitor days in the Lower Saxony Wadden Sea, 21.4 million visitor days in the Schleswig-Holstein Wadden Sea, and 4.8 million visitor days in the Western Pomerania Lagoons national park region (see Figure 1). The importance of these areas for nature tourism is also reflected in the high shares of overnight guests of 70% to 90% (see Figure 2). Conversely, terrestrial national parks record fewer visitor days, with the highest numbers in the Harz and Saxon Switzerland national parks, both with 1.7 million visitor days, and in Berchtesgaden national park with 1.6 million visitor days. Other less important national parks receive one million visitor days or less and are characterized by a high proportion of day visitors.

Biosphere reserves encompass cultural landscapes with

settlements and traffic areas, spatially organized in three zones to regulate the intensity of human use. These areas are designated by the UNESCO as model regions for sustainable development, with a focus on economic activities and interactions between humans and the biosphere (UNESCO 1996; Weixlbaumer/Hammer/Mose et al. 2020: 104; see also § 25 BNatSchG). The world network of biosphere reserves currently includes 748 areas,⁶ with Germany hosting 17 of them (additionally, the Karst Landscape South Harz is designated in state law, bringing the total to 18 biosphere reserves in Germany). The German biosphere reserves cover 2.03 million hectares (including marine areas; 1.36 million ha terrestrial area).⁷

Empirical analyses have recorded 71.6 million visitor days in German biosphere reserves each year (Job/ Majewski/Woltering et al. 2024). Annual visitation is highest in the important coastal biosphere reserve Wadden Sea of Lower Saxony, which is also designated as a national park. Among terrestrial biosphere reserves, the top performers are Berchtesgadener Land with 7.4 million visitor days, Swabian Alb with 7.1 million visitor days, and Rhön with 6.4 million visitor days (see Figure 1). In German biosphere reserves, day tourism plays a more prominent role than in the national parks, with day visitor shares of over 80% in Drömling, Bliesgau, Schaalsee, and Swabian Alb biosphere reserves (see Figure 2).

4 Data and methods

4.1 Dataset

Our analysis is based on data from economic impact studies (Job/Merlin/Metzler et al. 2016; Job/Majewski/Engelbauer et al. 2021; Job/Majewski/Woltering et al. 2024). Visitor data for German national parks were collected through standardized pen-and-paper surveys conducted between 2007 and 2022 (Job/Majewski/Engelbauer et al. 2021). The national park dataset comprised 23,208 detailed interviews, based on information provided by one visitor who represented the visitors' travel group, even if other group members had different origins. Similarly, data for German biosphere reserves were collected between 2010 and 2022 (Job/ Majewski/Woltering et al. 2024) and resulted in 19,291 detailed interviews. Our analysis focused on Germany, hence, the small share of international visitors to national parks and biosphere reserves (mostly < 5%) was not considered.

We used the extensive dataset on visitor numbers and structures (local⁸ or non-local day visitors and overnight guests), the 5-digit postal code of visitors' residences, and the mode of transport to examine the spatial patterns of visitor movements across Germany. The distances that visitors are willing to travel and the travel time required depending on the mode of transport were automatically calculated by specially written Python programs using appropriate routing APIs. Therefore, data on visitors' places of origin (visitors' 5-digit residential postal code) and their destinations (5-digit reference postal codes for the national parks or biosphere reserves) were required as a base. A representative reference point with WGS-849 compliant coordinates was generated for each postal code area. For destination areas, this reference point is located within national parks and biosphere reserves. For large areas with multiple destination units, such as the Schleswig-Holstein Wadden Sea national park or the Elbe River Landscape biosphere reserve, up to four destination postal codes were employed. Visitors were assigned to these reference points based on their proximity to the survey point where they were interviewed.

4.2 Data preparation using ArcGIS Pro

ArcGIS Pro was the primary GIS software used to generate reference points, with geospatial data downloaded in 2022. The 5-digit postal code areas as polygons, based on OpenStreetMap data, were obtained from the Esri Deutschland Open Data Portal and cleansed. Geospatial data of the administrative regions (VG products) were obtained from the Federal Agency for Cartography and Geodesy (BKG). To ensure realistic routing, the reference point (representative centre point) for each postal code area was chosen as the municipality point (VG250 PK from the BKG) with the highest population within the respective area. This approach was used because municipal areas are typically smaller than 5-digit postal code areas, and therefore at least one but usually multiple municipality points were located within a single postal code area. Municipality points (VG250_PK) and municipality polygons (VG_GEM) were obtained from the BKG geospatial dataset of administrative areas with population data (VG250-EW 31.12.). Using 'Spatial Joins', municipality point attributes were combined with municipality polygon attributes (population) and OpenStreetMap data (postal codes). This process in combination with the 'Summary Statistics' tool and further data processing steps

⁶ https://www.unesco.de/kultur-und-natur/

biosphaerenreservate (21.07.2024).

⁷ https://www.bfn.de/biosphaerenreservate (21.07.2024).

⁸ Local day visitors from the immediate surroundings were not considered in German biosphere reserves as these persons do not pursue a tourist purpose.

⁹ World Geodetic System 1984.

allowed the creation of a municipality point dataset, containing for each corresponding postal code area exactly one required municipality point (MAX [population] per postal code).

However, in some cases (e.g., larger cities), a municipal area extends over several or even many small postal code areas. For these postal code polygons, the representative point within a polygon was calculated mathematically using the 'Feature To Point' tool. This is usually not an issue for routing in cities with dense transport infrastructure. However, in rural areas, the calculated representative point of a postal code polygon may fall in natural areas like forests or lakes. This was rare and could be resolved by increasing the search distance around a start or end point (depending on the API used) to find a routable graph (traffic network of nodes and edges).

Subsequently, the representative centre points (municipality points with the highest population for each postal code area) and the calculated representative points (for postal code areas without municipality points) were transferred to a geospatial dataset. For each point, XY coordinates (WGS-84 compliant) were calculated using the 'Calculate Geometry' function. This dataset was exported as a table from ArcGIS Pro and used as a master data table, containing all 5-digit local postal codes and their representative centre point coordinates, by the Python programs for routing requests to transmit the origin and destination coordinates.

4.3 Python-based distance and travel time calculations using routing APIs and result data preparation and visualization

The information from the visitor surveys in German national parks and biosphere reserves (visitor structures, 5-digit postal code of visitors' residences and the mode of transport), the respective 5-digit destination postal code, together with the master data table served as input data for the distance and travel time request processings and calculations. The Openrouteservice API (Directions Service)¹⁰ was used to determine the road-based distances and time durations by car, based on coordinates of given pairs of WGS-84 compliant origin and destination points for route calculation and a default maximum search radius of 350 m for snapping to any routable road from a given origin and destination point. Since the Openrouteservice API currently supports only road-based route calculations, we used the HERE Public Transit API v8¹¹ to determine distances and travel times for routes using public transport, considering all available public transit modes. Routes were defined based on departure times whereby in this case, the earliest possible departure time was set to 5 a.m. and only weekdays were selected for the request. A maximum distance was specified for the walk to the nearest public transit stop or station. In most cases, the standard setting of a maximum distance of 2,000 m walking at a speed of 1 m per second was used.

Finally, the results of the distance and time calculations were visualized on maps. To ensure clarity on the maps, the 5-digit postal code polygons were merged into 2-digit postal code polygons using the 'Dissolve' tool and the calculated 2-digit postal code values column. Subsequently, a representative centre point was calculated for each 2-digit postal code polygon using the 'Feature To Point' tool, and its XY coordinates were determined using the 'Calculate Geometry' function. With another Python program, the master data tables and the individual routing result tables of each biosphere reserve and national park were used as input tables to prepare the tables required for map creation in ArcGIS Pro. The 'XY To Line' tool was used to generate the connecting lines between the origin points (2-digit postal code reference points) and the respective destination point for each individual biosphere reserve and national park (5digit postal code reference point), thus visualizing the travel linkages.

5 Results

The two maps in Figures 3 and 4 illustrate the travel linkages within the national transit region from the visitors' places of origin at the 2-digit postal code level to the destinations of German national parks (Figure 3) and biosphere reserves (Figure 4). In general, most visitors originate from the immediate surroundings of the national park or biosphere reserve. As the distance between the visitors' places of origin and the protected area increases, the number of cases decreases. In Saxon Switzerland national park, for example, most visitors arrive from the same or neighbouring postal code areas, while fewer visitors come from more distant postal code areas, as indicated by the fine pink lines

¹⁰ The API utilizes geographic data from OpenStreetMap, and the Directions Service was developed by HeiGIT – Heidelberg Institute for Geoinformation Technology gGmbH. The URL https://api. openrouteservice.org/v2/directions/driving-car used in requests, returns a route between two (or more, depending on the request parameters) locations for the selected driving-car profile and its settings as JavaScript Object Notation (JSON).

¹¹ This API uses agency data, external services, and data collected by HERE. The URL https://transit.router.hereapi.com/v8/routes provides the most efficient and relevant public transit routes between a given pair of locations.



Figure 3 Travel linkages from visitors' places of origin to German national parks



Figure 4 Travel linkages from visitors' places of origin to German biosphere reserves



Figure 5 Mode of transport to German national parks and biosphere reserves; Source: Job/Merlin/ Metzler et al. (2016); Job/Majewski/Engelbauer et al. (2021); Job/Majewski/Woltering et al. (2024)

connecting them to the reference point of the Saxon Switzerland national park.

A comparison of national parks reveals differences in their visitor reach. For instance, high visitation rates among the local and regional population are evident in the national parks Eifel and Lower Oder Valley. Visitors to the national parks Black Forest, Kellerwald-Edersee, and Hainich also predominantly originate from nearby areas, with slightly broader coverage in some cases. In contrast, the national parks along the German North and Baltic Sea coasts, as well as Müritz, Harz, Bavarian Forest, and Berchtesgaden show significantly longer linkages, extending to various parts of Germany.

Among the biosphere reserves, Schaalsee, Drömling, Bliesgau, and Swabian Alb display shorter connections to their surrounding areas. On the other hand, Schorfheide-Chorin, Elbe River Landscape, Spreewald, Upper Lausitz Heath and Pond Landscape, Karst Landscape South Harz, Thuringian Forest, Rhön, Palatinate Forest, and Black Forest exhibit somewhat broader distributions. The biosphere





Figure 6 Car distance and travel time to German national parks

reserves along the German North Sea and Baltic Sea coasts, together with Berchtesgadener Land, demonstrate the most extensive interconnections.

A comparison between the two protected area categories reveals that the national park map (Figure 3) is significantly more densely interconnected than the biosphere map (Figure 4), primarily because national park visitors come from diverse regions. Consequently, the attraction of national parks is spatially dispersed, whereas visitors to biosphere reserves tend to originate from a smaller number of 2-digit postal code areas. Not only is the spatial dispersion noteworthy, but there are also generally longer connections to national parks than to biosphere reserves. In contrast, the origins of visitors to biosphere reserves are more closely tied to the immediate surroundings of the areas.

With an average share of 80.3% for both national parks and biosphere reserves, the car predominates as the mode of transport to these areas. Across the regions, values mostly fall between 80% and 90% (Figure 5). A few exceptions can be attributed to area-specific features, such as the use of ferries and ships at the Wadden Sea national parks or bicycle traffic in the biosphere reserves Drömling or Elbe River Landscape, where cycling along the river is an important nature-based tourism activity.



Figure 7 Public transport distance and travel time to German national parks

The average travel distance from the visitors' home regions to German national parks is 278.6 km by car. Upon selecting visitors who really travelled by car, the actual travel distance reduces only slightly to 275.4 km. The longest distance travelled is 532.5 km for a visit to Jasmund national park (Figure 6, Figure 8) on Rügen Island. Berchtesgaden follows with 475.0 km, and the Western Pomerania Lagoons national park involves 440.9 km of travel. Lower Saxony Wadden Sea and Müritz national parks are close behind with distances of 375.2 km and 369.1 km respectively. The national parks Hainich, Eifel, and Kellerwald-Edersee are characterized by the shortest distances, each under 120 km. Overnight guests travel 368.4 km on average by car, exceeding the distances covered by non-local day visitors by nearly 250 km, as the latter travel 123.8 km on average. Local day visitors residing nearby travel 31.6 km on average to visit their national park.

The average travel time to national parks by car is 172.1 minutes (02:52 hours). At 170.8 minutes (02:50 hours), the actual travel time of visitors who really took the car deviates only minimally from the scheduled travel time. At 218.2 minutes (03:38 hours), overnight guests travel significantly longer than non-local day visitors for a single day, who travel 95.4 minutes (01:35 hours), and then local day visitors, who travel 36.5 minutes (00:37 hours).

Visitors spend the longest time travelling to Jasmund



Car and public transport distance (km) to national parks



Car and public transport travel time (minutes) to national parks

Figure 8 Car and public transport distance and travel time to German national parks

national park with 297.7 minutes (04:58 hours) by car (Figure 6, Figure 8). Comparable travel times are required to reach the Western Pomerania Lagoons national park at the Baltic Sea coast, with 264.2 minutes (04:24 hours), and the Lower Saxony Wadden Sea national park at the North Sea coast, with 259.3 minutes (04:19 hours). The terrestrial Berchtesgaden national park in the far southeast in the German Alps entails a similar travel time of 258.7 minutes (04:19 hours).

The use of public transport to travel to German national parks increases the average travel distance to 312.5 km, taking 284.5 minutes (04:44 hours). At 368.6 km, the ac-

tual travel distance deviates significantly from the planned distance. The actual travel time extends even further to 315.6 minutes (05:15 hours). Excluding train changes reduces the pure travel time to 244.3 minutes (04:04 hours). Jasmund national park also emerges as the least accessible area via public transport, with an average distance of 572.3 km, taking 477.5 minutes (07:58 hours). This is followed by Berchtesgaden national park at 522.0 km, taking 390.7 minutes (06:31 hours) (Figure 7, Figure 8). Conversely, trips to Hainich or Eifel national parks are considerably shorter, with less than 150 km. Overnight guests cover longer distances of 413.7 km, taking 355.3 minutes (05:55 hours),





Figure 9 Car distance and travel time to German biosphere reserves

than non-local visitors with 155.1 km, taking 184.0 minutes (03:04 hours), and local day visitors with 45.7 km, taking 83.9 minutes (01:24 hours).

The average travel distance from the visitors' home regions to German biosphere reserves is 208.7 km by car, with an actual travel distance for visitors who effectively took the car of 212.5 km. The longest distance travelled is 548.8 km for a visit to South-East Rügen biosphere reserve (Figure 9, Figure 11) which is of the same magnitude as the distance travelled to Jasmund national park of 532.5 km. With this similar catchment area, both areas might be visited during a stay on Rügen Island. The biosphere reserves at the German North Sea coast and Berchtesgadener Land biosphere reserve follow with journeys of over 300 km. A visit to the Black Forest biosphere reserve also involves a journey of up to 260 km. The biosphere reserves Schaalsee, Swabian Alb, Bliesgau, and Drömling are characterized by the shortest distances, each under 100 km. Overnight guests travel an average of 323.5 km, while day visitors travel 98.1 km.

The average travel time by car is 134.7 minutes (02:15 hours). The actual travel time of visitors who used a car is 134.4 minutes (02:15 hours). At 194.3 minutes (03:14



Public transport distance (km) to biosphere reserves



Figure 10 Public transport distance and travel time to German biosphere reserves

hours), overnight guests travel longer than day visitors at 77.9 minutes (01:18 hours).

Visitors spend the longest time travelling to Wadden Sea and Hallig Islands of Schleswig-Holstein biosphere reserve at 328.1 minutes (05:50 hours) by car (Figure 9; Figure 11). A similar travel time is required to reach the South-East Rügen biosphere reserve at 310.8 minutes (05:11 hours), as well as the Wadden Sea of Lower Saxony biosphere reserve at 259.3 minutes (04:19 hours; same value as for the national parks because of the same database).

With the use of public transport, the average travel distance to German biosphere reserves is 234.0 km, taking 239.1 minutes (03:59 hours). The actual travel distance is 285.1 km at 264.6 minutes (04:24 hours). Excluding train changes reduces the pure travel time to 199.9 minutes (03:20 hours). South-East Rügen biosphere reserve emerges as the least accessible area via public transport because of its location on Rügen Island, with an average travel distance of 582.9 km, taking 512.4 minutes (08:32 hours) (Figure 10, Figure 11). At 356.0 km and 325.1 minutes (05:25 hours), overnight guests cover longer distances than day visitors at 120.1 km, taking 162.9 minutes (02:43 hours).





Figure 11 Car and public transport distance and travel time to German biosphere reserves

6 Discussion

Visitors to German national parks and biosphere reserves travel various distances, as depicted both cartographically and mathematically in this paper. The travel linkage maps are similar to classic commuter traffic maps, which illustrate how employees travel from their residences to primarily urban places of work. However, unlike commuters, our target group travels to visit near natural and traditional landscapes within protected areas, mostly located in rural regions. Thereby, spatial situations related to the location of protected areas explain the distances travelled, along with the travel time required for the journeys.

It can be observed that travelling to national parks and biosphere reserves located in peripheral areas of Germany involves longer distances and travel times, indicating their relative inaccessibility compared to more centrally located protected areas. For example, overnight guests travel more than five hours by car and up to eight hours by public transport to reach peripheral and touristically important national parks and biosphere reserves such as Berchtesgaden national park in the Alps, Western Pomerania Lagoons national park at the Baltic Sea coast, Jasmund national park (Figure 6, Figure 7), or South-East Rügen biosphere reserve (Figure 9, Figure 10) on Rügen Island. In contrast, national parks like Eifel or Lower Oder Valley, which attract mostly day visitors, have shorter travel distances. Biosphere reserves, on the other hand, are identified as regional destinations, particularly the Schaalsee, Drömling, Bliesgau, and Swabian Alb biosphere reserves, where the average car distance is less than 100 km. Simultaneously, the proportion of day visitors to these regions exceeds 80% (Figure 2), with travel connections linking them to Hamburg, Wolfsburg, Saarbrücken, and Stuttgart. The proximity of these areas to urban centres, which serve as the primary sources of visitors, is reflected in both the travel distances and the visitor structures.

Mayer and Woltering (2018) also estimated travel distances to German national parks and found a range between 85.4 km to Eifel national park and 526.2 km to Jasmund national park (all visitors). Their findings basically align with the results of our automated calculation. However, comparing the overall averages from both studies reveals a 14.9 km deviation. Our automated calculation averaged 278.6 km, while Mayer and Woltering (2018: 378-379) report 267.9 km. This indicates that slight deviations in the results may occur due to variations in databases and evaluation methods. For example, Mayer and Woltering (2018) used Google Maps to estimate the shortest road distance between the place of origin and the national park, whereas our analyses relied on OpenStreetMap data. Harmonizing the approach for the analyses in this paper proved advantageous, as it allows a direct comparison between national parks and biosphere reserves. For spatial planning and management, our procedure offers an automated, GIS-based framework, which is transferable to other spatial analyses investigating the mobility of selected target groups, such as those seeking education or medical access, in the context of demographic change.

However, our analyses focused on visitor movements within Germany, as the audience at German national parks and biosphere reserves is predominantly German. Nonetheless, it may also be interesting to analyse international visitors, particularly in border areas and at internationally important destinations, such as Black Forest biosphere reserve, Berchtesgadener Land biosphere reserve, and Berchtesgaden national park (Job/Merlin/Metzler et al. 2016: 14–15; Job/Majewski/Woltering et al. 2024). Lastly, only the information of one person per travel group was used for this analysis, which could lead to a possible underrepresentation of individual places of origins.

The maps in Figures 3 and 4 show a greater density of travel linkages for national parks than for biosphere reserves, which can be attributed to the greater spatial dispersion of the former and the longer average distances trav-

elled by day visitors and overnight guests to reach them. In contrast, biosphere reserves are tourist destinations of more regional significance, which is also evidenced by higher day visitor shares (Figure 2). This demonstrated a difference between the attraction of the two protected area labels, which also affects visitor structures (Fredman/Hörnsten Friberg/ Emmelin 2007; Martins/Carvalho/Almeida 2021). In this context, another approach to measure visitors' awareness for protected area labels is to examine the affinity of visitors to national parks and biosphere reserves (Job/Merlin/ Metzler et al. 2016; Job/Majewski/Woltering et al. 2024). Referring to Leiper's 'tourist attraction system' (see Section 2), affinity can be an indicator of the attraction of the nucleus, the geographical point of interest or attraction, or the strength of the marker, which denotes the brand function of the national park or biosphere reserve destination (Wall Reinius/Fredman 2007: 845-852; Majewski 2024). Research shows that national parks attract a higher proportion of visitors with a high affinity at 28.3 % (Job/Merlin/ Metzler et al. 2016: 17), compared to biosphere reserves at 11.0% (Job/Majewski/Woltering et al. 2024: 35). This disparity is supported by our analyses, which show that national parks attract visitors from more distant locations, while the spatial attraction of biosphere reserves is less pronounced. The broader attraction of national parks implies a stronger branding of this label, which is consistent with the affinity numbers. This key finding about the different catchment areas of the two protected area categories can help spatial planning and development to implement target group-oriented tourism marketing.

Another important aspect for spatial planning is the mode of transport to travel to national parks or biosphere reserves. Regional and municipal mobility planning faces significant challenges, such as route expansions to remote areas and costs linked to socio-ecological transformation in transportation (Mark/Holec/Escher 2024). Particularly in the ecologically sensitive and rural national park and biosphere reserve regions, the transportation sector is under considerable pressure to act to alleviate the burden on nature, local communities, and tourists. Our analyses show that visitors' transport choices relate to the travel distance for visitors from their homes and the time required to cover this distance. On average, national park visitors travel 278.6 km by car, taking 172.1 minutes (02:52 hours). Opting for public transport increases the average travel distance to 312.5 km, with an increased travel time of 284.5 minutes (04:43 hours). For biosphere reserve visitors, the average car distance is 208.7 km, requiring 134.7 minutes (02:15 hours). The average public transport distance to German biosphere reserves is 234.0 km, with a time of 239.1 minutes (03:59 hours). This means that the travel time using public transport to travel to national parks and biosphere reserves is significantly higher than travel the time by private car.

Despite a positive trend in regional rail accessibility in Germany, general disparities persist between urban centres and peripheral regions, as well as between western and eastern Germany (Wenner/Thierstein 2021: 102). The considerable amount of time required to travel to Germany's protected areas via public transport may explain why car usage exceeds 80% on average in both the national parks and the biosphere reserves. In remote regions such as Bavarian Forest, Berchtesgaden, Jasmund, or Western Pomerania Lagoons national parks, as well as Upper Lausitz Heath and Pond Landscape biosphere reserves, the car share is almost 90%, highlighting the challenges of accessibility for spatial planning and development. However, even centrally located regions like Eifel national park, Palatinate Forest biosphere reserve, or Bliesgau biosphere reserve are frequently accessed by car, indicating that location and difficult accessibility are not the sole factors contributing to the high proportion of car usage.

These key findings lead to the following protected area management and spatial planning implications. Firstly, targeting overnight guests would affect regional development as encouraging longer stays would reduce the daily influx of visitors. In fact, a high proportion of day visitors can occur as peak visitation on particular days and with increased overall traffic volumes, particularly during favourable weather conditions for hiking or cycling excursions (Job/Majewski/ Woltering et al. 2024: 77).

Secondly, improving the accessibility of national parks and biosphere reserves through establishing more and better public transport options could mitigate traffic congestion. This, in turn, would help minimize ecological and social disruption to both the natural environment and local communities. However, implementing and financing leisure transportation poses a significant challenge for both protected areas and destination management as well as for local and state spatial traffic planning (Kagermeier/Gronau 2016: 213-215; Majewski/Job 2019: 196). Furthermore, cycling can be promoted as an active, healthy, and CO₂ neutral activity (Shaker/Hermans/Zahoor 2021: 96–99). Cycling already plays an important role in some regions like Elbe River Landscape, Drömling, and Bliesgau biosphere reserves (Figure 5). This can be attributed to various factors related to their spatial structures. The biosphere reserves Drömling and Bliesgau tend to be visited by recreational cyclists due to their proximity to urban centres, while the Elbe River Landscape attracts cycling tourists from all over Germany, as indicated by the travel linkages (Figure 4). Also, visitors opt for different modes of transport for arrival and departure compared to getting around within the destination. For example, the share of car usage for travel to Lower Saxony Wadden Sea national park is more than 80%, whereas the car accounted for just under a quarter of transportation within the destination, where visitors use the ferry or bicycles (Job/Bittlingmaier/Woltering 2023: 41).

7 Conclusions

National parks and biosphere reserves provide landscapes for nature tourism, which attract visitors from across the country. This, in turn, leads to visitor movements as people travel from their places of origin to a national park or biosphere reserve for a day trip or an overnight stay. In our analyses, a geographical approach was utilized to quantify visitor movements using automated, GIS-based calculations, which enriched our understanding of the spatial dimensions of nature tourism within these regions. As a result, visitor flows could be visually represented as distances between the visitors' hometowns and the national parks or biosphere reserves. Based on the idea of commuter traffic maps, our visitor travel linkages maps depict a vibrant network of lines, notably denser on the national park map.

National parks demonstrate a stronger national attraction for tourists than biosphere reserves, which exhibit a more pronounced regional focus. This contrast is evident in the average distances travelled, with both overnight guests and day visitors undertaking longer distances to visit national parks than biosphere reserves. The proximity of biosphere reserves to urban centres, which are the primary sources of travel, accounts for this difference.

The findings can be regarded as a measure of the role of nature in the context of tourism, with nature-based experiences in national parks exhibiting a strong nature tourism attraction. In contrast, biosphere reserves place a greater emphasis on sustainable and holistic development, which consequently diminishes their appeal as nature tourism destinations. Finally, the analysis revealed that the mode of transport to reach these regions influences the length of distances undertaken and travel times, further complicating accessibility to protected areas. Given that national parks and biosphere reserves are ecologically sensitive areas, transportation emerges as a crucial challenge for future protected area management, as well as spatial planning and development.

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