

# Beyond Spatial Proximity: A Temporal Accessibility Index for Equitable Nature Access in Bavaria’s Hiking Trails

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**Abstract:**

As a culturally enriching and health-promoting activity (Kim & Miller, 2019; Santarém et al., 2015), hiking has been popular among urban residents, particularly post-COVID-19 (Griffiths, 2020). Equitable access to natural environments significantly influences physiological, psychological, and immunological well-being (Yin et al., 2023). However, traditional accessibility metrics primarily emphasize spatial proximity, often overlooking critical temporal constraints, such as weekday evening availability, public transport schedules, and daylight hours. These hidden temporal barriers disproportionately exclude marginalized groups (e.g., caregivers and shift workers) from accessing nearby trails, even in geographically compact regions.

To address these limitations, this study refines the research focus to weekday evening accessibility, particularly relevant during summer months when extended daylight and improved weather conditions offer enhanced opportunities for outdoor activities. Specifically, this research introduces a refined Temporal Accessibility Index (TAI) to evaluate hiking trails accessible from urban centers on weekday evenings, emphasizing public transport connectivity.

Using Munich, Germany—a city known for its dense working population and advantageous geographic proximity to Alpine hiking trails—as a case study, the study analyzes trail feasibility based on real-time transit schedules, daylight availability, and trail duration. We analyze 32,953 trails from Wikiloc (<https://www.wikiloc.com>), a leading crowdsourced platform with over 14 million global trails and 11.3 million active users. Key variables are shown in Table 1. Trail lengths range from 0.0 m to over 1,168,232 km, with elevation gains and losses reaching up to 135,216.9 m, reflecting significant variation in physical demand and time requirements.

Data Type	Name	Description
Spatiotemporal attributes	Origin-destination coordinates	Geographic coordinates marking the start and end points of the trail.
	Trail length	The total distance of the trail
	Elevation profiles	A key indicator reflecting the difficulty level of the trail based on changes in elevation.
	Duration	Used to calculate the required time window for completing the trail.
Operational metadata	Trail type	Specifies whether the trail is a loop ( <i>Loop</i> ) that returns to the starting point or one-way ( <i>One Way</i> ), requiring transportation arrangements.
	Difficulty	Categorized as <i>Easy</i> , <i>Moderate</i> , <i>Difficult</i> , <i>Very Difficult</i> , <i>Experts Only</i> to indicate the level of challenge.
	Upload timestamps	The time period during which the trail data was uploaded, spanning from 2002 to 2024.
	Trail rank	The higher the score, the more popular the trail is among users.

Table 1. Description of Hiking Trail Data Attributes

Preliminary analysis of hiking data is presented in Figure 1. A marked increase in participation is observed in 2020 and 2024 (Figure 1a). The 2020 surge coincides with post-COVID-19, suggesting heightened interest in outdoor recreation following lockdowns and rising health awareness. The increase in 2024 follows the introduction of Germany’s €49 monthly public transportation ticket in 2023, which substantially lowered travel costs and improved access to natural areas. Seasonal patterns are also evident, with hiking activity peaking in spring and summer, likely driven by longer daylight hours and favorable weather conditions. Changes in trail usage patterns are shown in Figure 1b, where a growing preference for one-way routes—those with different start and end points—indicates increasing dependence on

public transport. These findings highlight how public policy and mobility infrastructure shape outdoor recreational behavior.

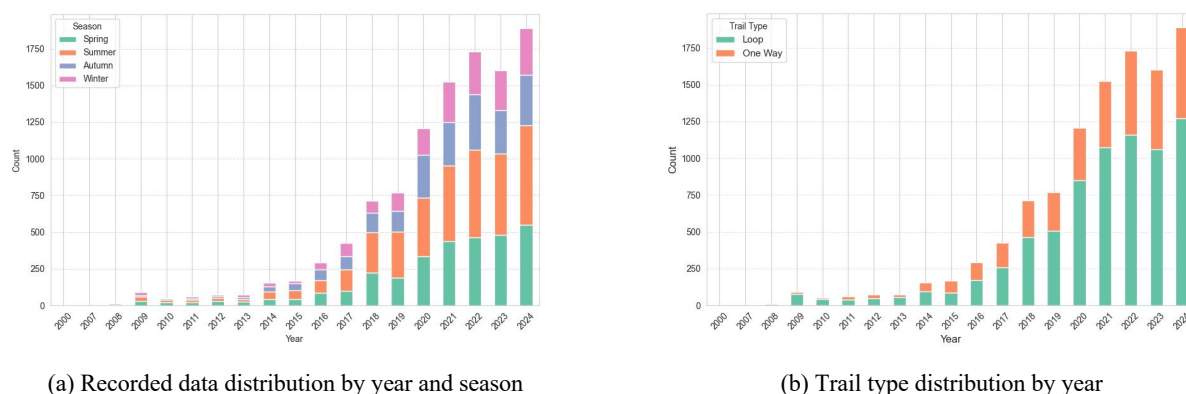


Figure 1. Description of Hiking Trail Data Attributes

The sustainable approach inherent in public transport utilization highlights this analysis's significance in urban and transit planning policies, providing actionable insights aimed at increasing equitable access to nature during weekday evenings.

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