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Opportunities and Limits of Open Data for Measuring and Profiling Destination Rail Connectivity: A Multi-Feed Pipeline Applied to Košice (Slovakia)

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Abstract

This pilot study presents an open, reproducible, multi-feed pipeline for measuring and profiling destination rail connectivity, applied to Košice (Slovakia), a peripheral cross-border destination. Seven General Transit Feed Specification (GTFS) feeds covering Slovakia and five neighboring countries are harmonized over a common analysis window from 14 December 2025 to 12 December 2026 (364 days), from which direct and time-feasible single-transfer inbound itineraries are constructed with a 10–90 min transfer window. The results are combined with municipal population, degree-of-urbanization classes, and a leisure rail-travel rate derived from Flash Eurobarometer 551 microdata. Four nested quantities are distinguished: scheduled rail connectivity—the services present in the timetables; the population catchment—residents aged 15 and over of the connected municipalities; the rail-traveling population, the catchment narrowed by the survey-measured travel rate; and the connecting-adjusted population—which further discounts the single-transfer layer by the share of rail travelers who are willing to change trains. Across Slovak municipalities 2,907,245 (56.0%) residents have a direct or single-transfer connection, 2,132,571 (41.1%) can make a same-day return on at least one day of the analysis window, and 821,892 (15.8%) can make a same-day return on at least 90% of days. Applying an age-banded leisure rail-travel rate to the residents aged 15 and over of those municipalities who live 50 km or more away by rail yields an expected rail-traveling population of approximately 837,000 (nominal interval 762,000–912,000), which is an upper bound before any discount for transfer acceptance. Cross-border coverage is unequal and asymmetry persists at one transfer. Between 14% and 54% of each neighboring country's measured catchment exists only because its national feed was loaded.

Keywords: open data; rail connectivity; GTFS; destination accessibility; cross-border mobility; reproducible methods

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1. Introduction

Over the past two decades, the rise and ongoing consolidation of open-data policies across the European Union have made data an integral part of the knowledge base not only of globally recognized destination management organizations (DMOs) but, increasingly, of smaller and peripheral destinations as well. As open data has become more deeply embedded, destinations' connectivity, as a basic destination element, has been transformed from a neutral descriptor to a lever of policy.

The European Parliament's (2026) recent resolution for the upcoming EU's strategy for sustainable tourism confirmed the necessity to balance the economic, social and environmental dimensions of tourism [1]. The resolution explicitly points out the critical importance of redistributing travelers from a small minority of destinations facing overtourism to emerging destinations and to remote and underserved regions [1,2]. Even though rail represents only 10% of journeys made, the resolution recognizes it as the cornerstone of sustainable tourism and calls for increased investment in its infrastructure, "*particularly cross-border sections and sections that are vital for international connectivity; alongside strengthened support for secondary and capillary networks, to ensure the accessibility of remote and peripheral regions*" [1,2].

European Commission's (2017) Delegated Regulation (EU) 2017/1926, supplementing Directive 2010/40/EU, advances the EU's open-data ambition for mobility by requiring transport authorities and operators to make the static travel and traffic data they already hold in machine-readable form (e.g., timetables, routes, fares, and access-node information) accessible for reuse through a National Access Point [3,4].

The purpose of this manuscript is to support local destinations' ongoing efforts in maximizing the use of open data in the domains of market analysis and marketing, aligned with the EU's long-term goals for sustainable tourism. This manuscript presents a reproducible approach for creating tourism destinations' inbound rail connectivity and related population catchment. The approach integrates General Transit Feed Specification (GTFS) data with municipality-level population data classified by urbanization degree. The developed approach was tested on Košice (Slovakia), a near-border regional capital, and at the same time a peripheral tourism destination at the European Union scale.

The importance of this study lies in addressing a basic precondition for any eventual efforts to redistribute tourist flows within the EU by rail. To even begin eventual domestic, cross-border, or even pan-European discussions among national and regional administrators and DMOs about cooperating to redistribute demand between destinations, the core selling points of their primary tourism resources must be matched. Once that condition is met, the connectivity profile of every participating destination must be identifiable in feasible ways to answer a simple question: Which of the redistributing destination's source markets can also reach the absorbing destination? In other words, disconnected and poorly connected destinations will not be able to absorb redirected demand. The following terms are used throughout this paper with their corresponding meanings:

- Connectivity: The existence and frequency of scheduled rail services between two places within the analysis window;
- Reachability: Whether a feasible itinerary exists at all, irrespective of frequency;
- Accessibility: Reachability weighted by the time it takes;
- Population Catchment: Residents of municipalities with a feasible inbound itinerary;
- Rail-Traveling Population: The population catchment multiplied by a survey-measured rate of leisure rail travel beyond 50 km;
- Service Coverage: The share of a defined denominator reached, always stated with that denominator;
- Gateway Dependence: Reliance on a single transfer station, under a stated definition.

1.1. Background and Related Research

The backbone of this study rests on four building blocks: (1) accessibility theory; (2)

the use of open GTFS data for accessibility analysis; (3) rail-specific accessibility and related impact of high-speed rail; and (4) the frame of tourism destination connectivity and accessibility.

1.1.1. Accessibility Theory and Measure Families

From a conceptual perspective, Hansen (1959) formalized accessibility as a potential measure in which opportunities are discounted by the cost of reaching them [5]. The long lineage of accessibility is captured in the synthesis of Geurs & van Wee (2004) [6]. Based on existing concepts, the field of accessibility is organized into four measure families:

1. Infrastructure-based measures (e.g., network speed or congestion);
2. Location-based measures (the opportunities reachable from a place, including contour and potential measures);
3. Person-based measures (what specific individuals can reach under time–space constraints);
4. Utility-based measures (the benefit derived from the available choices) [6].

Each of these families has its own intellectual roots. Location-based measures were built upon Hansen's (1959) gravity-based potential formulation and were later redefined to capture locations' ability to compete for a finite supply of opportunities [7]. Person-based measures trace back to Hägerstrand's (1970) space–time geography, which addresses a simpler question of what a person can actually reach within the time–space constraints of their day [8]. Kwan (1998) later reformulated the framework of the idea at the individual level [9]. Ben-Akiva & Lerman's (1979) utility-based measures treat accessibility as the expected benefit a traveler gets from their choice [10]. As Handy & Niemeier (1997) pointed out, no single measure suits every purpose, and ultimately, the measure's theoretical soundness, interpretability, and data requirements are essential for choosing a measure [11].

1.1.2. Open GTFS Data for Accessibility Measurement

The General Transit Feed Specification (GTFS) has become a standard for publishing schedule data and is widely adopted by transit and rail operators. Open GTFS data widely supports rigorous accessibility measurements and reproducible, GIS-based, and population-aware analyses of rail and transit. More importantly, open GTFS data has already proven to be a valuable asset not only for intra-urban, cross-regional, and international connectivity analysis but also in peripheral cross-border settings. Location-based accessibility research at scale began to spread once GTFS of public transport operators and private mass transit operators became widely available as open data.

Vannacci et al. (2015) demonstrated the value of open GTFS timetables by constructing time-aware rail accessibility indicators for several European regions (NUTS3) of Great Britain, the Netherlands, and France [12]. Pourramazani et al. (2026) developed an open GIS procedure for spatial-proximity modeling to analyze equity of public-transport access at the metropolitan scale of Valencia, Spain, based on the combination of open GTFS with a census population grid [13]. GTFS is applicable to any type of public transport; for example, Luo et al. (2019) compared the tram feeds of eight metropolitan cities using a derived generalized travel cost directly from networks' attributes [14]. The issue of stopover waiting times (moving between connections) and dealing with these issues in multimodal transport systems was captured by Kujala et al. (2018) via their self-developed Python 3.11 package computing Pareto-optimal journeys, which was tested in the greater Helsinki metropolitan area [15]. Scaling up to the national level, Huang et al. (2018) applied complex-network analysis to train timetables to trace how China's railway

network evolved across four stages of high-speed-rail development, showing that timetables alone can reveal the structure and growth of a real railway network [16].

1.1.3. Rail-Specific Accessibility and High-Speed Rail Impact

The positive impact of rail connectivity on a destination's potential and competitiveness has been established in the past. A number of studies link high-speed rail (hereinafter HSR) connectivity to tourism in terms of the spatial structure of potential incoming markets, demand and seasonality, and destination development across destinations worldwide.

Campa et al. (2016) applied Chen and Haynes's (2015) multivariate panel model (original case involving 27 Chinese regions) to 47 Spanish provinces, finding a positive yet weaker link between HSR network development's impact on inbound international tourism and related revenues than in China [17,18]. However, they concluded that the model's reliability is constrained by the limited availability of suitable open data tourism indicators [17]. Campa et al. (2019) moved further to analyze, in more depth, the impact of HSR on cultural tourism at the regional level, concluding that HSR may reinforce cultural tourism but only selectively in individual regions; at the same time, HSR availability by itself did not represent an extraordinary boost for cultural tourism [19]. Boto-García and Pérez (2023) demonstrated that HSR connectivity and related accessibility at the regional level also mitigate tourism seasonality, with the strongest effects at higher levels of network access [20].

In terms of China being the global leader in HSR infrastructure development, a heterogeneous set of studies may be identified. Li et al. (2019) and Hou (2019), applying large regional-level panel analyses, identified a larger positive impact of HSR on international inbound tourism in small- to medium-sized destinations [21,22]. Similarly, Zhou et al. (2023) found a stronger positive effect in smaller destinations, which faded over long-term observations [23]. Yin et al. (2019) found that HSR may completely reshape the spatial structure and concentration of tourist flows in the case of the metropolitan cities of Beijing and Tianjin [24].

1.1.4. Tourism, Connectivity of Peripheries, and Cross-Border Accessibility

In terms of the above-mentioned EU policy, both topics of rail accessibility in cross-border regions and peripheral destinations have been within the scope of European studies. Gutiérrez et al. (2019) surveyed tourists at Costa Daurada (Spain) who used peripheral HSR stations as transfer stations to their final destinations and found that direct public transport connections carry more weight in tourists' mode choice than the cost or duration of the onward trip [25]. Szymanska et al. (2021), addressing the strong market demand and the need to improve access to the remote, peripheral cross-border UNESCO World Heritage site of Białowieża Forest, proposed an intermodal tourist-mobility model combining the public-transport network with an e-vehicle rental service [26]. Székely et al. (2023), by measuring daily public-transport accessibility of Slovakia's eight regional urban centers from every municipality in their regions, identified that, from many peripheral municipalities (mainly on Sundays and in the sparsely populated areas of two regions), a car-free same-day visit to the regional seat is out of reach, which may lead to transport-related social exclusion [27].

Kołodziejczyk (2020) analyzed cross-border public-transport connectivity between Poland and Czechia (both Schengen members) in relation to the tourism attractiveness of destinations in both regions, concluding that poorly coordinated routes and timetables in combination with irregularly located crossing points weaken the accessibility of destinations to tourists without a car [28]. Wendt et al. (2021) compared transport infrastruc-

ture across the Bihor (Romania)–Hajdú-Bihar (Hungary)–Maramureş (Romania)–Zakarpattya (Ukraine) cross-border regions and found that accessibility shapes the intensity of cross-border tourism, acting as a strong point in the former region but as an obstacle to tourism development in the latter [29].

The issue of accessibility of peripheral tourism resources is not exclusive to border regions, but also resurfaces in urban destinations [30,31]. Masiero & Hrankai (2022) captured this with their discrete-choice experiment and hybrid choice model of utility-based tourist accessibility to peripheral attractions in Hong Kong, where in 2019, fewer than 5% of tourists reached peripheral attractions [30]. Their study concluded, among other things, that visitors' perceptions of the public-transport system influence whether tourists ever venture to attractions beyond the crowded urban core [30]. Moragues et al. (2024) identified a similar imbalance within the Spanish urban destinations of Palma and Málaga [31]. Comparing public-transport equity between the urban core and periphery by utilizing open GTFS data in combination with a Public Transport Need Index revealed service disparities in Palma (underserved peripheries) but a more evenly balanced network in Málaga [31].

1.1.5. Existing Open-Source Routing Engines and Libraries

Open-source timetable routing has converged on a family of algorithms and engines. Delling et al. (2015) introduced RAPTOR, which computes Pareto-optimal journeys over arrival time and number of transfers directly from the timetable; because it needs no preprocessing, it also works in fully dynamic settings [32]. The second-generation transit router of OpenTripPlanner implements a multi-criteria Range Raptor variant of the same algorithm [33]. Conveyal's R5 belongs to this family but is built for accessibility analysis. Through the r5r interface documented by Pereira et al. (2021), it returns percentile travel times over a time window and applies one of several decay functions to produce cumulative-opportunity or gravity-based measures [34]. For computing journeys and for aggregating accessibility once a network and a set of weighted destinations exist, these tools are more rigorous and better engineered than the procedure reported here. This study is not an alternative to them and does not claim to improve on either capability.

Instead, it addresses two layers that such engines take for granted. The first lies beneath the routing step and concerns feed identity, which neither engine's documentation discusses. setup_r5() builds a routable network from an OSM extract and GTFS input and accepts more than one feed, but no documented mechanism establishes that two feeds describe the same station, and the OpenTripPlanner documentation is equally silent on this [33,34]. Given independently produced national feeds, an engine therefore treats one physical border station, published under different identifiers and spellings, as separate stops between which no transfer can be built. The second layer lies above the routing step. Accessibility is computed over point origins and destinations to which the user has already attached opportunity counts, and the documented interface has no representation of administrative or statistical geography, no knowledge of the NUTS hierarchy or the LAU-NUTS correspondence, and no population data beyond a demonstration grid [34]. Assembling municipal boundaries, degree-of-urbanization classes and resident population—harmonized across five national statistical offices that use incompatible identifier conventions and age bands—is a precondition for using such an engine, not a service it provides. The pipeline developed in this pilot study implements both layers. It also keeps a provenance record that pins each feed by retrieval timestamp and digest so that a reported result remains reproducible after the publisher has overwritten the feed.

1.2. Aims of Study

To achieve the purpose described, several partial aims are drawn that altogether answer a set of research questions:

1. Assess the availability and usability of open GTFS data and related open statistical data through governmental pipelines for the countries within scope of this study.
2. Utilize available open GTFS data in a reproducible and configurable pipeline for computing destinations' inbound rail connectivity profiles. The aim addresses the questions of a destination's direct and (pre-defined) feasible single-transfer reach and the quality of connections in terms of three basic measures (journey time, journey efficiency, and service frequency).
3. Characterize the rail connectivity profile of the destination's catchment by resident population, degree of urbanization, regional purchasing power, and selected Flash Eurobarometer microdata.
4. Quantify the distinctive cross-border reach of the analyzed destination, partially including its gateway transfer hubs.

In summary, the main aim of this work is to provide destinations and DMOs with a reproducible, transferable, open-data approach, piloted on the peripheral near-border destination of Košice. Based on the identified direct and single-transfer connectivity, the main conclusion is that Košice is exactly the type of destination that the new EU strategy addresses. Domestically, without transfers, Košice is only a county-level (NUTS 3) hub that does not fully cover all towns of Eastern Slovakia (NUTS 2), and it is heavily dependent on the main corridor connecting to the capital, Bratislava. In contrast, a single transfer extends the city's inbound catchment to cover 56% of Slovakia's population. In terms of cross-border connectivity, direct foreign connections are limited to the Budapest (Hungary) and Prague (Czechia) main lines, while single transfers open up Košice to a population of over 11 million across the four neighboring EU countries.

The four aims translate into four research questions, each answered by number in the Discussion Section:

1. **RQ1.** How available and usable are open GTFS feeds and related open statistical data for the countries in scope, and how do feed provenance, completeness and the length of the analysis window limit what can be measured across the border?
2. **RQ2.** What is the destination's inbound rail connectivity profile, direct and with one transfer, in terms of service coverage, journey time, journey efficiency, and service frequency when computed with a reproducible, configurable pipeline?
3. **RQ3.** What do resident population, degree of urbanization, regional purchasing power and car ownership reveal about the destination's population catchment, and what do they leave out?
4. **RQ4.** How large is the cross-border population catchment that the destination reaches within the available feeds, and how much does it depend on individual transfer stations?

2. Materials and Methods

2.1. Basic Parameters of the Case Study

The city of Košice (Slovakia, Central Europe) was selected as the tested anchor destination. Its geographical predisposition, combining cross-border proximity with a peripheral position at the EU scale, creates a particularly well-suited case for the pilot application. In terms of cross-border relations, its short aerial distance to three neighboring countries (Hungary (6 km), Poland (55 km), and Ukraine (58 km)) places the city at the intersection of several national transport networks.

At the domestic scale, Košice is the second largest city in the country and one of the two most eastern urban centers. At the same time, as the largest economic hub in eastern

Slovakia, the city and its closest surroundings function as the main economic gateway for the whole region. However, internationally, Košice currently may be considered a peripheral urban destination within the European Union. As neighboring Ukraine's EU candidate status is progressing towards full membership, the city's strategic importance as an international hub may grow. Understanding the city's current rail connectivity may therefore not only advance local discussions about EU policy implementation but also may help the local DMO in preparations to reach out to new target groups in advance.

2.2. Input Data Selection Process

2.2.1. Open GTFS Data

Given the time that has passed since Delegated Regulation (EU) 2017/1926 was published, the first attempt to select suitable data focused on the official portal for European data, which logs and aggregates open data harvested from member states' national portals and EU institutions [35]. Since manual searches for available GTFS data across the European portal, national data portals, and national rail operators' pages produced mixed results, alternative sources had to be identified for three of the neighboring EU member states and Ukraine (Table 1) [35, 36]. The community-led journey-planning platform Transitous, which makes harmonized GTFS feeds available from publicly available data, was identified as a suitable alternative source [37].

Table 1. Overview of GTFS data availability.

Country	Status at data.europa.eu	Status at National Data Portal	Status at National Rail Operator	Status at transitous.org
Slovakia	URI reference to national rail operator's page [38].	Up-to-date GTFS data covering the entire domestic rail network, including foreign stations [39].	URI reference to national data platform [40].	Up-to-date data referenced from the national data portal [41].
Austria	Outdated data from 2019; URI reference to a deprecated page of the national rail operator [42].	Outdated data from 2019 [43].	Up-to-date GTFS data covering the entire domestic rail network, including foreign stations [44].	Up-to-date data referenced from the national portal for mobility data [45].
Czechia	Up-to-date data in NeTEx format [46].	URI reference to up-to-date data at the national portal for mobility data [47,48].	Not identified.	Up-to-date transformed data from the national portal for mobility data [49].
Hungary	No reference at the national level [50].	URI reference to a non-existent page of the national operator [51].	Data accessible only upon approved request; data contains only Hungarian stations [52].	Up-to-date transformed and extended data of the national operator [53].
Poland	No reference at the national level [54].	URI references to several carriers (mixed data formats); PKP national authority data available only upon request [55].	Not identified.	Up-to-date transformed data of the national operator [56].
Ukraine	Not identified [57].	Not identified [58].	Not identified.	Up-to-date subset of main Ukrainian train stations

Country	Status at data.europa.eu	Status at National Data Portal	Status at National Rail Operator	Status at transitous.org
				combined with European stations [59].

Due to the mixed availability of official GTFS data published by national rail operators or governmental institutions, all input feeds within the study originated from Transitous [37]. For Czechia, a ready-to-use GTFS feed from Transitous, created using Koňařík's (2026) JrUtil transformation library, was selected [49,60]. For Austria, Hungary, and Slovakia, the GTFS feed derived from the national operator's data, processed and extended by the Transitous community to also include foreign stops and routes, was selected [41,45,52,53]. For Poland, Transitous data harmonizing the feeds of all carriers operating under the auspices of the national operator PKP PLK, generated with Kuranowski & Kasznia's (2026) PolishTrainsGTFS solution, was integrated [37,61]. For Ukraine, Brüchert's (2026) contribution to Transitous, covering the national rail operator Ukrzaliznytsia and foreign stops, was selected [37,62].

2.2.2. Open Data on Population and Degree of Urbanization

For the purposes of identifying stations via administrative boundaries and degree of urbanization, three data layers were selected. The Eurostat (2024) spatial dataset for Local Administrative Units (hereinafter LAUs) was used to capture the station-municipality relation through a spatial join of the station coordinates [63]. To identify the degree of urbanization of each administrative unit, the DEGURBA dataset distributed by Eurostat (2021) was selected [64]. For additional hierarchical relations (regions, countries, and base for local statistical identifiers), Eurostat's (2024) NUTS layers were joined [65]. To describe the economic status of the regions within reach, Eurostat's (2024) purchasing power standard per inhabitant at NUTS3 was integrated [66].

In the case of Ukraine, a different pipeline had to be adopted, since individual settlement boundaries (national administrative level 4) do not cover the country in full. Hromadas (national administrative level 3), which are the equivalent of the EU LAU2 level, were therefore taken from the UN OCHA (2022) dataset and joined with population figures obtained from the open data portal maintained by the Ministry of Digital Transformation of Ukraine (2022) [67,68]. To classify the hromadas by degree of urbanization, the raster grid of Bondarenko et al. (2024), which follows the EU DEGURBA logic, was used [69]. To capture the economic status of the relevant cross-border regions, data on gross regional product from the same open data portal were partially integrated [70].

To scale population size by basic age group within the studied EU member states, the latest municipality-level population data from each national statistical office were integrated into three age bands (under 15, 15–64, and 65 and over), matching the age bands of the Eurobarometer survey data [71–75].

2.2.3. Open Data on Accommodation Demand, Destination Choice and Rail Travel

To assess whether the analyzed foreign countries hold a significant share of Košice's inbound accommodation demand and whether the city can absorb more visitors, two datasets of the Statistical Office of the Slovak Republic were integrated for the districts Košice I–IV. The first, the occupancy of accommodation establishments by country of origin, gives the number of visitors and overnight stays from Austria, Czechia, Hungary, Poland, and Ukraine—monthly and for the year—against the domestic, foreign, and total figures [76]. The second, the occupancy, revenues, and capacities of accommodation

establishments, gives the quarterly and annual context of supply and demand (the number of establishments, rooms and bed places, net occupancy rates, and accommodation revenue split into foreign and domestic visitors) [77]. Together, they express each country's arrivals and nights as a share of foreign and total demand and give its average length of stay [76,77].

Reaching a destination by rail matters only if the destination offers what travelers look for. To assess the match between the destination's offer and its markets, the European Commission's (2022) Flash Eurobarometer 499 was integrated [78]. To convert the population that the rail network makes reachable into a rail-traveling market and to test whether the study's unit of analysis (a journey with one train change) matches how people actually travel, four groups of questions from the European Commission's (2025) Flash Eurobarometer 551 were integrated [79].

2.3. Data Pipeline and Processing

The pilot pipelines were assembled and tested in Python using standard libraries within Visual Studio Code (version 1.147.0) with assistance from Anthropic's agentic coding tool Claude Code [80]. For transparency, all input data, the codebase, and the resulting datasets are available in the study's public GitHub repository [81].

Every step of the process is documented as a reusable Python module orchestrated from a Jupyter notebook, adjustable via a configuration file, enabling users to set the input GTFS feeds as domestic or foreign, the transfer-window thresholds for connecting trains, the maximum length of the analysis window in days, and the analyzed destination's stations as the hub definition (see Figure 1).

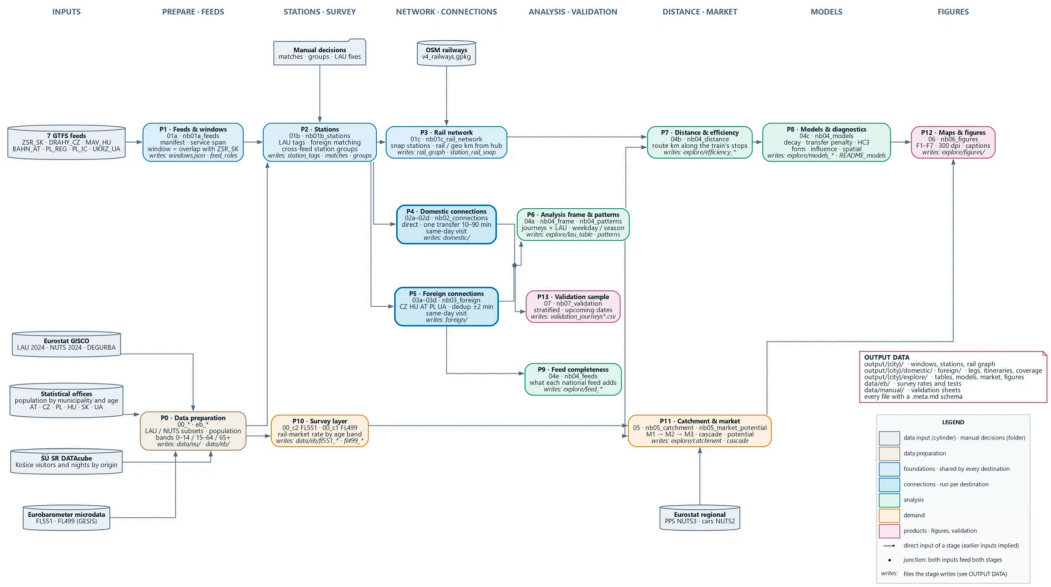


Figure 1. Schema of the project's pipeline [81].

2.3.1. Notebooks 00_a to 00_b5: Preparation of Municipality-Level Data

The spatial unit of this study is the municipality: the Local Administrative Unit (LAU) in the five EU countries and its Ukrainian equivalent, the hromada. On the first run, the notebook downloads any input data not yet in place. After harmonization, a subset covering each country at each level is created. In the case of degree of urbanization, each municipality is classified as a city, a town or suburb, or a rural area using the Eurostat DEGURBA classification [64]. To reproduce the DEGURBA classification for Ukraine, the classes were derived from the GHS-DUG degree-of-urbanization grid (1

km) using a simple rule:

- A hromada is a city if it wholly contains at least one urban-center cell;
- Otherwise, it is a town if urban clusters and centers cover at least 15% of its area;
- Otherwise, it is rural [69].

The municipal population and its three age bands (0–14, 15–64, 65+) were taken from each national statistical office as exact counts at the end of 2025 [71–75]. Each table was keyed to the LAU codes and checked in three ways: every municipality covered, the age bands summing to the total, and territorial changes resolved. One Austrian merger (Söchau and Fürstenfeld) was dissolved into a single unit. The Ukrainian population is the State Statistics Service estimate by hromada [68]. Regional gross domestic product per inhabitant in purchasing power standards was attached to the NUTS 3 regions [66].

The population data have limitations. Austria's data refer to 1 January 2026, while those for Czechia, Hungary, Poland, and Slovakia refer to 31 December 2025. Because of the ongoing war, the official Ukrainian population is an estimate for 1 January 2022 without age bands. The degree-of-urbanization classification dates from 2021, and no more recent data could be identified.

2.3.2. Notebook 00_c1: Destination Criteria (Flash Eurobarometer 499)

The survey was conducted by telephone in October 2021 on a probability sample (n = 25,714), so its intervals are design-based [78]. The notebook loads the manually downloaded input data and extracts the responses of the studied EU countries to Question 4, which asks which aspects matter when choosing a destination [78]. Respondents could give up to four of ten criteria, such as cultural offerings, the natural environment, price, and reachability by low-impact transport. The combined answers were estimated at the national level for the five EU study countries. They are computed on Kish's effective sample size, since the public file carries the weight but no sampling-design variables. Countries differ in how many of the four answers respondents give: 32% of Slovaks but 62% of Austrians stop at two or fewer. Shares are therefore compared within countries as ranks rather than as absolute levels across countries. Regional differences were tested with a Wald test of one common rate per country, with Poland tested at NUTS 1. No regional contrast was supported, so only national rates are used.

In terms of limitations, the survey dates from 2021 and describes residents' attitudes in general, not in relation to Košice.

2.3.3. Notebook 00_c2: Rail-Traveling Market and Connecting Behavior (Flash Eurobarometer 551)

This mobility survey was conducted online in August–September 2024 on a non-probability quota sample (n = 25,803), with about 1000 respondents in each study country [79]. The notebook loads the manually downloaded input data and extracts the responses of the studied EU countries on four topics:

- Market Size: the frequency of leisure journeys of 50 km or more (Q1_1) and train use for such journeys (Q2). The rail market is the share of residents aged 15+ who make such journeys at least once or twice a year and used a train for them. It is computed per respondent (a joint condition, not a product of two shares) and by age band (15–64, 65+), matching the municipal population bands. Respondents not asked about modes (no journeys in either purpose) count as not converted.
- Connecting Behavior: whether respondents combine trains of different operators in one journey (Q12), how hard that booking was (Q13) and why they do not (Q14). The share of the rail market that combines operators at least once or twice a year is the narrowing applied to the one-transfer catchment only.

- Planning Factors: Q3, up to three of eleven factors. These show whether travelers weigh what the study measures; they enter no calculation.
- Combining Modes: Q8–Q10 bound the rail-only scope; they enter no calculation.

All estimates are weighted by the national post-stratification weight. Each interval is the 95% binomial interval on Kish's effective sample size. Because the sample is not a probability sample, these intervals are nominal: The precision the estimates would have under random sampling. The quota panel was compared with a probability sample. The share who never travel was compared with that in Flash Eurobarometer 499 to see whether the panel overstates the rail market. The weighting was checked regionally. The Slovak regional composition was compared with the population aged 15+. A regional reading was tested with the same Wald test as for FL499.

In terms of limitations, the leisure-travel question has a 50 km floor. The conversion is therefore applied only beyond 50 km of rail distance. Furthermore, the sample is a non-probability quota panel, and the comparison with the probability survey suggests that the rates are upper bounds. Applying one national rate to every municipality assumes no regional or urban–rural difference, which the survey cannot resolve below country level.

2.3.4. Notebook 00_d1: Košice's Accommodation Demand by Country of Origin

The notebook downloads the two subsets via the Statistical Office's API [76,77]. Each country's arrivals and nights are expressed as a share of foreign and of total demand, together with its average length of stay. Shares are computed from the annual totals, and the mean of the monthly shares is reported as a check. Each country's contribution to the net bed-place occupancy rate is checked for consistency in the same way.

2.3.5. Notebook 01a: Timetable Feeds and Analysis Windows

The notebook downloads the input data only if it is not already present. Each file is identified by its SHA-256 checksum, its file date, and its feed information version in a feed manifest, so the run can be repeated on the same inputs. The snapshots chosen were the latest at the time of the study. Since Transitious does not keep a public archive of superseded feeds, and the pipeline may be reused on newer feeds; for testing and transparency, the snapshots used are also available at the project's repository. The results are based on the feeds listed in Table 2.

Table 2. GTFS feeds used in the study.

Feed Local ID	File	Feed Version	File Date	Provider	Data Origin	Licence
ZSR_SK	sk_zsr.gtfs.zip	2026-05-13	2026-05-20	Transitous	Železnice Slovenskej Republiky (ŽSR)	CC0-1.0
DRAHY_CZ	cz_CZPTT_new.gtfs.zip	2026-11-03	2026-11-04	JrUtil via Transitous	JrUtil	CC0-1.0
MAV_HU	hu_mav.gtfs.zip	2026-05-19	2026-05-20	Transitous	MÁV Személyszállítási Zrt.	CC0-1.0
BAHN_AT	BAHN_AT.zip	2026-05-19	2026-05-20	Transitous	Mobilitätsverbünde Österreich OG	CC0-1.0
UKRZ_UA	ua-ukrzaliznytsya.gtfs.zip	2026-07-09	2026-07-09	Transitous	OpenStreetMap contributors	CC0-1.0
PL_REG	polish-trains.zip	2026-06-06	2026-06-08	PolishTrainsGTFS (M. Kuranowski)	PKP PLK, Otwarte Dane Kolejowe	CC-BY-4.0
PL_IC	PL_kasznia.zip	2026-05-18	2026-05-20	gtfs.kasznia.net	PKP Intercity via mkuran.pl	CC-BY-4.0

For each feed, the service span is defined as the first to the last day on which at least 50% of the feed's median daily number of trains run, which cuts thin start-up and tail days (see Table 3). The domestic analysis window is the ŽSR span. Each foreign feed is analyzed over its overlap with that span. Train counts are computed per run date from the calendar bitmasks, so weekday, holiday, and seasonal differences stay visible.

Table 3. Service span and analysis window of the input GTFS feeds.

Feed	Agencies	Routes	Trips	Stops	Stations	Service Start	Service End	Window Start	Window End	Window Days
ZSR_SK	6	2309	2512	887	887	2025-12-14	2026-12-12	2025-12-14	2026-12-12	364
MAV_HU	3	12,317	37,650	1197	1134	2026-01-19	2026-11-15	2026-01-19	2026-11-15	301
UKRZ_UA	4	79	79	118	116	2025-12-14	2026-12-12	2025-12-14	2026-12-12	364
BAHN_AT	13	22,960	46,423	7683	1135	2025-12-14	2026-12-12	2026-03-12	2026-12-12	276
DRAHY_CZ	42	8801	77,997	9511	2729	2025-12-14	2026-12-12	2025-12-14	2026-12-12	364
PL_IC	1	9	58,101	2098	498	2026-05-18	2026-08-26	2026-05-18	2026-08-26	101
PL_REG	13	194	35,516	12,187	3115	2026-06-04	2026-07-06	2026-06-05	2026-07-06	32

Several limitations apply. The feeds are planned timetables. They do not record cancellations, replacement buses, or capacity, and they include only what each publisher chose to release. The Polish windows are short (101 and 32 days), so their results describe summer 2026 and may not transfer to the rest of the year. The window rule is a heuristic: a feed that loses services gradually rather than abruptly would not be trimmed by it.

2.3.6. Notebook 01b: Station Catalog, Municipality Tagging and Cross-Feed Matching

The many stops of the seven feeds were reduced to a catalog of railway stations. Stops served only by bus routes were dropped. Child stops without any train call were folded into their parent station. Every remaining stop was then assigned to exactly one station. Each station was tagged with its municipality by a point-in-polygon test. In Slovakia, the polygon result was checked against the station name (fuzzy similarity ≥ 0.90) and moved to a better-matching neighboring municipality where the name indicated it. Abroad, the polygon result was kept. Foreign stations were matched to their ŽSR counterparts in tiers:

- UIC station code;
- Exact name and then the name core without suffixes;
- A position check within 0.5 km in the same municipality for automatic acceptance
- Candidates within 1.0 km, sent to manual review.

The same tiers link stations across feeds into groups that represent one physical station. Manual decisions are kept in versioned files (data/manual/) and applied on every run, so no match depends on an undocumented hand edit.

As a limitation, the matching relies on names and codes as published. A wrong UIC

code or a renamed station could create or break a link.

2.3.7. Notebook 01c: Rail Network and Distance from Košice

The notebook loads a preassembled OpenStreetMap railway network (extract of 28 May 2026, 440,511 line features). The layer was clipped to the six countries plus a 5 km buffer and projected to ETRS89-LAEA (EPSG:3035). Mainline rail, narrow gauge, and the Tatra electric railway were kept; trams, subways, platforms, and abandoned or disused lines were excluded. The network had to be partially repaired:

- Vertices were joined on a 0.5 m grid.
- Dead ends closer than 25 m to another component were joined (8147 gap joins).
- Each station was snapped to the nearest track within 2 km and linked to tracks within 300 m.
- Isolated components were bridged over railway sections tagged as under construction where a path of at most 15 km existed (15 bridges).

For every station on the component that contains Košice station, the shortest track path from the hub, the geodesic distance, and the detour factor were computed. Track length and line length per country were derived with a two-buffer method that counts parallel tracks once for line-km. The error of the shortest-path assumption was measured separately in Notebook 04b. OpenStreetMap completeness and tagging vary by country, and the bridges over construction sections and the gap joins can create connections that may not exist in operation.

2.3.8. Notebook 02a: Domestic Direct Connections

All trains in the ŽSR timetable that call at the selected hub were extracted in both directions (inbound to Košice and outbound from it) over the 364-day window. The timetable has 2512 trips and 31,423 station calls. Trains were expanded to their individual run dates from the calendar bitmasks. Times are kept in GTFS format beyond 24:00, so a train running after midnight stays on its service date.

The unit of analysis is the municipality (LAU). A journey is a distinct train, counted once per municipality, however many of its stations it serves. Journeys per day are the number of journeys over the window divided by its 364 days. The city of Košice is the destination and is excluded from every denominator. Bratislava's district municipalities count as one unit.

Coverage is reported against three nested denominators:

- All 2889 Slovak municipalities (5,187,121 residents);
- The 535 municipalities with a station;
- Those with a direct train.

2.3.9. Notebook 02b: Domestic Connections with One Transfer

One-transfer journeys pair a first train with a second train at any intermediate station. The connection time must be 10–90 min. The same minimum applies at every station. Station groups allow a change between platforms or stops of the same physical station. Pairing is done per run date:

- Each first train takes the earliest second train that runs that day within the connection window;
- When several first trains feed the same second train, only the latest counts;
- This prevents one connection from being counted several times.

Journeys that cross midnight are paired with the next day's services. For each municipality, the notebook records the following:

- Distinct journeys and the distinct first and second trains behind them;
- The median wait;
- The main transfer station and its frequency-weighted share of the municipality's journeys;
- The fewest transfer stations that carry 90% of them.

The base connection window (10–90 min) was tested against six alternatives from 10–60 to 30–120 min.

In terms of limitations, a feasible connection in the timetable does not guarantee that the connection is held when the first train is late. The fixed 10 min minimum ignores station size and platform changes.

2.3.10. Notebooks 02c and 02d: Domestic Same-Day Visits by Direct Train and with One Transfer

For each municipality, the notebook counts the days of the window on which a same-day inbound/outbound pair exists. It classifies municipalities by whether a visit is possible on at least one day, on at least 50% of the days, or on at least 90% of them. The minimum stay was varied at 240, 360, and 480 min. A same-day visit is defined normatively per run date with the following thresholds:

- Arrive in Košice by 11:00;
- Stay at least 360 min;
- Leave Košice at 17:00 or later;
- Be back at the origin by 23:59.

2.3.11. Notebook 03a: Direct Trains Between Košice and Places Abroad

The domestic engine of 02a was run once per neighboring country on the ŽSR feed together with that country's national feed.

Cross-border trains often appear in both feeds: The ŽSR feed lists the foreign section, and the national feed lists the whole train. Such copies were identified as a leg between the same station groups departing and arriving within ±2 min. The national copy was kept, and the ŽSR copy was removed; 7010 legs were dropped, 5504 of them Czech and 1226 Hungarian. A train calling at several stations of one municipality counts once for it. Population is the latest national figure (00_b).

The foreign windows differ in length, so the per-day figures are averages over different parts of the year. For Poland, they describe 32 summer days only. The ±2 min duplicate rule could, in principle, merge two genuinely separate trains running at the same minute between the same stations; the list of dropped legs is kept for inspection. Ukraine's broad-gauge network is reached only via the few trains to the Chop–Uzhhorod area that ŽSR and Ukrzaliznytsia publish.

2.3.12. Notebook 03b: Connections Abroad with One Transfer

The notebook uses the same rules as Notebook 02b. The first leg is a ŽSR train to or from Košice, and the second may be a ŽSR train or a foreign-feed train. Two further cleaning steps were applied:

- ŽSR copies of foreign-feed trains were removed as in 03a.
- "Transfers" onto the same physical train were dropped.

A sensitivity variant, the city transfer, allows a change between any two stations of the same municipality with at least 45 min; this covers, for example, a change between two Budapest terminals.

In addition to the limits of domestic one-transfer connections, four apply here:

- Journeys of 10–17 h are timetabled connections, not realistic travel options;
- The foreign network depends on the completeness of each national feed (see Notebook 04e);
- The city-transfer variant assumes a local transfer that is not modeled in time or cost;
- Poland is observed on 32 summer days.

2.3.13. Notebook 03c: Same-Day Visits from Abroad by Direct Train

The same-day rule of Notebook 02c was applied to the direct options of Notebook 03a per day of each country's window, with the same dwell sensitivity. As in Notebook 02c, the thresholds are normative. A visit from Budapest takes about four hours each way, so it is feasible in the timetable rather than attractive in practice.

2.3.14. Notebook 03d: Same-Day Visits from Abroad with Up to One Transfer Each Way

The approach follows Notebook 03c, with each direction allowed to be a direct train or a one-transfer journey from Notebook 03b. As in Notebooks 02d and 03b, overnight visits, the relevant form for tourism, are not measured here; they are addressed through the accommodation data (00_d1) and the market estimates (05).

2.3.15. Notebook 04a: Analysis Frame and Service Patterns of the Four Networks

The outputs of Notebooks 02 and 03 were combined into one analysis table for the four networks: domestic and foreign, each direct and with one transfer. The table has 109,769 journey × municipality rows and 2747 municipality rows for both directions. For every journey, the route distance was computed on the 01c graph as the track distance along the stations at which the train(s) call. For each municipality, the notebook then derives the following:

- Journeys per Day in Calendar Slices: Weekday, weekend, month, and season, each computed as run days in the slice divided by the days of the slice in the window;
- A Service Pattern: every day, weekday only, weekend only, or partial;
- The inbound–outbound difference, computed from the timetable in each direction and never mirrored;
- The GTFS service types.

Regional totals are recounted from distinct journeys rather than summed over municipalities, so a train serving five municipalities counts once for the region. Coverage is also given at fixed service thresholds of at least 1, 2 and 5 journeys a day.

Seasonal comparisons are possible only for the full-year runs (Slovakia, Czechia, Ukraine); Hungary and Austria lack part of the year, and Poland has only summer days. Reservation-only or restricted trains cannot be identified in the feeds and are counted like any other train. The weekend ratio is a median over municipalities and hides individual lines with no weekend service.

2.3.16. Notebook 04b: Distance, Journey Time, and Journey Efficiency

Three distances were computed for each journey:

- The route distance along the stations served (route km);
- The shortest track path from Košice (rail km, from Notebook 01c);
- The straight line (geo km, from Notebook 01c).

The route distance was validated against the distances that three feeds publish (Czechia, Austria, Ukraine) for 3339 consecutive station pairs.

The base quality measure is the average journey time to Košice of a municipality (LAU), taken over its itineraries (1):

$$\bar{\tau}_l = \frac{1}{|I_l|}\sum_{i \in I_l} \tau_i, \quad \tau_i = \begin{cases} T_i, & \text{direct} \\ T_i + WT_i, & \text{single transfer} \end{cases} \tag{1}$$

where

- $\bar{\tau}_l$ is the average journey time of LAU l in minutes;
- I_l are the distinct itineraries i serving LAU l. An itinerary calling at several stations of one LAU is counted once, with its shortest ride;
- T_i is the in-vehicle travel time;
- WT_i is the waiting time at the transfer station, so for a single-transfer journey, τ_i runs from the first departure to the final arrival;
- τ_i is the journey time of itinerary i.

Service frequency is measured as the average number of itineraries per day (2):

$$f_l = \frac{R_l}{W_c}, \quad R_l = \sum_{i \in I_l} n_i, \quad n_i = |\{d \in W_c : i \text{operates on} d\}| \tag{2}$$

where

- f_l is the number of distinct complete journey opportunities per day for LAU l;
- R_l is the total number of service days across all itineraries of LAU l;
- W_c is the analysis window of the run in days: 364 for Slovakia, Czechia and Ukraine, 301 for Hungary, and 276 for Austria and 32 for Poland;
- n_i is the number of days d in the window on which itinerary i is in service. For a single-transfer itinerary, a day is counted only if both legs run that day and the transfer is feasible within the configured limits.

The rail-network distance of each station is the shortest path to the hub on the OpenStreetMap track graph, with both snap distances included. The LAU mean is taken over its itineraries (3):

$$r_s = \frac{1}{1000}\left(\sigma_s + d_G(v_s, v_h) + \sigma_h\right), \quad \bar{r}_l = \frac{1}{|I_l|}\sum_{i \in I_l} r_{s(i)} \tag{3}$$

where

- r_s is the rail-network distance of station s in km;
- σ_s and σ_h are the snap distances in meters from the station and the hub to the nearest track edge (at most 2 km);

- v_s and v_h are the graph nodes inserted for station s and hub h;
- d_G is the shortest-path (Dijkstra) distance in meters along the track between the two nodes, with each edge weighted by its length (EPSG:32634);
- $s(i)$ is the boarding station of itinerary i;
- $\bar{r}_l$ is the mean rail-network distance of LAU l.

The route distance of a journey follows the train. It is the sum of the shortest track distances between the journey's consecutive calls (4):

$$r_i^{route} = \frac{1}{1000} \sum_{k=1}^{K_i - 1} d_G(v_{s_k}, v_{s_{k+1}}), \quad \bar{r}_l^{route} = \frac{1}{|I_l|} \sum_{i \in I_l} r_i^{route} \tag{4}$$

where

- r_i^{route} is the route distance of itinerary i in km;
- $s_1, \ldots, s_{K_i}$ are the stations itinerary i calls between the boarding station and the hub; for single-transfer journeys, both legs are included;
- d_G is the shortest-path distance between two consecutive calls. Each search is limited to 3 × geodesic distance + 20 km, and r_i^{route} is undefined if any pair along the journey is undefined;
- $\bar{r}_l^{route}$ is the mean route distance of LAU l.

The straight-line distance is the great-circle (haversine) distance between a station and the hub (5):

$$g_s = 2R \arcsin\sqrt{\sin^2\frac{\varphi_h - \varphi_s}{2} + \cos\varphi_s \cos\varphi_h \sin^2\frac{\lambda_h - \lambda_s}{2}}, \quad \bar{g}_l = \frac{1}{|I_l|} \sum_{i \in I_l} g_{s(i)} \tag{5}$$

where

- g_s is the geodesic distance of station s in km;
- φ and λ are latitude and longitude, $R = 6371.0088$ km;
- $\bar{g}_l$ is the mean geodesic distance of LAU l.

The route distance was validated against the distances that three feeds publish (Czechia, Austria, and Ukraine) for consecutive station pairs (6):

$$q_{ab} = \frac{r_{ab}^{route}}{r_{ab}^{pub}} \tag{6}$$

where

- q_{ab} is the validation ratio for the consecutive station pair (a, b);
- r_{ab}^{route} is the computed route distance;
- r_{ab}^{pub} is the distance the feed publishes: the difference in shape_dist_traveled, converted to km, with the median taken per pair;
- The median, the 5th and 95th percentiles, and the shares within ±5% and ±10% are reported.

The detour factor compares the distance traveled with the shortest separation (7):

$$D_l = \frac{\bar{r}_l^{route}}{\bar{r}_l}, \quad D_s^{geo} = \frac{r_s}{g_s} (g_s > 0.5 \ \text{km}) \tag{7}$$

where

- D_l is the detour of LAU l's journeys over the shortest track path;
- D_s^{geo} is the track detour of station s over the straight line.

Journey efficiency is the number of minutes spent per kilometer. It is computed on all three distances, and the two track-based forms are linked exactly by detour factor (8):

$$e_l^{route} = \frac{\bar{\tau}_l}{\bar{r}_l^{route}}, \quad e_l^{rail} = \frac{\bar{\tau}_l}{\bar{r}_l}, \quad e_l^{geo} = \frac{\bar{\tau}_l}{\bar{g}_l} [\text{min} \cdot \text{km}^{-1}], \quad e_l^{rail} = e_l^{route} \cdot D_l, \quad v_l = \frac{60}{e_l} \tag{8}$$

where

- e_l^{route} is the operating efficiency: how fast the trains run along the path actually taken. It is the headline measure;
- e_l^{rail} is the access efficiency, which penalizes roundabout journeys; e_l^{geo} is the straight-line form;
- v_l is the equivalent speed in km/h;
- Each form is defined for $\bar{r}_l^{route} > r_{min}$, with $r_{min} = 5$ km. The cut-off excludes LAUs next to the hub, where the denominator approaches zero, and its effect is shown at $r_{min} \in \{0,3, 5,10\}$ km.

Per network, efficiency is summarized by the frequency-weighted mean, with the unweighted median as the comparator. Each LAU is placed against the network mean (9):

$$\bar{e}_N = \frac{\sum_l f_l e_l}{\sum_l f_l}, \quad \tilde{e}_N = \text{median}_l e_l, \quad \Delta_l = e_l - \bar{e}_N, \quad \hat{\Delta}_l = \frac{e_l}{\bar{e}_N} \tag{9}$$

where

- N is the network: domestic or foreign × direct or single transfer;
- e_l is any of the three forms of Equation (8);
- Δ_l is the signed difference in LAU l from the network mean in min/km;
- $\hat{\Delta}_l$ is the ratio to the network mean: $\hat{\Delta}_l > 1$ means slower than the network average, and $\hat{\Delta}_l < 1$ means faster.

As a robustness check, the ratio of means e_l is compared with the mean of the journeys' own ratios (10):

$$e_l^{MoR} = \frac{1}{|I_l|} \sum_{i \in I_l} \frac{\tau_i}{r_i^{route}}, \quad \kappa_l = \frac{e_l^{route}}{e_l^{MoR}} \tag{10}$$

where

- e_l^{MoR} is the mean of the per-journey efficiencies of LAU l;
- κ_l is the ratio of the two forms, which departs from 1 only when a LAU is served by journeys of very different length;
- The median of κ_l, the share with $|\kappa_l - 1| \le 0.05$, and the Spearman rank correlation of the two forms are reported.

2.3.17. Notebook 04c: Models of Distance Decay, Transfer Penalty and Frequency, with Diagnostics

The notebook computes the measures listed below.

Distance decay is the linear regression of journey time on distance, estimated on both the route distance and the rail distance (11):

$$\bar{\tau}_l = \alpha + \beta \bar{r}_l + \varepsilon_l \tag{11}$$

where

- $\bar{r}_l$ stands for $\bar{r}_l^{route}$ (Equation (4)) or the rail distance $\bar{r}_l$ (Equation (3));
- α is the predicted journey time at zero distance in minutes. It is not a transfer penalty, which Equation (14) estimates;

- β is the marginal time cost per km, the decay measure; $60/\beta$ is the line-haul speed;
- ε_l is the residual: how much shorter or longer the LAU's journey is than distance predicts.

The parameters are ordinary least-squares estimates, and R^2 is the share of the variance in journey time explained by distance (12):

$$\hat{\beta}=\frac{\sum_l(\bar{r}_l-\langle\bar{r}\rangle)(\bar{\tau}_l-\langle\bar{\tau}\rangle)}{\sum_l(\bar{r}_l-\langle\bar{r}\rangle)^2},\quad \hat{\alpha}=\langle\bar{\tau}\rangle-\hat{\beta}\langle\bar{r}\rangle,\quad R^2=1-\frac{\sum_l\hat{\varepsilon}_l^2}{\sum_l(\bar{\tau}_l-\langle\bar{\tau}\rangle)^2} \tag{12}$$

where

- $\hat{\alpha}$ and $\hat{\beta}$ are the estimates of the two parameters;
- $\langle\bar{r}\rangle$and $\langle\bar{\tau}\rangle$ are the sample means of distance and journey time across the LAUs;
- $\hat{\varepsilon}_l$ is the fitted residual.

The curvature of the decay is checked by adding a squared distance term (13):

$$\bar{\tau}_l=\alpha+\beta\bar{r}_l+\beta_2\bar{r}_l^2+\varepsilon_l \tag{13}$$

where

- β_2 is the curvature: $\beta_2>0$ means the gradient steepens with distance, and $\beta_2<0$ means that it flattens. It is a check of shape, not a proposed model.

The transfer penalty is estimated as a model term. Direct and single-transfer LAUs are pooled, with a transfer indicator and its interaction with distance (14):

$$\bar{\tau}_{l,t}=\alpha+\beta\bar{r}_{l,t}+\delta T_{l,t}+\gamma T_{l,t}\bar{r}_{l,t}+\varepsilon_{l,t} \tag{14}$$

where

- t is the level of service (direct, single transfer), and $T_{l,t}=1$ for single-transfer rows, while it is 0 for direct rows;
- α and β are the direct-service intercept and slope;
- $\delta=\Delta\alpha$ is the difference in intercepts: the transfer penalty in minutes at equal distance;
- γ is the difference in slopes (minutes per km).

LAUs served both directly and with one transfer give a matched comparison (15):

$$\Delta\tau_l=\bar{\tau}_l^{1T}-\bar{\tau}_l^{D}=a+b\,\Delta r_l+\varepsilon_l,\quad \Delta r_l=\bar{r}_l^{1T}-\bar{r}_l^{D} \tag{15}$$

where

- $\bar{\tau}_l^{1T}$ and $\bar{\tau}_l^{D}$ are the LAU's mean single-transfer and direct journey times, and $\bar{r}_l^{1T}$ and $\bar{r}_l^{D}$ are the corresponding distances;
- a is the extra time of the transfer at equal distance;
- b is the extra time per additional km of the transferred route;
- The mean and median of $\Delta\bar{\tau}_l$ are reported as the raw difference.

Power forms test whether time and frequency scale proportionally with distance (16):

$$\log\bar{\tau}_l = a_\tau + b_\tau \log\bar{r}_l^{route} + \varepsilon_l, \quad \log f_l = a_f + b_f \log\bar{r}_l + \varepsilon_l \tag{16}$$

where

- b_τ is the elasticity of journey time with respect to route distance;
- b_f is the elasticity of frequency with respect to rail distance;
- a_τ and a_f are the intercepts on the log scale.

To test whether the network is organized by market size or by its own operating pattern, frequency is first correlated with distance and with population. Both variables are heavily skewed, so the correlations are taken on logs (17):

$$\rho(x,y) = \frac{\sum_l (x_l - \langle x \rangle)(y_l - \langle y \rangle)}{\sqrt{\sum_l (x_l - \langle x \rangle)^2 \sum_l (y_l - \langle y \rangle)^2}}, \quad \rho_S(x,y) = \rho(\mathrm{rank}x \mid \mathrm{rank}y) \tag{17}$$

where

- $x_l = \log f_l$, and $y_l = \log\bar{r}_l$ or $\log P_l$;
- P_l is the LAU's population, standing in for demand;
- ρ is the Pearson correlation;
- ρ_S is the Spearman rank correlation: the Pearson correlation of the ranks, which needs no linearity, resists outliers and handles ties;
- Each correlation is reported pooled and per country.

The correlations are given with 95% intervals: Fisher's z for Pearson and a bootstrap for Spearman (18):

$$\rho \in [\tanh(\operatorname{artanh}\rho \mp \frac{1.96}{\sqrt{n-3}})], \quad \rho_S \in [Q_{0.025}(\rho_S^*), Q_{0.975}(\rho_S^*)] \tag{18}$$

where

- n is the number of LAUs entering the correlation;
- ρ_S^* denotes the Spearman coefficients of 2000 bootstrap resamples of the LAUs, and Q denotes their percentiles.

Frequency is then modeled on distance and population jointly (19):

$$\log f_l = \gamma_0 + \gamma_r \log \bar{r}_l + \gamma_P \log P_l + \varepsilon_l \tag{19}$$

where

- γ_0 is the intercept on the log scale;
- γ_r is the distance decay of frequency net of population size;
- γ_P is the demand elasticity;
- ε_l is the part of the LAU's frequency that is not explained by size or distance.

Where the fit leaves much unexplained, the residuals are read by country (20):

$$\hat{\varepsilon}_l = \log f_l - (\hat{\gamma}_0 + \hat{\gamma}_r \log \bar{r}_l + \hat{\gamma}_P \log P_l), \quad \bar{\varepsilon}_c = \frac{1}{|L_c|} \sum_{l \in L_c} \hat{\varepsilon}_l \tag{20}$$

where

- $\hat{\varepsilon}_l$ is the LAU's residual on the log scale, from the model without country effects;
- $\hat{\gamma}_0$, $\hat{\gamma}_r$, and $\hat{\gamma}_P$ are the fitted coefficients of Equation (19);
- L_c is the set of LAUs in country c, and $|L_c|$ is its size;
- $\bar{\varepsilon}_c$ is the country's mean residual, and $e^{\bar{\varepsilon}_c}$ the multiplier on its expected frequency.

For the foreign networks, every model is also estimated with country fixed effects so that each relationship is tested within countries rather than only between them (21):

$$y_l = \mathbf{x}_l' \boldsymbol{\beta} + \mu_{c(l)} + \varepsilon_l \tag{21}$$

where

- y_l and $\mathbf{x}_l$ are the outcome and regressors of Equations (11), (14), (16) or (19);
- $\mu_{c(l)}$ is the fixed effect of the country c of LAU l, which absorbs each country's level;
- The domestic networks lie in one country, so they carry no country term.

LAUs that have a station but no journey enter a two-part model. Its first part is a

logit for being served (22); its second part is the frequency model of Equation (19), estimated on the served LAUs:

$$\Pr(S_l=1)=\Lambda(\theta_0+\theta_1\log r_l^{min}+\theta_2\log P_l),\quad \Lambda(z)=\frac{1}{1+e^{-z}},\quad R^2_{pseudo}=1-\frac{\mathrm{Dev}}{\mathrm{Dev}_0} \tag{22}$$

where

- $S_l=1$ if LAU l has at least one journey among the LAUs with a station;
- r_l^{min} is the rail distance of the LAU's station nearest to the hub;
- θ are the logit coefficients, with robust ($HC1$) standard errors;
- Dev and Dev_0 are the deviances of the fitted model and of the intercept-only model.

Standard errors are heteroskedasticity-robust ($HC3$) throughout, and 95% intervals are $\hat{\beta}\pm 1.96\mathrm{SE}$ (23):

$$\hat{V}_{HC3}=(X'X)^{-1}X'\,\mathrm{diag}\left(\frac{\hat{\varepsilon}_l^2}{(1-h_l)^2}\right)X(X'X)^{-1},\quad h_l=\mathbf{x}_l'(X'X)^{-1}\mathbf{x}_l \tag{23}$$

where

- X is the design matrix, and $\hat{\varepsilon}_l$ is the OLS residual;
- h_l is the leverage of LAU l;
- Heteroskedasticity is tested by Breusch–Pagan, with the p-value reported for each fit.

Where a model pools at least five countries, standard errors clustered by country are reported beside $HC3$ (24):

$$\hat{V}_{CL}=(X'X)^{-1}\left(\sum_{c=1}^{G}X_c'\hat{\boldsymbol{\varepsilon}}_c\hat{\boldsymbol{\varepsilon}}_c'X_c\right)(X'X)^{-1} \tag{24}$$

where

- G is the number of countries (clusters), with $G\geq 5$;
- X_c and $\hat{\boldsymbol{\varepsilon}}_c$ are the rows and residuals of country c;
- With five clusters, the result is a check, not a replacement for $HC3$.

The functional form is tested by Ramsey's RESET and chosen by a fixed rule (25):

$$y_l = \mathbf{x}_l'\boldsymbol{\beta} + \phi\hat{y}_l^2 + \varepsilon_l, \quad H_0 : \phi = 0; \quad \text{form} = \begin{cases} \text{linear}, & p_{lin} \geq 0.01 \\ \log - \log, & p_{lin} < 0.01, p_{log} \geq 0.01 \\ \text{linear}, \text{ caveat}, & p_{lin} < 0.01, p_{log} < 0.01 \end{cases} \tag{25}$$

where

- $\hat{y}_l$ is the fitted value of the model, and ϕ is the coefficient of its square, tested by an F-test;
- p_{lin} and p_{log} are the RESET p-values of the linear form and the log–log form;
- "linear, caveat" reports the linear slope as a descriptive average gradient, not as a structural parameter.

The influence of single LAUs is measured by Cook's distance (26):

$$D_l = \frac{\hat{\varepsilon}_l^2}{ps^2} \cdot \frac{h_l}{(1-h_l)^2}, \quad D_l > \frac{4}{n} \text{flagged}, \quad \Delta\hat{\beta}_l = \hat{\beta} - \hat{\beta}_{-l} \tag{26}$$

where

- p is the number of parameters, s^2 is the residual variance, and n is the number of LAUs;
- $\Delta\hat{\beta}_l$ is the leave-one-out change in a coefficient, where $\hat{\beta}_{-l}$ is the estimate without LAU l;
- Each decay fit is re-estimated without the five LAUs with the largest D_l and without LAUs of 100,000 or more inhabitants. No LAU is removed from the headline estimates.

Spatial dependence is measured by Moran's I of the outcome and of the residuals on the same k-nearest-neighbor weights (27):

$$I = \frac{\sum_l \sum_m w_{lm} z_l z_m}{\sum_l z_l^2}, \quad w_{lm} = \begin{cases} 1/k, & m \in N_k(l) \\ 0, & \text{otherwise} \end{cases} \tag{27}$$

where

- z_l is the deviation from the mean of the outcome y_l or the residual $\hat{\varepsilon}_l$;
- $N_k(l)$ denotes the k LAUs nearest to l, with $k \in \{3,5,8,10\}$ and $k = 5$ reported. The weights are row-standardized;
- Significance is a pseudo p-value from 999 random permutations;
- $I_y - I_{\hat{\varepsilon}}$ is the part of the outcome's spatial structure absorbed by the covariates.

https://doi.org/10.3390/ijgi15120541

Spatial-lag and spatial-error models (maximum likelihood, $k=5$) are estimated for the decay and joint models to check whether the OLS coefficients move (28):

$$\mathbf{y}=\rho W\mathbf{y}+X\boldsymbol{\beta}+\boldsymbol{\varepsilon}, \quad \mathbf{y}=X\boldsymbol{\beta}+\mathbf{u}, \quad \mathbf{u}=\lambda W\mathbf{u}+\boldsymbol{\varepsilon} \tag{28}$$

where

- W is the weight matrix of Equation (27);
- ρ is the spatial lag coefficient: the dependence of a LAU's outcome on its neighbors' outcomes;
- λ is the spatial error coefficient: the dependence of the unexplained part on the neighbors'.

2.3.18. Notebook 04e: Feed Completeness and What the Data Can and Cannot Show

The notebook compares the seven feeds on size, declared calendar and analysis window, exceptions, and known omissions. To separate data availability from rail connectivity, every foreign country run was repeated with the ŽSR feed alone and compared with the run that includes the national feed using the same window and rules. The station-merge radius for feeds without parent stations (ŽSR, MÁV, Ukrzaliznytsia) was varied at 0.5, 1, 2 and 5 km.

The comparison cannot detect services missing from all feeds. Two feeds cover only part of the year, and their calendars were checked only through their exception counts:

- Hungary: An older 301-day snapshot.
- Austria: From March, with 492,655 removed service days.
- Ukrainian domestic services beyond the border area are represented only as far as Ukrzaliznytsia's feed includes them.

2.3.19. Notebook 05: Population Catchment, Rail Market and Market Potential

The catchment is the set of municipalities reachable inbound by direct train or with one transfer in the headline runs. Its levels are exclusive: a municipality with any direct train counts as direct and never in the one-transfer layer, and it carries the journey time of its level (29):

$$L_c^D=\{l\in c: f_l^D>0\}, \quad L_c^{1T}=\{l\in c: f_l^{1T}>0\}\setminus L_c^D, \quad \tau_l=\begin{cases}\bar{\tau}_l^{D}, & l\in L_c^D\\ \bar{\tau}_l^{1T}, & l\in L_c^{1T}\end{cases} \tag{29}$$

where

- L_c^D and L_c^{1T} are the direct and one-transfer layers of the catchment of country c, and $L_c=L_c^D\cup L_c^{1T}$;
- f_l^D and f_l^{1T} are the inbound direct and one-transfer frequencies of Equation (2);
- $\bar{\tau}_l^{D}$ and $\bar{\tau}_l^{1T}$ are the mean journey times of Equation (1), and τ_l is the journey time

used below.

Three mass levels were defined. The first, the population catchment, counts residents aged 15 and over (30). Children (0–14) are left out of every rate base; they are 2.83 million, 13.8% of the catchment:

$$M1_l = P_l^{15-64} + P_l^{65+} \tag{30}$$

where

- P_l^{15-64} and P_l^{65+} are the residents of LAU l aged 15–64 and 65 and over.

The second, the rail-traveling population, applies the age-banded Flash Eurobarometer 551 rates of traveling 50 km or more for leisure and using the train for it (31). The national rates are 44.7% (HU) to 59.4% (CZ) (00_c2). The survey describes journeys of 50 km or more, so the conversion is applied only beyond 50 km of rail distance. The inner ring (52 municipalities, 163,412 residents aged 15+) is reported at $M1$ and excluded from the converted totals:

$$M2_l = P_l^{15-64}\eta_c^{15-64} + P_l^{65+}\eta_c^{65+}, \quad \text{defined for } \bar{r}_l \geq 50 \text{ km} \tag{31}$$

where

- η_c^{15-64} and η_c^{65+} are the FL551 shares of residents of country c in each age band who travel 50 km or more for leisure and use the train for it;
- $\bar{r}_l$ is the rail-network distance of Equation (3);
- Ukraine is not covered by FL551, so its municipalities are reported at $M1$ only.

The third, the connecting-adjusted level, discounts $M2$ by the share of rail travelers who also accept a train change (32). The discount applies only to the one-transfer layer, because a direct traveler never connects. Since Austria and Poland have no direct train, the discount applies to their whole catchment:

$$M3_l = M2_l \cdot \pi_l, \quad \pi_l = \begin{cases} 1, & l \in L_c^D \\ \pi_c = Pr(T2 \mid T1), & l \in L_c^{1T} \end{cases} \tag{32}$$

where

- π_c is the FL551 share of the rail travelers of country c ($T1$) who also accept a train change ($T2$).

Market potential is reported in two forms. The contour form, the primary measure, is the mass within a mean journey time τ and its share of the catchment (33):

$$C_c^M(\tau) = \sum_{l \in L_c : \tau_l \leq \tau} M_l, \quad S_c^M(\tau) = \frac{C_c^M(\tau)}{\sum_{l \in L_c} M_l} \tag{33}$$

where

- M_l is any of the mass levels $M1_l$, $M2_l$, and $M3_l$;
- $C_c^M(\tau)$ is the mass reachable within τ minutes, and $S_c^M(\tau)$ is its share of the country's catchment;
- $\tau \in \{60,90,120,180,240,300,360\}$ min.

The exponential form weights each municipality by a decay in journey time with a half-life h, which is swept as a grid rather than estimated. The results are expressed as effective population and as a share of each country's national rail market (34):

$$A_c^M(h) = \sum_{l \in L_c} M_l 2^{-\tau_l / h}, \quad G_c^M(h) = \frac{A_c^M(h)}{\sum_{l \in L_c} M_l}, \quad \Phi_c^M(h) = \frac{A_c^M(h)}{M2_c^{nat}} \tag{34}$$

where

- $A_c^M(h)$ is the effective population: population-equivalents at zero journey time;
- $h \in \{60,90,120,180,240\}$ min is the half-life grid;
- $G_c^M(h)$ is the share of the catchment's mass left after the geography's cost;
- $\Phi_c^M(h)$ is the share of the national rail market for $M2$ and $M3$;
- $M2_c^{nat} = \sum_{k \in c} (P_k^{15-64} \eta_c^{15-64} \mid P_k^{65+} \eta_c^{65+})$ is the rail-traveling population of all LAUs k of country c, without the 50 km floor;
- Journey time is the only cost term.

The survey rate's nominal interval is carried through by evaluating every total at the lower and upper bounds of both age-band rates (35):

$$M2_l^{lo} = P_l^{15-64} \eta_c^{15-64,lo} + P_l^{65+} \eta_c^{65+,lo}, \quad M2_l^{hi} = P_l^{15-64} \eta_c^{15-64,hi} + P_l^{65+} \eta_c^{65+,hi} \tag{35}$$

where

- η_c^{lo} and η_c^{hi} are the bounds of the nominal (design-effect-adjusted binomial) interval of each rate; FL551 is a non-probability quota survey, so the interval is not a margin of error;
- $M3_l^{lo}$ and $M3_l^{hi}$ follow by Equation (32), and the bounds of C and A follow by Equations (33) and (34);
- One pair of rates applies to all municipalities of a country, so all sit at their bounds together, and a total's relative width depends only on its age mix: it is nearly the same for every total of a country;
- The half-life is unknown rather than uncertain, so it is never given an interval.

Urbanization is a bounded sensitivity. The city, town, and rural propensities are

shifted and normalized over the whole country so that the national rail market stays unchanged (36):

$$M2_c^{(w)} = \frac{1}{\bar{w}_c} \sum_{l \in L_c} w_{d(l)} M2_l, \quad \bar{w}_c = \frac{\sum_{k \in c} w_{d(k)} M1_k}{\sum_{k \in c} M1_k}, \quad (w_1, w_2, w_3) \in \{(1.2, 1, 0.8), (0.8, 1, 1.2)\} \tag{36}$$

where

- $d(l)$ is the DEGURBA class of LAU l (1 city, 2 town and suburb, 3 rural), and w_d is its propensity relative to towns;
- $\bar{w}_c$ is the mean propensity over all LAUs k of country c, weighted by their population aged 15+;
- A catchment more urban than its country gains under the city-high corner and loses under the rural-high one; the uniform case $(1, 1, 1)$ returns M2.

Purchasing power (PPS per inhabitant, NUTS3, 2023) [66] and car ownership (cars per 1000 inhabitants, NUTS2, 2023) [82] are reported as characteristics of the catchment, not as weights. The survey rate is already observed behavior that contains income effects, and a regional value adds no variation within a region. Each is compared between the catchment and its country (37):

$$\bar{X}_c^{cat} = \frac{\sum_{l \in L_c} M1_l X_{g(l)}}{\sum_{l \in L_c} M1_l}, \quad \bar{X}_c^{nat} = \frac{\sum_{k \in c} P_k X_{g(k)}}{\sum_{k \in c} P_k}, \quad Q_c^X = \frac{\bar{X}_c^{cat}}{\bar{X}_c^{nat}} \tag{37}$$

where

- $X_{g(l)}$ is the PPS per inhabitant of the NUTS3 region, or the cars per 1000 inhabitants of the NUTS2 region, that contains LAU l;
- $\bar{X}_c^{cat}$ is the catchment's mean, weighted by population aged 15+, and $\bar{X}_c^{nat}$ is the country's mean, weighted by total population P_k;
- Q_c^X is the catchment's level relative to its country per service level;
- The catchment is also split by the country's population-weighted PPS quartiles; Ukraine has neither figure and is never pooled.

2.3.20. Validation Against Operators' Journey Planners and Transferability

The computed journeys were checked against the operators' own journey planners. A validation sample of 63 inbound journeys was drawn with a fixed seed, one per municipality, and stratified to cover the cases most likely to fail: domestic and foreign journeys, both direct and with one transfer; every destination country, with about ten journeys each and the PKP Intercity run sampled separately; four transfers between two feeds, which test station identity across feeds; and four connections across midnight.

For each journey, the validation table gives a run date between 17 November and 12

December 2026, the computed times, the transfer station, the train numbers, and the planner to query. Planners answer only for upcoming dates, and they are the only source that shows whether a train actually runs. For the feeds for which their windows reach 12 December (Slovakia, Czechia, Austria and Ukraine), the date is taken from the feed. The Hungarian and Polish windows end earlier, so their dates are projected: the projected date is the first date in the period on the same weekday, and a train is projected only if it ran on at least 80% of that weekday's dates in its window.

A journey scores yes when the planner offers the same trains with times within 5 min, partly when it offers the journey with a different transfer or a time difference of more than 5 min, and it scores no when it offers no such journey. The time difference is the planner's arrival minus the computed arrival. A projected journey that the planner no longer offers is recorded as a finding in its own right.

The sample is small by design. It tests whether the engine reproduces journeys that operators actually offer, not the coverage figures themselves. The projected dates for Hungary and Poland assume that a regular train still runs on the same weekday, and because planners reflect the timetable on the day of checking, a mismatch may come from a timetable change after the feed snapshot as well as from an error in the computation.

To test whether the method transfers to another city, the whole pipeline was re-run with Bratislava as the destination and every rule unchanged. As for Košice, the hub city is treated as one unit and excluded from every catchment, and the hub comprises all its stations at which trains into the city end: Bratislava hl. st., Petržalka, where the Vienna trains end, and Nové Mesto, where the Prievidza trains end. With these three stations, every ŽSR train that reaches Bratislava calls at a hub station (682 of 682), so no journey depends on a train change within the city. The feeds, windows, station catalog, and cross-feed groups (01a, 01b) are shared with the Košice run; the rail-network distances (01c) and all later steps were recomputed from Bratislava hl. st.

The comparison uses the same feeds and windows and inherits their limits; Poland is again observed on 32 summer days. A train that appears only in a foreign feed and never in the ŽSR feed, such as an Austrian regional train ending in Bratislava, is not seen, and this applies to both destinations. No accommodation data by origin were used for Bratislava. The comparison shows that the method runs unchanged and produces plausible differences consistent with the geography of the two cities. It does not validate either result.

3. Results

To better understand the impact of geographical position on Košice as a tourism destination, the following subsections summarize the main results separately in the context of the local tourism market profile and the domestic and cross-border railway connectivity of the studied area (Figure 2). The study area holds 72.4 million residents in the five EU countries. Ukraine adds 41.2 million residents in the 1470 hromadas based on population estimates. Most municipalities are rural: 2568 of the 2927 Slovak LAUs against 45 cities and 314 towns. In Ukraine, 74 hromadas are classified as cities, 114 as towns, and 1581 as rural. For the 1470 hromadas, where both are available, the area-based rule and the official population-based rule agree for 1163 (79%).

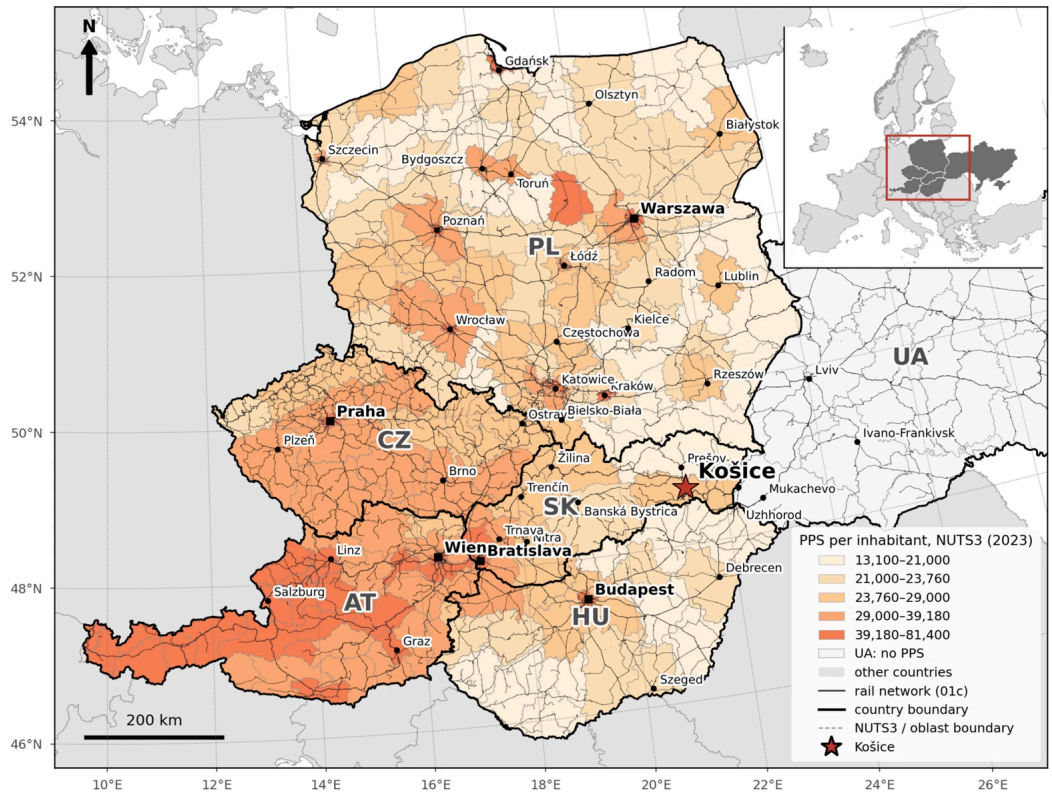


Figure 2. The study area in European context.

3.1. Košice's Accommodation Demand in Relation to FL499

In 2025, Košice's accommodation establishments recorded 243,622 guests and 475,706 overnight stays, 8686 bed places, and a net occupancy rate of 19.2% of permanent bed places (23.4% of rooms). Foreign visitors accounted for 40.6% of guests and 44.5% of nights. The five study countries together made up 22.9% of all guests and 56.4% of foreign guests (52.2% of foreign nights). Ukrainian guests stayed longest at 2.5 nights against 1.5–1.9 for the other four. Together, the five countries account for 4.45 of the 19.2 percentage points of bed-place occupancy, about a quarter of it (Table 4).

Table 4. Share of studied foreign countries on Košice's occupancy.

Origin	% of Foreign Guests	Average Nights	Points of the 19.2% Occupancy Rate
Ukraine	18.4	2.5	1.85
Czechia	15.2	1.9	1.15
Poland	10.5	1.6	0.69
Hungary	8.2	1.6	0.53
Austria	4.1	1.5	0.24
Five together	56.4	2.0	4.45

According to the investigated Flash Eurobarometer 499 question, cultural offerings rank first among destination criteria in Czechia (52.6%, 95% CI 49.0–56.2), Hungary (50.2%) and Poland (42.5%), third in Slovakia (44.7%), and fourth in Austria (31.4%); the EU-27 average is 43.7%. Košice has the largest urban heritage reserve in Slovakia, which suggests that the city partly offers the cultural resources that residents of these countries value when choosing a destination.

3.2. Rail-Traveling Market and Connecting Behavior

The rail market, the share of residents aged 15+ who make leisure journeys of 50 km or more at least once or twice a year and use the train for them, ranges from 44.7% in Hungary (nominal 95% CI 41.5–48.0) to 59.4% in Czechia (56.3–62.5). Austria (49.6%, 46.4–52.8), Slovakia (50.3%, 47.0–53.5), and Poland (50.8%, 47.7–54.0) lie in between. The rate falls with age in every country except Slovakia, where residents aged 65+ (48.8%) do not differ detectably from those aged 15–64 (50.7%); in Czechia, the drop is 21.3 percentage points.

Only part of the rail market combines operators in one journey at least once or twice a year: 47.7% in Hungary, 53.1% in Austria, 59.4% in Slovakia, 61.9% in Poland, and 68.6% in Czechia. The countries that most need a transfer to reach Košice are therefore not the ones most used to transferring. Among those who rarely or never combine operators, 35 to 55% had no need because one operator took them to their destination, 12 to 21% found no suitable combination, 13 to 22% said the journey would have taken too long, and 8 to 17% feared being stranded by a missed connection. These are the same constraints that the timetable analysis computes. Slovaks also name the number of connections among their three most important planning factors more often than respondents in any other EU-27 country (22.6%, against 13.9% across the EU-27), while the other four study countries range from 18.6% to 21.1%.

3.3. Station Catalog and Rail Network Distance

The station catalog contains 9614 stations: 887 from the domestic feed and 8727 from the foreign feeds. Of these, 9446 lie in the six study countries and 168 outside them. Every in-scope station was assigned to a municipality. The 8696 foreign stations kept the municipality given by their location, 58 stations were moved to a neighboring municipality on the evidence of their name, and 364 were set from manual corrections.

Of the 890 candidate pairs between foreign stations and their ŽSR counterparts, 438 were resolved by UIC station code, 300 by exact name, 90 by the name core without suffixes, and 12 by train-sequence evidence, while 49 were settled in manual review and one candidate was rejected. Grouping stations across feeds produced 1217 links (914 by location, 186 by name, 101 by UIC code and 16 manual), with no conflicts and no open review items. The result is 8755 physical stations, 778 of which are served by two to five feeds. These groups allow a journey to change between national operators at a border station even though each feed identifies the stop differently.

The final rail graph has 2.99 million nodes and 3.24 million edges in 1,198 components. The component that contains Košice holds 137,958 km of track and 9350 of the 9614 stations, including 874 of the 887 ŽSR stations. Of the 264 stations left outside it, 168 lie outside the study countries, 72 have no track within 2 km, and 24 sit on separate components, mostly isolated narrow-gauge and local lines that do not connect to Košice.

Station snapping is precise. The median snap distance is 4.4 m, and three quarters of the stations lie within 19.4 m of the track. As a reference, the graph puts Košice–Žilina at 241.7 km against 242 km in the ŽSR line kilometrage. Detour factors have a median of 1.38 (interquartile range 1.33 to 1.47, full range 1.02 to 3.86, n = 9348). No value falls below 1, which confirms that the graph is internally consistent.

3.4. Domestic Infrastructure and Connectivity

With a population of almost 5.5 million and an area of 49,034 km^2, Slovakia ranks among the smaller EU member states (Figure 2). In terms of population distribution and degree of urbanization, almost 42% of the population lives in rural municipalities covering around 82% of the country (Figures 3 and 4). Towns and suburbs, with 37% of the

population and 16% of the area, come second (Figures 3 and 4). Lastly, only 21% of the population lives in urban cities, which cover 2% of the country. In terms of railway infrastructure, Slovakia has a railway network with an estimated length of 8767 km and 708 operating stations. Every urban center, almost half of the towns and suburbs, and 15% of rural municipalities have at least one train station in service (Figures 3 and 4).

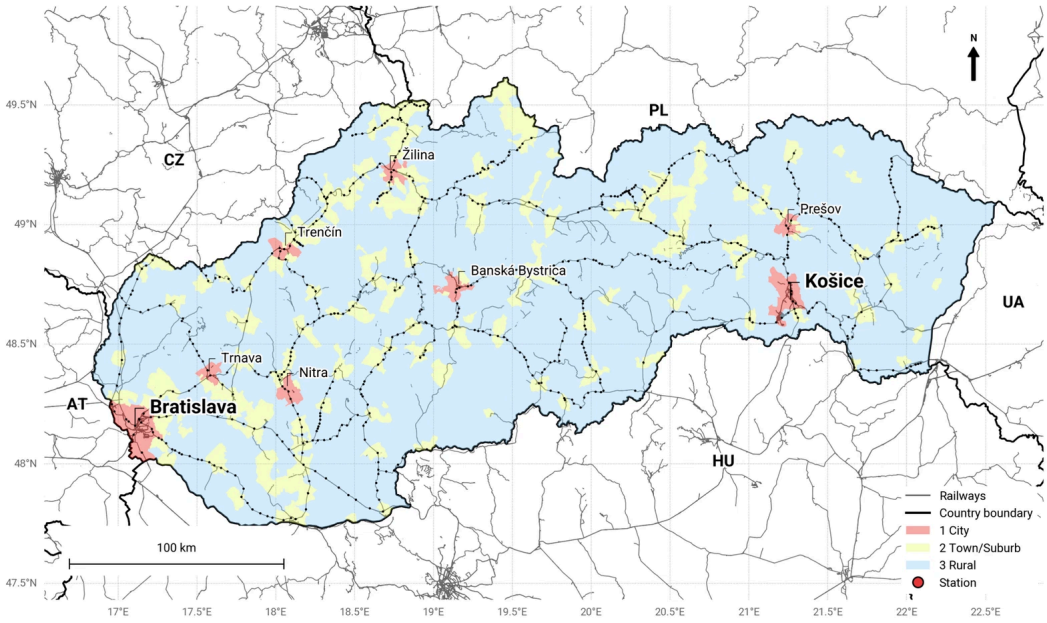


Figure 3. Slovakia's degree of urbanization in the context of railway infrastructure.

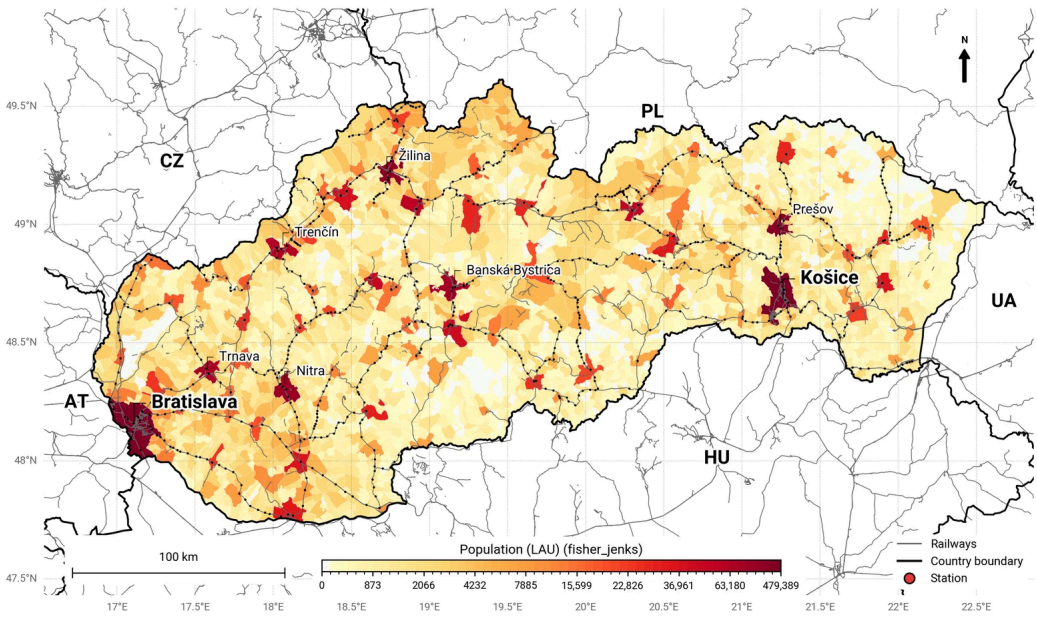


Figure 4. Slovakia's population distribution at LAU2 in the context of railway infrastructure.

Out of the eight regional urban centers of Slovakia, Košice is the second largest at the national level and the largest in Eastern Slovakia; together with the city of Presov, it is one of only two urban centers east of Banská Bystrica, the capital of Central Slovakia (Figure 3). Population-wise, the two major urban centers lie on opposite sides of the country. The capital Bratislava (pop. 480,000) lies on the western border of the country in a trilateral cross-border region with Austria and Hungary. Košice (pop. 230,000) is near the other end of the country, in close proximity to the borders with Hungary. Together

with Prešov (pop. 81,000), they make up 27% of Slovakia's urban population (Figure 4).

The regional (NUTS 3) GDP in 2024 mirrors this spatial pattern with a nuance. In absolute numbers (billions of Euro), the capital Bratislava region (36.5) is way ahead of the second Košice region (15.5) and following regions (spanning from Trnava region 14.9 to Presov region: 11.8). Adjusting the regional GDP to regional purchasing power standard per capita, the Košice region (24,800) falls to fifth place, and the neighboring Presov region (18,200) falls to last eight place, suggesting that relative wealth remains concentrated in the west of the country (Figure 5).

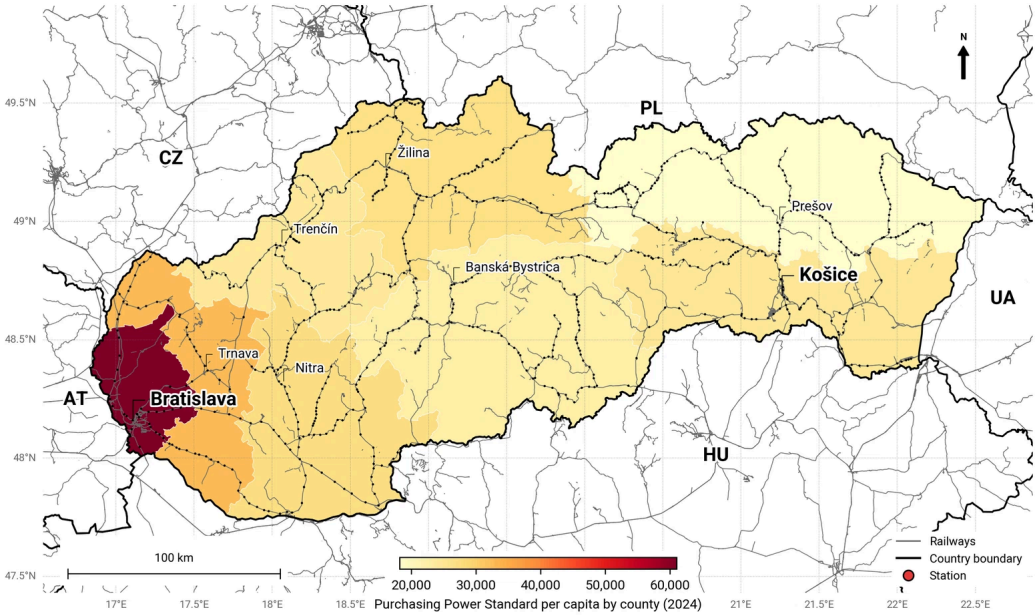


Figure 5. Purchasing power standard per capita in Slovak counties.

3.4.1. Direct Domestic Connectivity to Košice

By direct train connections, Košice is reachable from 115 stations in 107 municipalities, 3.7% of Slovakia's municipalities, covering 27.2% of its population (excluding Košice). By degree of urbanization, these are five of the seven urban centers (83.7% of the urban population), 39 towns (27.5% of the town population), and 63 rural municipalities (4.3% of the rural population) (Figure 6). Most of the connections outside the Košice region run along the northern route linking Košice with the capital. Notably, Banská Bystrica, the regional capital of Central Slovakia, has no direct connection to Košice via the central or southern route (Figure 6).

At the regional level (NUTS 3), the distribution of direct connections confirms Košice's role primarily as a regional hub. More than half of the directly connected stations (63) lie within the Košice region itself, and 70% of the region's stations are outside the city. At the level of towns and suburbs, 15 municipalities representing 78.7% of the region's town population are directly connected, and the 44 connected rural municipalities hold 19.3% of its rural population. Outside the Košice region, coverage extends partially into the neighbouring Prešov region, which accounts for a further 28 stations (24.3% of all direct connections, yet only 22.4% of the region's stations): the regional capital, nine towns (36.1% of the town population) and 15 rural municipalities (5.9%). The remaining regions are connected almost exclusively through main-line stations, with 5.7 to 6.8% of their stations covered, while the Nitra region has no direct connection at all. The two eastern regions, which concentrate 79.1% of the directly connected stations, are among the economically weaker regions of the country, so in territorial terms, Košice's

direct rail catchment is drawn predominantly from its poorer regions. In population terms, however, the capital of the wealthiest region, Bratislava (58,000 PPS per inhabitant, 2023), alone contributes a third of the directly connected population (480,902 inhabitants) through its main-line connection.

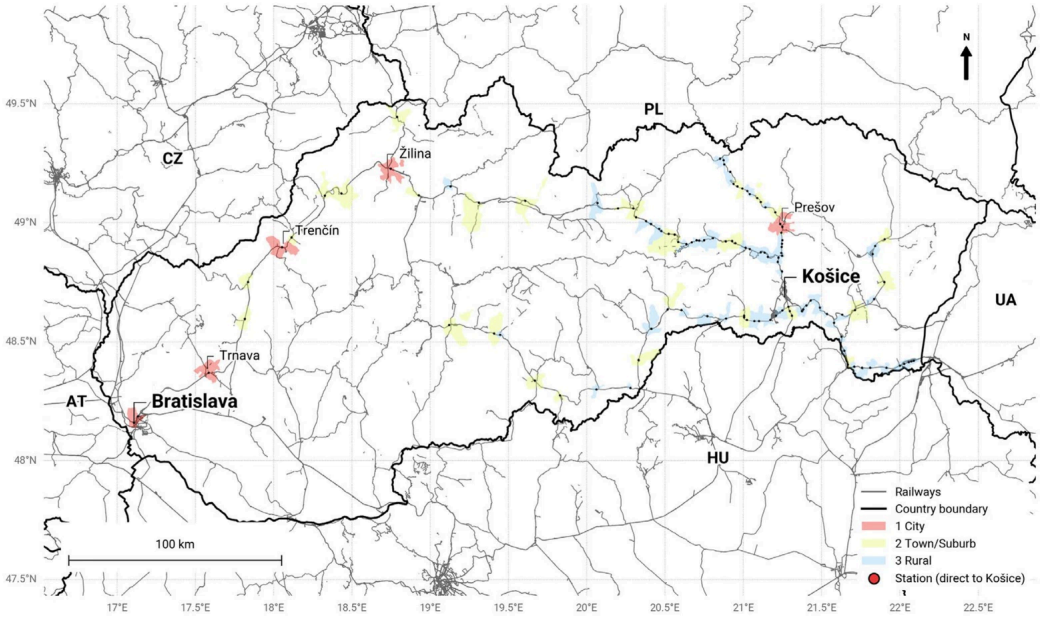


Figure 6. Direct connections to Košice by degree of urbanization.

In terms of mean journey time, only 30% of the catchment population is within 90 min and 14.5% within 60 min (Figure 7a). Bratislava alone, holding one third of the catchment population, has a mean journey time of five and a half hours at a route distance of 439 km (Figure 7a). Journey time from Košice is an almost deterministic function of rail distance (Figure 7a): The linear fit (0.82 min/km on an 11.2 min intercept) explains 98% of the variance and implies a marginal speed of 73 km/h with no break in slope. Two groups of municipalities depart from this norm. Three western regional capitals (Trenčín, Trnava and Bratislava) are reached 20 to 40 min faster than the network norm through the northern main InterCity line, while the intermediate corridor towns the InterCity skips (Leopoldov, Piešťany, Nové Mesto nad Váhom, Trenčianska Teplá) are 31 to 35 min slower, and the branch toward the Ukrainian border (Čierna nad Tisou, Biel, Dobrá) is 15 to 17 min slower (Figure 7a).

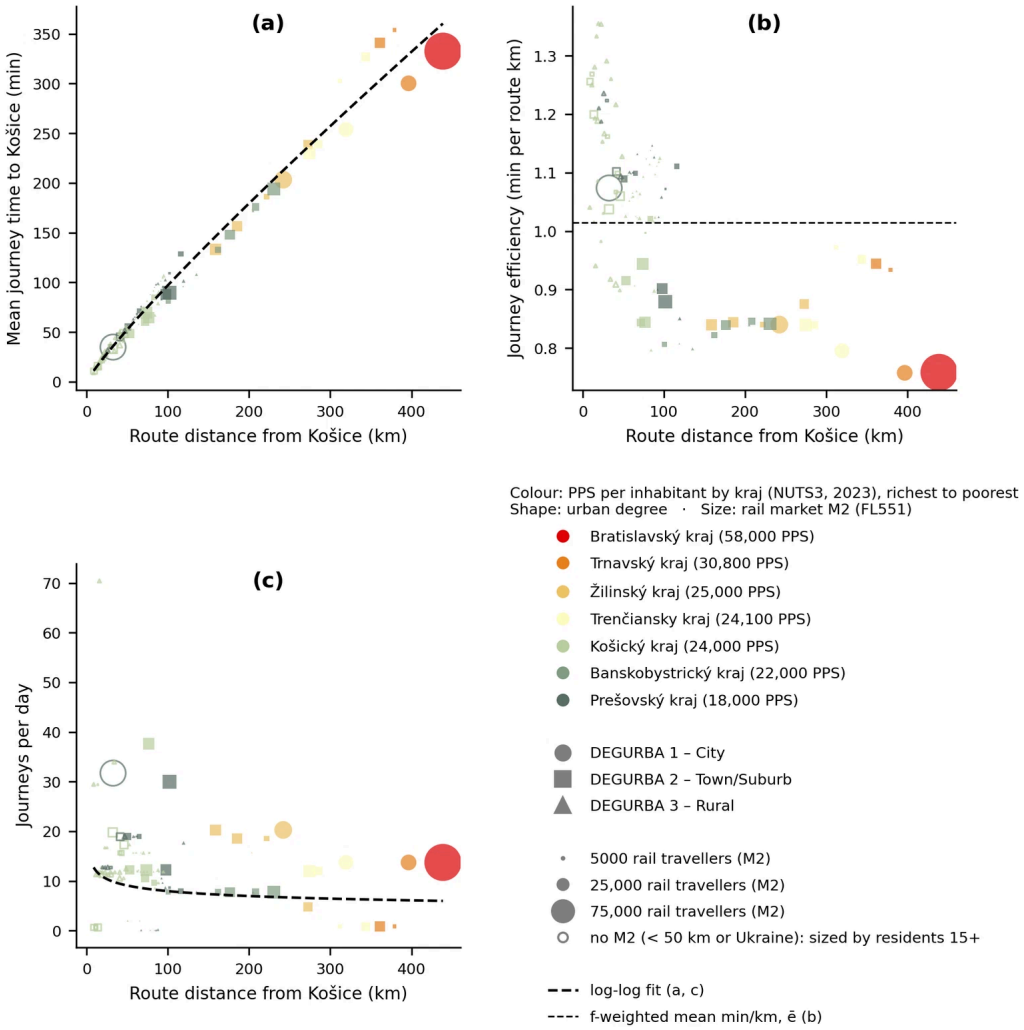


Figure 7. Base analysis of direct connectivity to Košice in terms of degree of urbanization, rail market size, regional purchasing power standard per inhabitant, and route network distance in relation to (**a**) average journey time, (**b**) journey efficiency, and (**c**) average trips per day.

Journey efficiency declines hyperbolically with distance to a network minimum of 0.76 min/km at Trnava and Bratislava (Figure 7b). The distance-band means fall from 1.18 min/km within 25 km to 0.85–0.89 min/km beyond 200 km (Figure 7b). The immediate surroundings of the city are the least time-efficient (Bohdanovce 1.36, Ruskov 1.35, Vyšná Myšľa 1.33, Slanec 1.29 min/km). This reflects a fixed access overhead, dense stopping patterns toward the Hungarian border and toward Slanec, and route circuity: Bohdanovce lies 19 km from Košice by rail but 13 km in a straight line (Figure 7b).

The best-served places are junctions and towns in eastern Slovakia: Kysak with 70.4 direct journeys per day; Spišská Nová Ves with 37.7; Margecany with 34.0; Prešov with 31.7; Poprad with 29.9; and Kostoľany nad Hornádom and Trebejov with 29.5 (Figure 7 c). Among the urban centers, Prešov leads with 31.7 journeys per day, Žilina has 20.3, and the three western regional capitals have 13.7 each (Figure 7c).

For the 107 directly connected municipalities, journey time is linear in route distance: 0.823 min/km (95% CI 0.766–0.881, heteroskedasticity-robust *HC*3) on an intercept of 11.2 min (7.1–15.3), R^2 = 0.979. A quadratic term is negligible (−0.0002, CI −0.0007 to 0.0003, p = 0.39), and the linear form passes the specification rule (RESET p = 0.044 ≥ 0.01). The slope is stable: 0.840 (0.786–0.894) without Bratislava, 0.822 (0.777–0.866) without the five most influential municipalities, and 0.826 (0.772–0.880) on shortest-path rail

distance. Residual variance is not constant (Breusch–Pagan $p < 0.001$), hence the robust errors. Seven municipalities exceed the Cook's distance threshold of 4/n, all at the western end of the main line: Bratislava (the only one above 1, $D = 1.05$), with Trnava and Trenčín, faster than the norm, and Leopoldov, Piešťany, Nové Mesto nad Váhom and Trenčianska Teplá, which are slower. The residuals are spatially clustered (Moran's $I = 0.27$, $p = 0.001$, $k = 5$ nearest neighbors; 0.18–0.33 for $k = 3$–10), as neighbouring stations share lines and timetables. A spatial error model leaves the slope practically unchanged at 0.805 min/km (0.765–0.845; $\lambda = 0.52$). In a spatial lag model ($\rho = 0.47$), the implied total effect is 0.85 min/km. Frequency, by contrast, does not decay with distance among directly connected municipalities: The elasticity of journeys per day with respect to rail distance is −0.19 (CI −0.48 to 0.09, $R^2 = 0.02$). With population added and spatial dependence modelled (spatial error, $\lambda = 0.78$), only population matters (elasticity 0.19, CI 0.08–0.31; distance −0.27, CI −0.89 to 0.35). Whether a station-bearing municipality has a direct service at all depends strongly on distance and size: In a logit for the 535 municipalities with a station (107 served), the coefficient on log rail distance is −2.47 (−2.88 to −2.05), and on log population, it is 0.81 (0.55–1.07), pseudo-R^2 0.44. Doubling the distance cuts the odds of a direct service to about one fifth ($2^{-2.47} \approx 0.18$), and doubling the population raises them by about three quarters ($2^{0.81} \approx 1.76$).

The 107 directly connected municipalities hold 1,202,685 residents aged 15 and over (M1). Applying the Flash Eurobarometer 551 age-band shares of rail use to the municipalities beyond 50 km of Košice gives a rail market (M2) of 535,069, with a nominal interval of 486,700 to 583,438. The 37 municipalities within 50 km (165,387 residents, 137,220 of them aged 15 and over) are left out because the survey question refers to longer trips. As direct services need no transfer, $M3$ equals M2. Bratislava alone accounts for 38.3% of this market (205,178), followed by Žilina (34,381), Trnava (27,015), Trenčín (23,453) and Poprad (20,799). Measured against journey time, the market is distant: Only 3.0% of $M2$ lies within 60 min (16,316, five municipalities beyond the 50 km floor), 20.5% within 90 min, 31.6% within three hours, and 52.3% within five hours. The rest, essentially Bratislava, follows at 5.5 h. With exponential distance decay, the effective rail market is 74,725 at a 60 min half-life (14.0% of the direct M2; 3.3% of the national rail market), 168,215 at 120 min (31.4%; 7.3%), and 285,886 at 240 min (53.4%; 12.5%), each about ±9% on the survey's nominal interval. Purchasing power is a characteristic of this catchment, not a weight: The population-weighted mean of the direct catchment is 35,057 PPS per inhabitant (NUTS3, 2023), 1.23 times the national mean of 28,508. This is driven by Bratislava: The richest quartile of regions holds 45.9% of the direct $M2$ in only four municipalities. Car ownership in the catchment is slightly above the national level (521 vs. 488 passenger cars per 1000 inhabitants, NUTS2, 2023; ratio 1.07).

3.4.2. Single-Transfer Domestic Connectivity to Košice

The 356 municipalities reached only with one transfer (1,493,866 inhabitants) lie far from Košice in time: The population-weighted mean journey time is 328 min over a population-weighted mean rail distance of 277 km (343 km along the route travelled) (Figure 8). The two largest additions, Nitra (420 min) and Banská Bystrica (400 min), stand out. Barely 1% of this population is within 90 min, with 11.7% within three hours and 37.9% within five hours (Figure 9a). Journey time grows more slowly than distance (log–log elasticity 0.66 on route distance, 95% CI 0.64–0.67). Measured along the route travelled, time is almost as predictable as for direct journeys (R^2 0.965 against 0.979). Against the shortest rail path, the fit is much looser (R^2 0.84 against 0.98), because transfer journeys often detour through their hub: Banská Bystrica is reached over 417 km of track, although it lies 210 km from Košice by the shortest rail path. The largest gains against the

network norm, 33 to 42 min, occur on the southern line (Prša, Holiša, Šíd) and in the southwest (Štúrovo, Úľany nad Žitavou, Križovany nad Dudváhom). Municipalities on secondary lines are much slower: the Hron valley (Hronské Kľačany +85, Veľké Kozmálovce +83, Tlmače +81 min) and the Banská Štiavnica branch (+59 to +64) (Figure 9 a).

Journey efficiency again declines hyperbolically with distance, around a frequency-weighted network mean of 1.24 min/km (48 km/h). Band means fall from 2.29 min/km within 50 km and 1.64 at 50–100 km to 0.88 beyond 400 km (Figure 9b). The fixed access overhead and the transfer wait dominate short itineraries, so the least efficient journeys start around Košice itself (Veľká Ida 2.46, Cestice 2.42, Sokoľany 2.40 min/km). Measured along the route travelled, Banská Bystrica (0.96) and Nitra (0.94) are both more efficient than the network mean. Banská Bystrica's long journey time therefore comes from the detour, not from slow running: on the shortest rail path, its efficiency is 1.91 min/km, against 1.15 for Nitra (Figure 9b).

Service frequency declines weakly with distance (r = −0.26, 95% CI −0.34 to −0.17) and rises weakly with population (r = 0.29, 0.21 to 0.37). Distance alone explains 7% of the variance in log journeys per day, and distance with population explains 18% (Figure 9c). Among the municipalities reached only with a transfer, Banská Bystrica has 34.3 journeys per day, and Nitra has 11.6; towns average 14.1, and rural municipalities average 9.6. The best served of them are towns and villages on the main lines in the west and north: Ilava and Dubnica nad Váhom (53.7 each); and Pezinok (50.6), Martin (47.0) and the Liptov villages on the main line (Liptovská Sielnica 47.0, Liptovská Teplá 46.0) (Figure 9c).

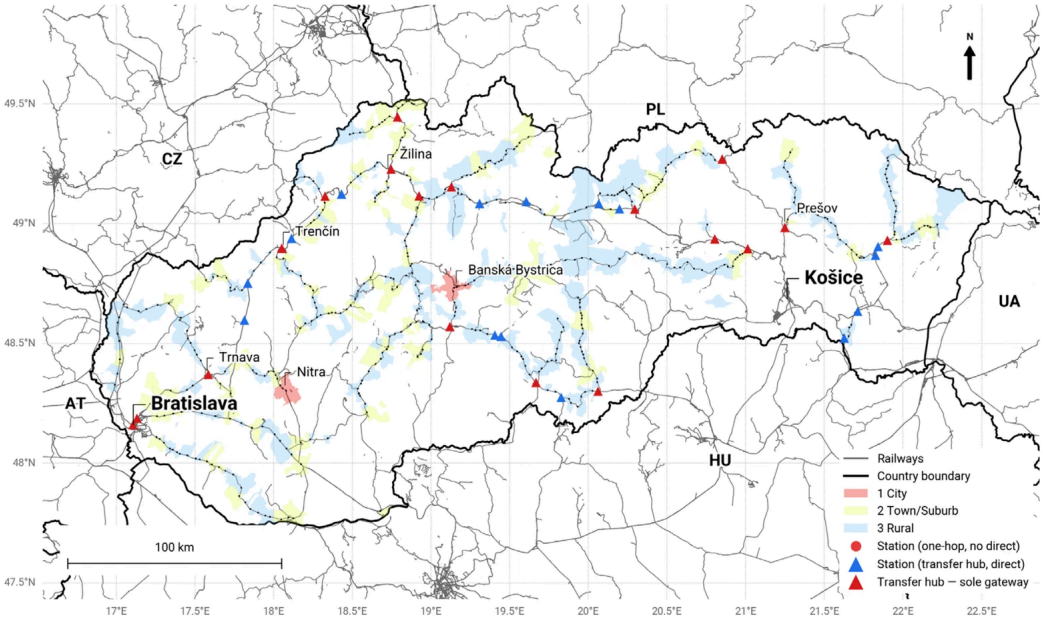


Figure 8. Single-transfer-only connections to Košice by degree of urbanization.

For the 463 municipalities reached with one transfer, journey time rises by 0.738 min per route kilometers (95% CI 0.727–0.748, *HC*3) on an intercept of 74.3 min (71.1–77.5), R^2 = 0.965. Both functional forms fail the RESET test ($p < 0.01$), so the linear form is kept with a caveat. The quadratic term is small and negative (−0.00035, CI −0.00044 to −0.00026), so time grows more slowly at long distances. The log–log elasticity is 0.656 (0.641–0.671, R^2 = 0.969). On shortest rail distance, the slope is 0.801 (0.769–0.834), but the fit loosens (R^2 = 0.841), because many journeys detour through their hub. The slope is unchanged without Bratislava (0.738) and without the five most influential municipali-

ties (0.737, 0.726–0.747). No single municipality dominates (maximum Cook's D 0.03). The residuals are strongly clustered in space (Moran's I = 0.76, p = 0.001, k = 5; 0.64–0.79 for k = 3–10), as whole lines share one hub and one connection. A spatial error model gives a slope of 0.697 min/km (0.678–0.716; λ = 0.84), and a spatial lag model (ρ = 0.26) gives an implied total effect of 0.76 min/km. The transfer penalty is estimated on the 570 directly or one-transfer connected municipalities: At equal route distance, a transfer adds 63.1 min (57.8–68.3), falling by 0.086 min per km (0.027–0.144), so it is about 46 min at 200 km and 29 min at 400 km. For the 107 municipalities with both kinds of service, the fastest one-transfer journey is on average 85 min slower than the direct one (median 73). A matched comparison attributes 41.7 min of this (38.3–45.2) to the transfer itself and 0.81 min to each extra kilometers of detour. Frequency falls with distance (elasticity −0.41, CI −0.56 to −0.26, R^2 = 0.07). With population added, distance has an elasticity of −0.51 (−0.67 to −0.34) and population has 0.36 (0.28–0.45), R^2 = 0.19. Both effects survive a spatial error model (distance −0.62, CI −0.96 to −0.27; population 0.26, 0.20–0.31; λ = 0.78). Among the 535 municipalities with a station, the odds of any one-transfer service fall steeply with distance (logit coefficient on log rail distance −2.88, CI −3.71 to −2.05) and rise with population (0.53, 0.30–0.75; pseudo-R^2 0.21). Doubling the distance cuts the odds to about one seventh ($2^{-2.88} \approx 0.14$), and doubling the population raises them by 44%.

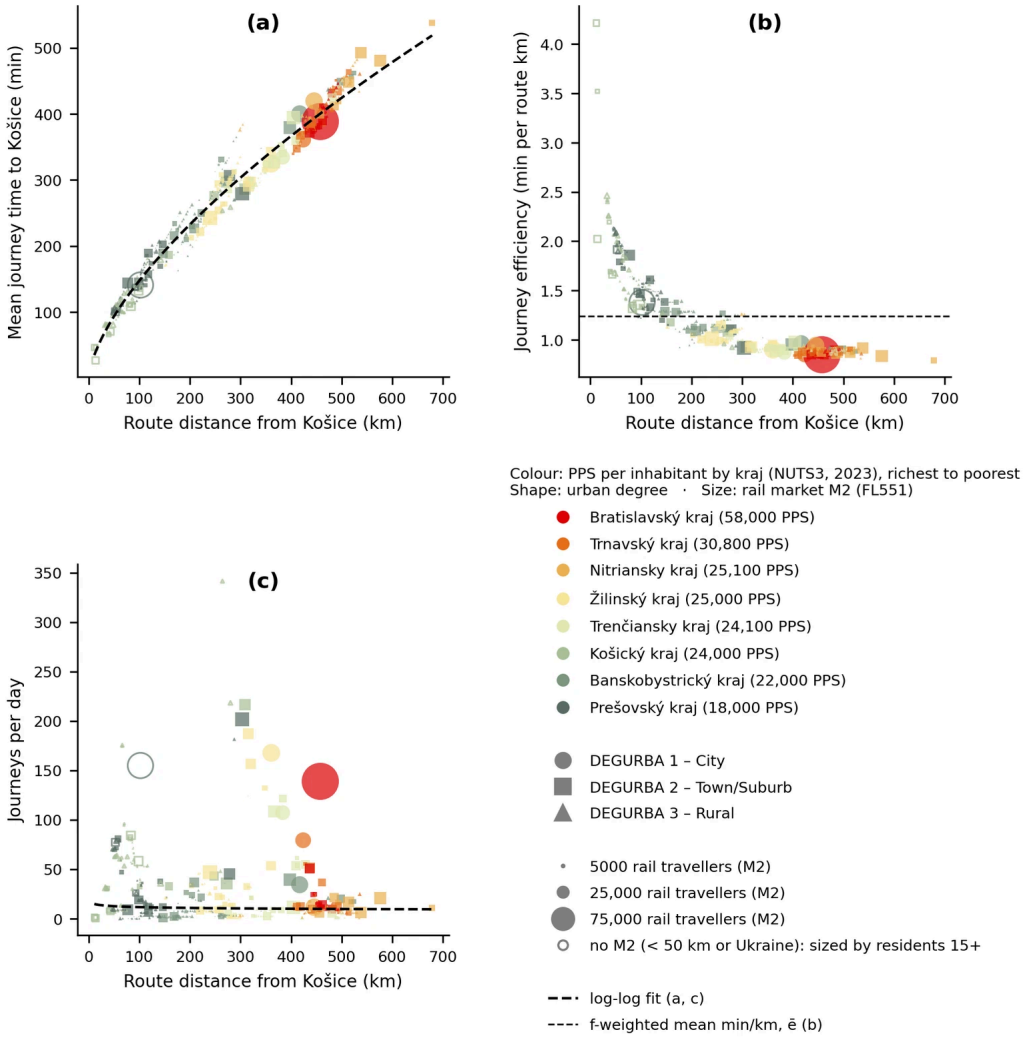


Figure 9. Base analysis of single-transfer connectivity to Košice in terms of degree of urbanization, rail market size, regional purchasing power standard per capita, and route network distance in re-

lation to (**a**) average journey time, (**b**) journey efficiency, and (**c**) average trips per day.

The 356 municipalities reached only with a transfer hold 1,278,206 residents aged 15 and over (M1). Beyond the 50 km floor, which excludes 11 municipalities with 22,086 residents (18,476 aged 15 and over), the Flash Eurobarometer 551 rates give a rail market (M2) of 632,771 (nominal interval 575,864–689,678). Only 59.4% of rail travellers state that they would accept a transfer, so the transfer-adjusted market (M3) is 376,135 (342,308–409,962). Nitra (19,408) and Banská Bystrica (18,818) contribute most, followed by Martin (13,064), Prievidza (11,082) and Nové Zámky (9349). Almost none of this market is near in time: 0.1% of *M*3 lies within 90 min, 1.1% within two hours, 10.1% within three, 36.7% within five and 48.7% within six hours. With exponential decay, the effective market is 16,805 at a 60 min half-life (4.5% of *M*3; 0.7% of the national rail market), 66,494 at 120 min (17.7%; 2.9%; nominal interval 60,551–72,437) and 150,716 at 240 min (40.1%; 6.6%). Together with direct services, the effective market at a 120 min half-life rises from 168,215 to 234,709 (10.2% of the national rail market). The one-transfer network therefore adds about two-fifths to the direct market, although it more than doubles the reachable population. Unlike the direct catchment, the one-transfer catchment is slightly poorer than the country (26,949 PPS per inhabitant against 28,508, ratio 0.95), and its car ownership is at the national level (491 against 488 cars per 1000, ratio 1.01). For direct and one-transfer services combined, the ratios are 1.08 for PPS and 1.04 for cars. Weighting the survey rates toward cities (1.2/1/0.8 for city, town, rural) raises the combined *M*2 of 1,167,840 by 7.0%, and the opposite weighting lowers it by 6.5%.

3.4.3. Domestic Same-Day Visits

With direct trains only, a same-day visit is possible from 94 municipalities with 1,320,647 inhabitants, with 25.5% of Slovakia's population outside Košice and 93.4% of the directly connected population. In total, 13 of the 107 directly connected municipalities (92,732 inhabitants) drop out. They are the corridor towns skipped by the InterCity, which have less than one direct train a day (Piešťany, Nové Mesto nad Váhom, Trenčianska Teplá and Leopoldov); Čadca, three places next to the city with only occasional direct trains (Čaňa, Valaliky and Geča); and the small stations of the Plaveč line.

By degree of urbanization, direct same-day visits are possible from 5 of the 7 urban centers (83.7% of the urban population), 31 towns (23.2%) and 58 rural municipalities (4.1%). The pattern is as regional as direct service itself. The Košice region contributes 56 municipalities (38.5% of its population), the Prešov region contributes 20 (26.5%), and the Banská Bystrica region contributes eight (16.1%). The western and northern regions are reached only through their main-line towns, giving 21.0% in the Žilina region, 19.1% in Trenčín, 11.2% in Trnava and 65.0% in Bratislava, where only the capital qualifies. The Nitra region again has none. Reliability also varies through the year. Prešov allows a visit every day, whereas Bratislava, Trnava, Trenčín, Žilina and the other towns on the northern main line allow it on 315 of 364 days (86.5%). Requiring a visit on at least 90% of days therefore shrinks the direct figure to 81 municipalities and 520,858 inhabitants (10.0%).

Allowing one transfer in either direction extends same-day visits, possible on at least one day of the year, to 293 municipalities with 2,132,571 inhabitants (41.1% of the population), of which 199 municipalities (811,924 inhabitants) are reachable only with a transfer. Of the population that can reach Košice by rail with at most one transfer, 73.4% can also return the same day. Banská Bystrica joins the urban centers with a visit possible every day, raising coverage to 6 of 7 (91.7% of the urban population), and coverage rises to 91 towns (49.6% of the town population) and 196 rural municipalities (13.2%). The transfer matters most in the north and center of the country. A same-day visit is now

possible for 55.1% of the population in the Žilina region, 49.6% in Prešov, 42.8% in Košice, 33.9% in Banská Bystrica, 31.5% in Trenčín and 30.2% in Trnava, and for 75.8% in the Bratislava region.

The Nitra region, including the city of Nitra (75,301 inhabitants), still has no same-day visit on any day. A visit possible on at least half of the days covers 265 municipalities (39.7% of the population) and on at least 90% of days 154 municipalities with 821,892 inhabitants (15.8%). The required stay matters only at the long end: Shortening it to four hours changes nothing, while eight hours reduces the transfer-inclusive figure to 267 municipalities (37.7% of the population). In market terms, the residents aged 15 and over of the same-day municipalities beyond 50 km contain an expected 837,001 rail travelers by the Flash Eurobarometer 551 rates (M2; nominal interval 761,711–912,290), equivalent to 16.1% of all residents outside Košice; discounted for transfer acceptance (M3), the figure is 713,754.

3.5. Foreign Connectivity

All cross-country figures in this section report observed connectivity within the available feeds. The Ukrainian feed is OpenStreetMap-derived and carries 118 stops, so its zero says nothing about Ukrainian railways; Polish figures rest on a 32-day window and are bounds, not estimates.

Košice's geographical position relative to neighboring countries is disadvantageous in the short term, though not without potential. Only one regional capital lies nearby (Miskolc, Hungary, 80 km) (Figures 10 and 11). In total, twenty regional capitals in three neighboring countries (Hungary, Poland and Czechia) with a population similar to or larger than that of Košice lie within the same distance as Bratislava (Figure 3). Together, these regional capitals account for a combined population of 4.9 million (Figures 10 and 11). As for urban centers, a further 39 foreign urban centers within the same range (including Ukraine) contribute an additional population of 4.1 million.

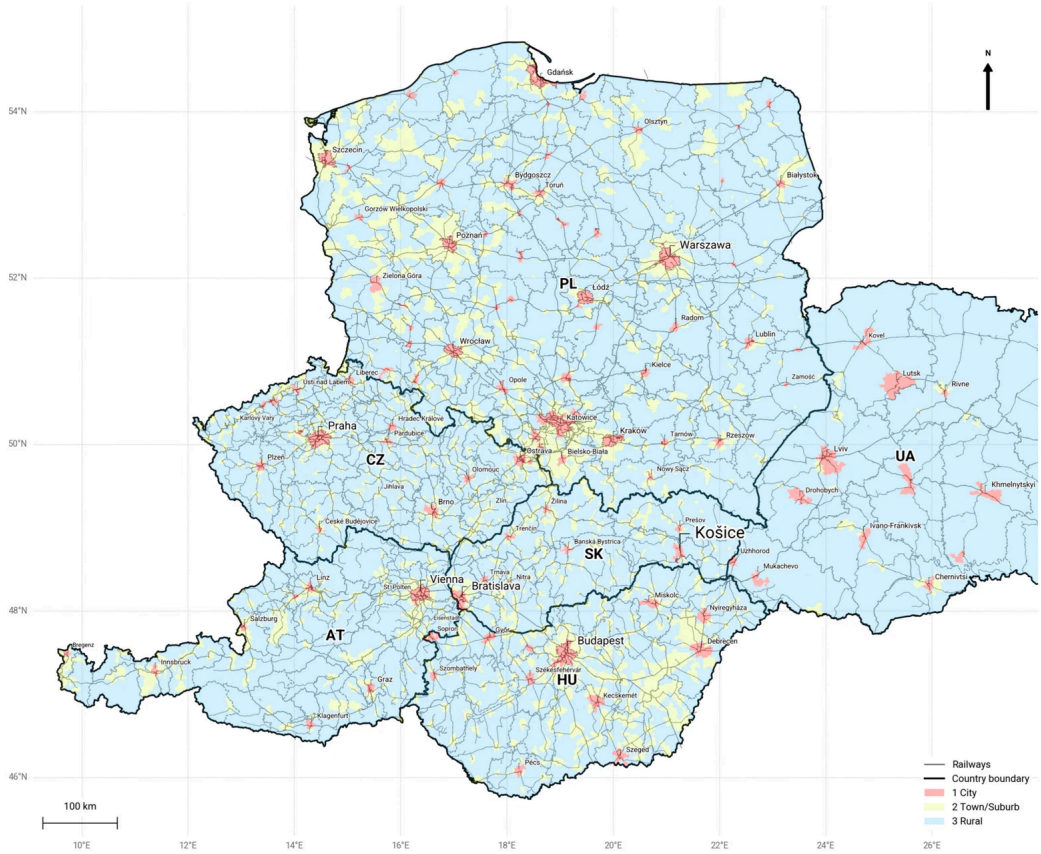


Figure 10. Košice in relation to the rail network, regional capitals, and degree of urbanization of neighboring countries.

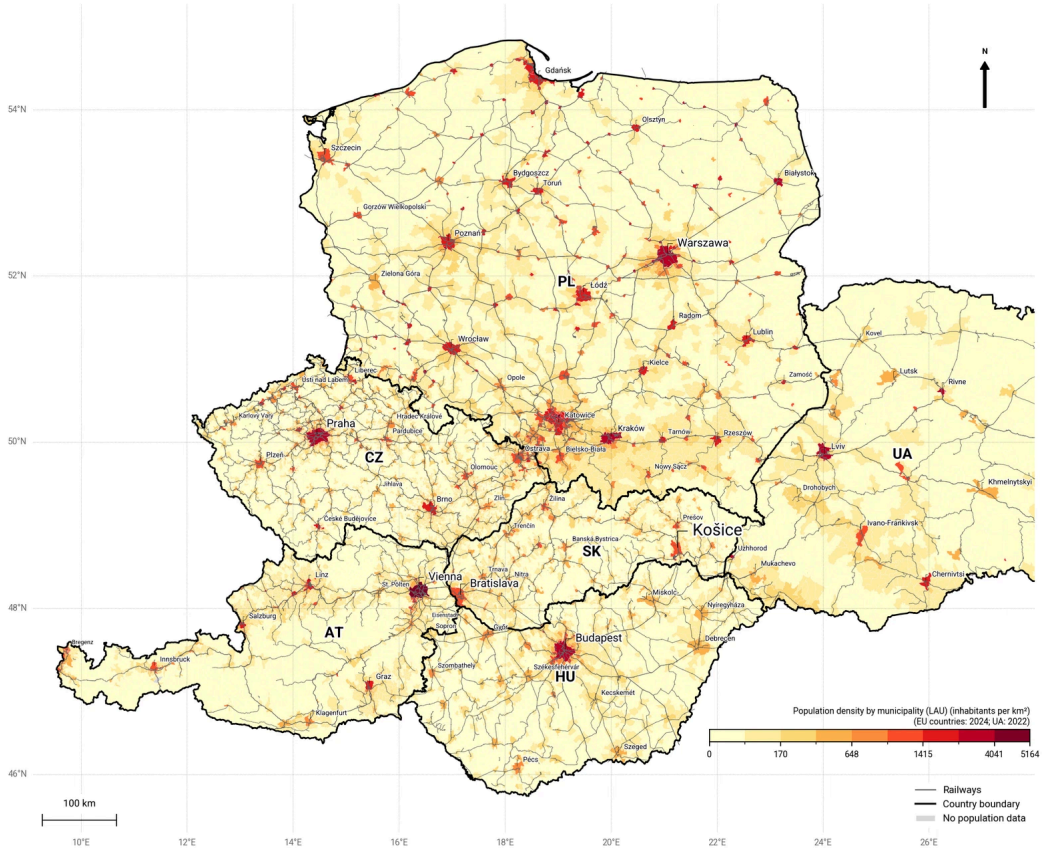


Figure 11. Population density per km^2 in municipalities of the studied area.

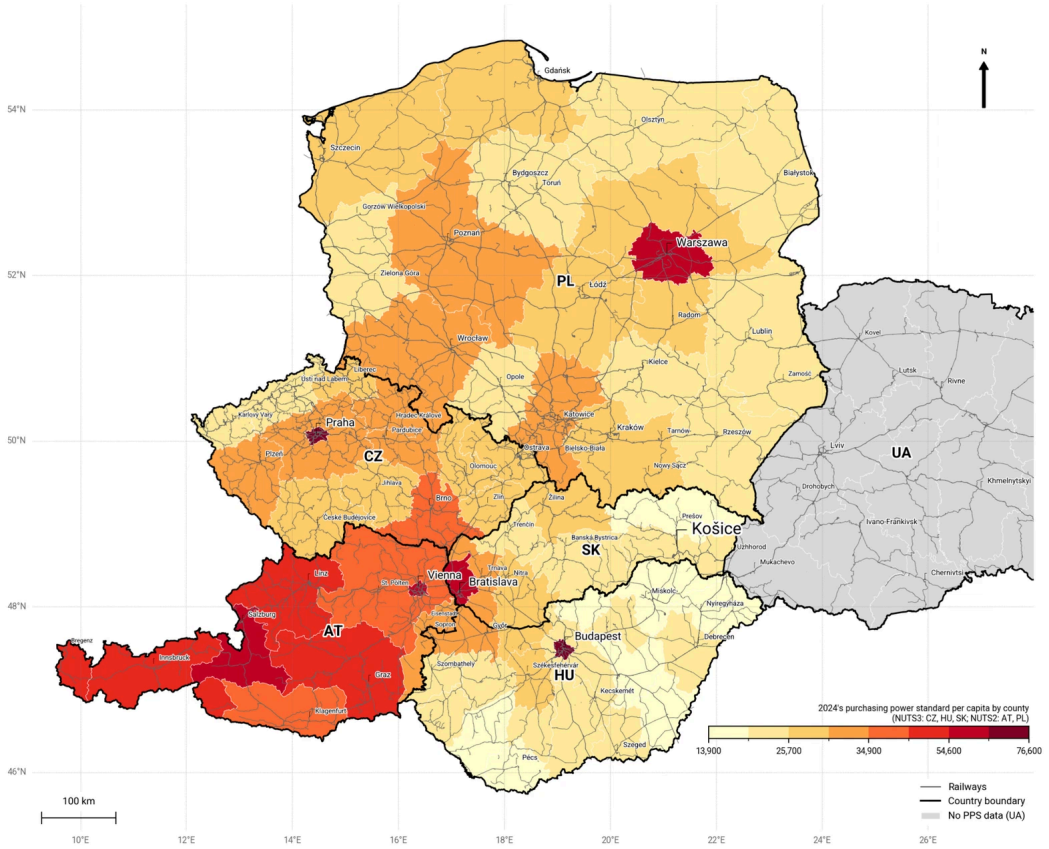


Figure 12. Purchasing power standard per inhabitant at county level.

Economically, Košice lacks what Bratislava may find in Vienna, a prosperous cross-border partner in close proximity (Figure 12).

Ukraine lies outside this comparison because regional purchasing power is not published for it and regional GDP is used instead. The Zakarpattia oblast, the 23rd of Ukraine's regions, produced a GDP of 2.34 billion EUR in 2021, less than 20% of the Košice region's 12.38 billion EUR in the given year.

In comparison, Bratislava can draw on Vienna. Košice has no stronger neighboring partner. Except for Budapest, none of these are within reach for daily interaction.

3.5.1. Foreign Direct Connectivity

Košice's direct rail links into the neighboring countries are few (Figure 13). Poland and Austria have no direct connection at all, although both capitals, Warsaw and Vienna, have direct flights to Košice. Hungary is served by a single line, Košice–Miskolc–Budapest, and Czechia by the main line through Čadca, Třinec and Ostrava to Prague (Figure 13). The open-access timetable data for Ukraine cover only the nearest places: the cities of Uzhhorod and Mukachevo and the town of Chop, all located in Zakarpattia oblast (Figure 13).

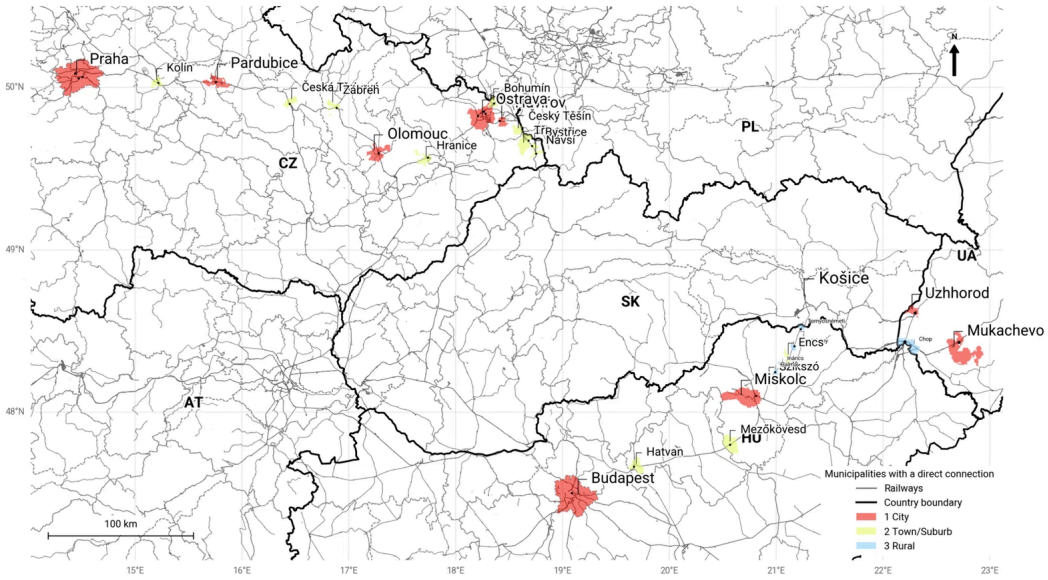


Figure 13. Foreign municipalities with direct connections to Košice.

The 27 foreign municipalities with a direct train hold 4.2 million inhabitants: 19.4% of Czechia's population and 19.7% of Hungary's, against 0.6% of Ukraine's. Of this population, 94.5% lives in cities, which covers 62.3% of Czechia's and 57.3% of Hungary's urban population. Towns and suburbs add 211,112 inhabitants in 13 municipalities, and five rural municipalities add a further 20,505. By region, the Czech catchment comprises the Moravian-Silesian region (seven municipalities, 434,646 inhabitants), the Olomouc region (Olomouc, Hranice, Zábřeh; 136,364), the Pardubice region (Pardubice, Česká Třebová; 107,695), Kolín (33,392) and Prague (1,407,084). The Hungarian catchment comprises eight municipalities of Borsod-Abaúj-Zemplén county (170,864), Hatvan (19,353), and Budapest (1,675,777) (Figure 13).

Budapest and Prague hold 73% of the catchment population; their mean journey times are 229 min over 270 km of route and 552 min over 701 km. Journey time again follows rail distance closely: the linear fit (0.77 min/km on a 37.7 min intercept) explains 96% of the variance (Figure 14a). The two Ukrainian cities depart from it (Uzhhorod 247 min for 105 km, 113 min above the norm; Mukachevo 209 min for 146 km, 59 min above), which points to a border-crossing overhead (Figure 14a).

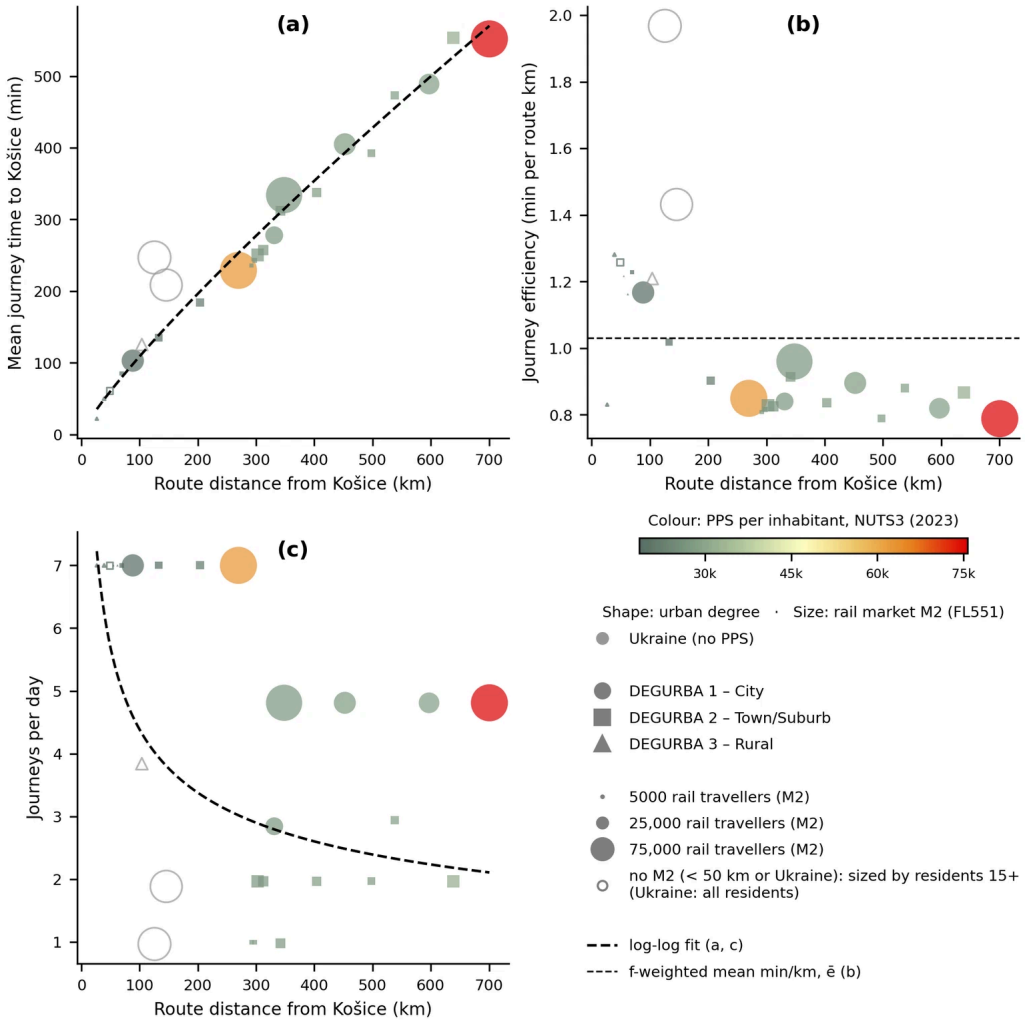


Figure 14. Base analysis of foreign direct connectivity to Košice in terms of degree of urbanization, rail market size, regional purchasing power standard per capita, and route network distance in relation to (**a**) average journey time, (**b**) journey efficiency, and (**c**) average trips per day.

Journey efficiency still declines with distance (Figure 14b). All 14 Czech municipalities lie below the frequency-weighted network mean of 1.03 min/km, between 0.79 (Prague) and 0.96 (Ostrava). The Hungarian municipalities within 150 km range from 0.83 (Hidasnémeti) to 1.28 min/km (Novajidrány). Uzhhorod is the least time-efficient place in the network (1.97 min/km), followed by Mukachevo (1.43) (Figure 14b).

Frequency is set by the line rather than by distance or size. Every Hungarian municipality has the same seven direct journeys a day (Figure 14c). On the Czech main line, Prague, Pardubice, Olomouc and Ostrava have 4.8 a day, the other Czech towns have 1.0 to 2.9, and the Ukrainian municipalities have 1.0 (Uzhhorod) to 3.8 (Chop) (Figure 14c). Within Czechia, frequency rises with distance (r = 0.56, 95% CI 0.05–0.84) because the larger cities are the more distant ones (r with population 0.83, 0.54–0.95).

For the 27 foreign municipalities with a direct train, journey time rises by 0.766 min per route kilometer (95% CI 0.708–0.824, *HC*3) on an intercept of 37.7 min (14.0–61.3), R^2 = 0.960. The linear form passes the specification test (RESET p = 0.75), and a quadratic term is negligible (p = 0.70). Without the seven cities above 100,000 inhabitants, the slope is 0.801 (0.755–0.846), and without the five most influential municipalities, it is 0.788 (0.746–0.830). Uzhhorod is the only influential observation (Cook's D 0.42 > 4/n). Adding country effects leaves the slope at 0.805 (0.712–0.897), shows no Hungarian difference

(+3.5 min, CI −25.5 to 32.4), and puts the Ukrainian journeys 75.8 min (0.9–150.7) above Czech ones at equal distances. This is the border-crossing cost, although it rests on only three observations. The residuals show no significant spatial clustering (Moran's $I = 0.10$, $p = 0.07$; with country effects −0.14, $p = 0.16$). Country-clustered errors need at least five clusters, so they are not used with three countries. Frequency falls with distance in the pooled data (elasticity −0.37, CI −0.58 to −0.17, $R^2 = 0.23$), but the decline disappears once country effects are added (+0.21, CI −0.10 to 0.52). The Hungarian line carries about four times the Czech frequency (country effect +1.45 log points, CI 0.79–2.11), and the model with country effects explains 62% of the variance. Population adds nothing within countries (elasticity 0.12, CI −0.04 to 0.29). Whether a foreign municipality with a station has a direct train at all depends steeply on distance and size: In a logit over 4271 municipalities with a station (27 served), the coefficient on log rail distance is −2.73 (−3.32 to −2.14) and the log population is 0.95 (0.72–1.17), with a pseudo-R^2 of 0.38. Doubling the distance cuts the odds to about one seventh ($2^{-2.73} \approx 0.15$), and doubling the population nearly doubles them ($2^{0.95} \approx 1.93$).

The directly connected Czech municipalities hold 1,808,312 residents aged 15 and over ($M1$), and the Hungarian ones hold 1,638,924. Applying the national Flash Eurobarometer 551 rates gives a rail market (M2) of 1,079,708 in Czechia (nominal interval 1,004,750–1,154,665) and 729,822 in Hungary (658,225–801,419). Three Hungarian border municipalities within 50 km are excluded. Ukraine is not covered by the survey and has no rail-market estimate. Together, the foreign direct market of 1.81 million is 3.4 times the domestic direct one (535,069). It is concentrated in the two capitals: Prague accounts for 66.6% of the Czech market (718,671), and Budapest accounts for 90.3% of the Hungarian market (659,322), followed by Ostrava (143,312), Miskolc (54,189) and Olomouc (52,753). In journey-time terms, the two markets differ sharply. Hardly any of the Czech market lies within four hours (0.2%, Návsí); 6.3% lies within five hours and 21.4% within six, with Prague beyond. The Hungarian market is 0.4% within 90 min and 7.8% within two hours, and all of it is within four hours. With exponential decay at a 120 min half-life, the effective market is 77,912 in Czechia (7.2% of its direct $M2$; 1.4% of the Czech national rail market) against 212,671 in Hungary (29.1%; 5.9%). At 240 min, the figures are 274,998 (25.5%; 5.0%) and 391,265 (53.6%; 10.8%). Both catchments are far richer than their countries because they are dominated by the capitals: 59,438 PPS per inhabitant against a Czech mean of 35,119 (ratio 1.69), and 58,551 against a Hungarian mean of 29,096 (2.01). Car ownership is above the national level in the Czech catchment (680 against 598 cars per 1000, ratio 1.14) and slightly below it in the Hungarian catchment (419 against 435, 0.96).

3.5.2. Foreign Single Transfer

A single transfer extends Košice's foreign reach to a further 749 municipalities with 13.3 million inhabitants (Figure 15). It reaches 44.9% of the Czech and 26.0% of the Hungarian population that has no direct train. In Austria and Poland, which have no direct service at all, it opens a limited set of main-line places (41 and 28 stations). These cover 34.3% of Austria's population but only 11.2% of Poland's, and the Polish figure rests on the 32 summer days of the Polish regional timetable (Figure 15). The two Ukrainian municipalities with one-transfer journeys, Chop and Mukachevo, already have direct trains, so the transfer adds no new place in Ukraine.

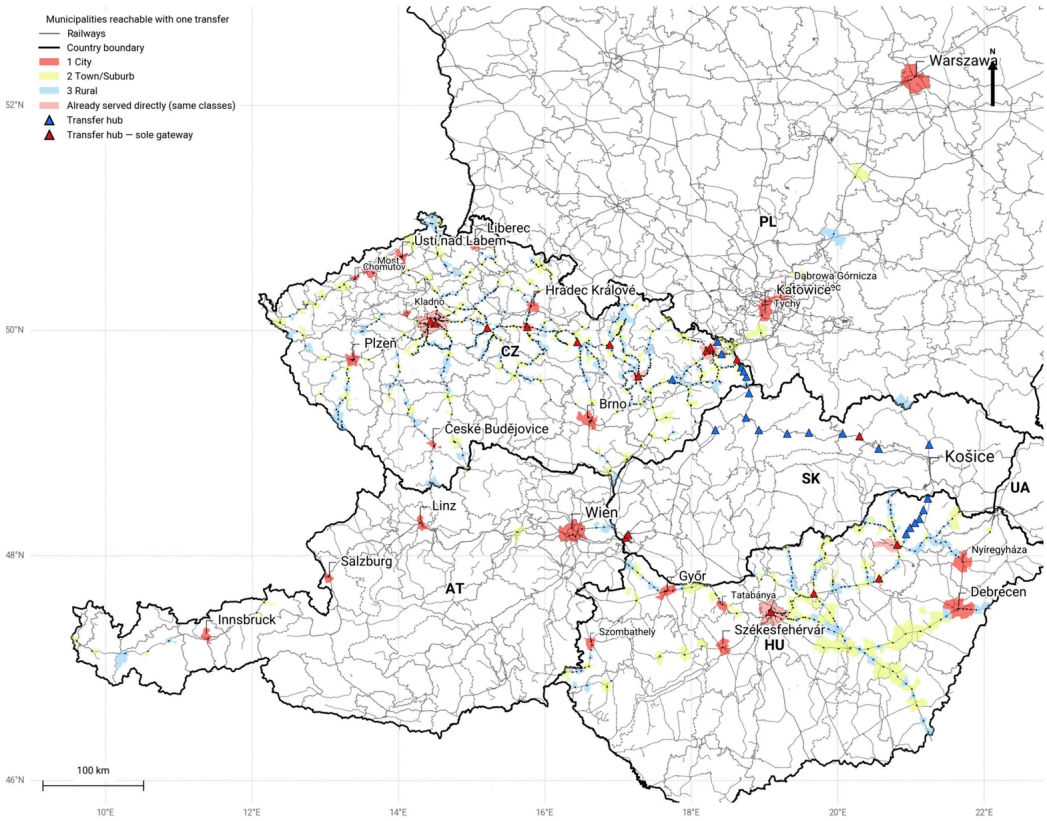


Figure 15. Foreign municipalities with single-transfer connections to Košice.

Single-transfer itineraries serve cities first. They cover almost all of the remaining Czech urban population (98.2%) and half of the Hungarian population (50.2%). In Austria, they cover 90.5% of the urban population, led by Vienna (2.04 million). In Poland, urban coverage (30.2%) is concentrated in Warsaw (1.87 million), Kraków (0.82 million) and the Upper Silesian cities near the border, such as Katowice (277,415). Towns and suburbs are covered up to 59.3% in Czechia and 31.7% in Hungary, but only 8.2% are covered in Austria and 3.5% in Poland. Rural coverage is marginal everywhere (Czechia 13.6%, Hungary 7.4%, Austria 1.5% and Poland 0.3%).

Most newly reached municipalities depend on a single transfer station: 61.8% use only one, and 69.8% route at least 90% of their journeys through one. Czech and Hungarian municipalities mostly change trains at stations in their own country.

Bratislava is the only transfer station used by all four neighboring EU countries. It is the sole gateway for the Upper Silesian cities (Katowice, Sosnowiec, Tychy and Dąbrowa Górnicza; 806,048 inhabitants in eight Polish municipalities) and for Tyrolean and border towns in Austria (Kufstein, Wörgl, St. Anton am Arlberg, Kittsee and Marchegg). Graz, Bregenz and Lustenau, however, reach Košice only through Budapest. In eastern Slovakia, Poprad is the only gateway for the Polish spa town of Muszyna (11,012 inhabitants).

Journey time again grows with the distance along the route traveled (Figure 16a). The linear fit (0.76 min/km on a 94 min intercept) explains 91% of the variance. Against the shortest rail path, the fit is much looser (R^2 0.72), and Polish journeys lie more than four hours above it. Along the route actually traveled, however, they are close to the norm (+14 min on average), because trips from Warsaw, Kraków and Katowice detour via Bratislava or Olomouc: Warsaw is 1089 km away by that route but 587 km by the shortest rail path. Austrian journeys are on average 34 to 46 min faster than the norm, and those from western Austria are up to two hours faster (Salzburg −100 and Innsbruck

−146 min) (Figure 16a).

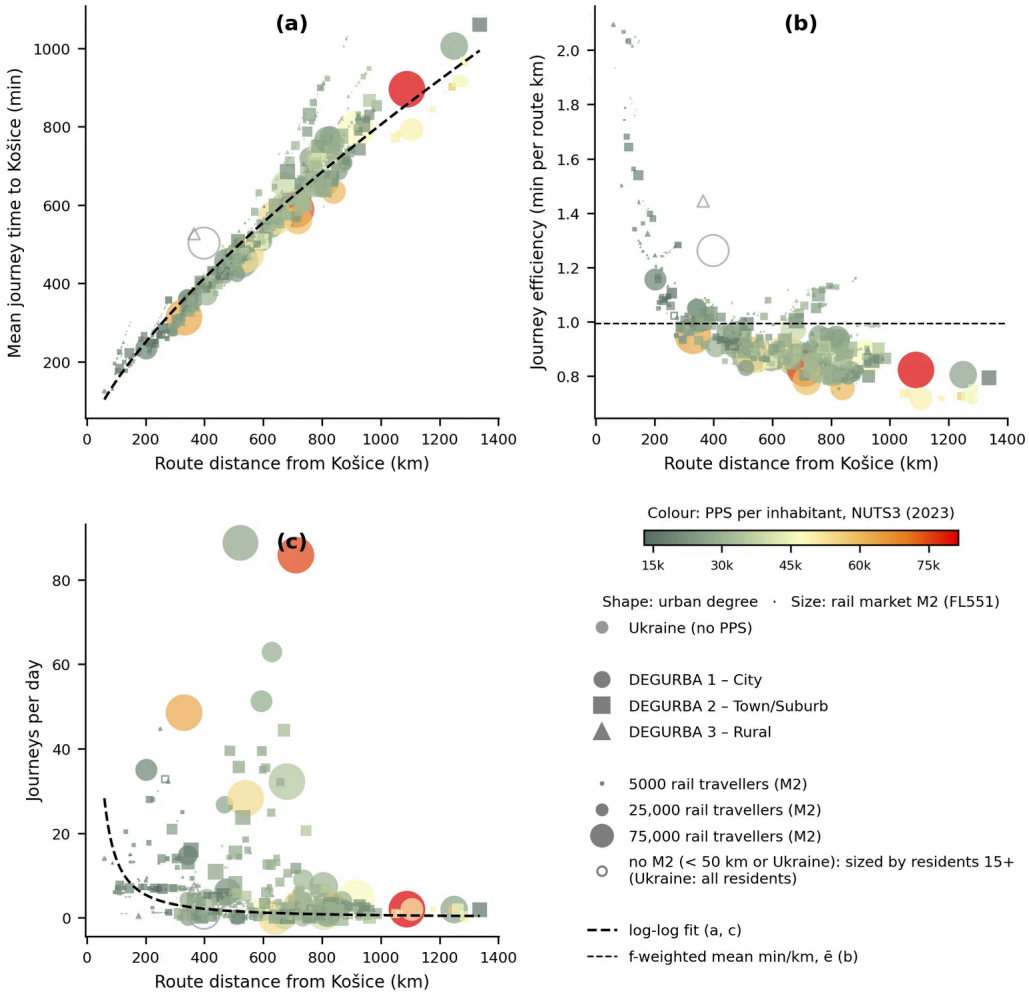


Figure 16. Base analysis of foreign single-transfer connectivity to Košice in terms of degree of urbanization, rail market size, regional purchasing power standard per capita, and route network distance in relation to (**a**) average journey time, (**b**) journey efficiency, and (**c**) average trips per day.

Journey efficiency declines with distance around a frequency-weighted network mean of 1.00 min/km (Figure 16b). The short cross-border itineraries from Hungary are the least efficient, averaging 1.80 min/km within 100 km of route, with a maximum of 2.09 at Méra. Beyond 300 km, the band means fall to 0.98, 0.91 and 0.87 min/km (Figure 16b).

One-transfer service is thin: 72.8% of the municipalities have fewer than five journeys a day, and 46.3% have fewer than two (Figure 16c). The Czech main corridor is served best (Ostrava 88.7, Prague 85.8, Pardubice 62.9 and Olomouc 51.2 journeys a day), followed by Budapest (48.5) and Vienna (28.3). The Polish cities have between one and five (Kraków 4.8, Warsaw 2.0 and Katowice 1.0) (Figure 16c).

For the 775 foreign municipalities reached with one transfer, journey time rises by 0.763 min per route kilometer (95% CI 0.742–0.784, *HC*3) on an intercept of 94.3 min (84.2–104.3), R^2 = 0.912. The linear form passes the specification rule (RESET p = 0.010), and a quadratic term is not significant (p = 0.07). With errors clustered by country (five clusters), the slope interval widens to 0.709–0.817. Country effects leave the slope at 0.756 and, relative to Austria, add 39.7 min for Czechia (8.7–70.8), 28.1 for Hungary (−1.7

to 58.0), 51.4 for Poland (17.0–85.9) and 164.1 for Ukraine (89.5–238.6). On shortest rail distance, the Polish premium rises to 296 min (212–380), which reflects the detour through the transfer hub rather than slow running. The slope is stable without the 25 cities (0.767) and without the five most influential municipalities (0.767). The residuals are strongly clustered in space (Moran's I = 0.71, p = 0.001; 0.59–0.76 for k = 3–10). A spatial error model gives 0.692 min/km (0.664–0.721; λ = 0.81), while a spatial lag model (ρ = 0.48) implies a total effect of 0.80 min/km. In a pooled model of the 802 directly or one-transfer connected foreign municipalities, a transfer adds 56.6 min at equal route distance (30.9–82.3; with country-clustered errors 14.7–98.4; with country effects 75.8, 58.0–93.7). For the 26 municipalities with both kinds of service, the one-transfer alternative is on average 168 min slower (median 183). Almost all of this extra time is explained by the extra distance (0.97 min per km of detour, CI 0.74–1.19; transfer intercept 13.2 min, CI −13.8 to 40.3). Frequency falls steeply with distance and is best described in logs, with an elasticity of −1.29 (−1.47 to −1.12, R^2 = 0.14), or −2.02 (−2.33 to −1.71) within countries. Population adds a small positive effect (0.20, CI 0.12–0.29; within countries 0.34, 0.25–0.42), and both survive a spatial error model (distance −1.48, CI −2.02 to −0.94; population 0.31, 0.25–0.38). The decline is strongest in Hungary (r = −0.63, CI −0.71 to −0.54) and weaker in Czechia (−0.30, −0.38 to −0.22). It is absent in Austria (−0.11, −0.45 to 0.26) and Poland (0.04, −0.39 to 0.47). Whether a foreign municipality with a station can be reached with one transfer at all depends only on distance (logit coefficient on log rail distance −1.12, CI −1.27 to −0.96; population −0.004, CI −0.06 to 0.05; pseudo-R^2 0.05). Doubling the distance roughly halves the odds ($2^{-1.12} \approx 0.46$).

The foreign municipalities reached only with a transfer hold 11.4 million residents aged 15 and over: Austria: 2,721,037; Czechia: 3,371,757; Hungary: 1,706,410; and Poland: 3,619,164. By the Flash Eurobarometer 551 rates, they contain rail markets (M2) of 1,356,596 in Austria (nominal interval 1,241,340–1,471,852), 1,995,045 in Czechia (1,852,948–2,137,142), 760,623 in Hungary (685,209–836,037), and 1,831,454 in Poland (1,676,417–1,986,490). The share of rail travelers who would accept a transfer differs by country: 68.6% in Czechia, 61.9% in Poland, 53.1% in Austria, and 47.7% in Hungary. The transfer-adjusted market (M3) is therefore 1,368,298 in Czechia, 1,134,484 in Poland, 719,799 in Austria, and 362,848 in Hungary: 3.59 million in total, twice the foreign direct market (1.81 million). Warsaw (503,682) and Vienna (463,818) contribute most, followed by Kraków (222,255), Brno (140,606), Katowice (75,982) and Graz (70,703). Almost none of this market is within reach of a short trip: nothing in Austria and 1.1% in Czechia within six hours; 1.0% in Poland; and in Hungary 1.3% within three hours, 7.7% within four and 39.9% within six. With exponential decay at a 120 min half-life, the effective market is 37,470 in Austria (5.2% of $M3$; 1.0% of the national rail market), 47,071 in Czechia (3.4%; 0.9%), 48,820 in Hungary (13.5%; 1.3%) and 13,008 in Poland (1.1%; 0.1%). At 240 min, the figures are 159,742, 238,991, 128,821 and 110,768 (4.1%, 4.3%, 3.5% and 0.7% of the national markets). Adding these to the direct services raises the effective market at a 120 min half-life from 77,912 to 124,982 in Czechia (+60%; 2.3% of the national rail market) and from 212,671 to 261,490 in Hungary (+23%; 7.2%). The catchments reached with a transfer also differ in income. The Polish one is much richer than its country (56,261 PPS per inhabitant against 29,284, ratio 1.92), and the Austrian one is slightly richer (52,924 against 46,439, 1.14), both dominated by the capitals. The Czech and Hungarian ones are poorer (0.83 and 0.76), because their capitals are already in the direct catchment. Car ownership is close to the national level except in Austria (449 against 566 cars per 1,000, ratio 0.79; Czechia 0.97, Hungary 0.99, Poland 1.03). Weighting the survey rates toward cities (1.2/1/0.8) changes the combined direct and one-transfer $M2$ by +9.9%/−9.6% in Czechia and +11.0%/−11.2% in Hungary.

3.5.3. Foreign Same-Day Visit

Across the border, a same-day rail visit to Košice is in practice possible only from Hungary. The rule is the same as in the domestic analysis: Arrive by 11:00, stay at least six hours, leave at 17:00 or later, and be home by 23:59. With direct trains, all ten Hungarian municipalities on the Košice–Miskolc–Budapest line qualify, with 1,865,994 inhabitants or 19.7% of Hungary's population, and the visit is possible on 275 of the 301 days of the Hungarian timetable (91.4%). No directly connected Czech or Ukrainian municipality qualifies. Prague (552 min each way) and Ostrava (334 min) are too far for a visit to fit into one day, and Uzhhorod and Mukachevo, although close, have too few trains to allow an arrival and a return on the same day.

Allowing one transfer in either direction extends same-day visits in Hungary to 75 municipalities with 2,504,582 inhabitants (26.4% of the population), 65 municipalities and 638,588 inhabitants more than with direct trains alone. This is 65.1% of the Hungarian population that can reach Košice by rail with at most one transfer. The catchment comprises three cities, Budapest, Miskolc and Nyíregyháza (1,929,119 inhabitants together), as well as 36 towns (504,983) and 36 rural municipalities (70,480). Geographically, it runs from Borsod-Abaúj-Zemplén county (32 municipalities, 302,676 inhabitants) along the northeastern corridor through Heves (15; 127,998) and Nógrád (8; 57,991) to Pest county (16; 157,122) and Budapest, and it also reaches Szolnok and Nyíregyháza. Most of these places allow the visit on 275 of 301 days, but it is less reliable from Nyíregyháza and Szolnok (180 days, 59.8%) and from Salgótarján (184 days, 61.1%). Debrecen (202,331 inhabitants), Győr and the western Hungarian cities have one-transfer connections but no same-day visit, because their fastest journeys take five to seven hours. In Czechia, a single village qualifies, Střelná in the Zlín region (539 inhabitants), on 300 of 364 days. Austria, Poland, and Ukraine have no same-day visits on any day, even with one transfer.

The Hungarian result depends on the length of the stay. A four-hour stay gives the same catchment as a six-hour one, but with an eight-hour stay, no Hungarian municipality qualifies by direct train or with a transfer because no return train leaves Košice late enough. By the Flash Eurobarometer 551 rates, the 75 Hungarian municipalities hold 973,498 rail travelers (M2) among their 2,186,475 residents aged 15 and over, and 846,065 of them would also accept a transfer (M3). This is about one and a half times the domestic same-day rail market outside Košice (837,000).

4. Discussion

The results carry several limitations, each of which biases them in a known direction. The survey conversion rate is an upper bound, as testing showed, so the rail-traveling population is a ceiling rather than a central estimate; a probability-sampled measure of leisure rail travel by distance band would replace it. The 32-day Polish window can only understate coverage of seasonal services and may overstate whatever ran in that month, so the Polish figures are bounds rather than estimates until the analysis can be rerun on a full-year Polish feed. The Ukrainian feed is derived from OpenStreetMap and has only 118 stops. The feeds also contain no data on fares, reliability, booking or capacity, and the analysis leaves out the first and last mile. Each of these would reduce effective access, so every figure here is an upper bound on practical reachability; the next step is to add access and egress legs on the street network.

Validation against official journey planners reproduced both direct and single-transfer journeys poorly. Of the 63 sampled Košice journeys, the planner offered the same trains within five minutes for 11, a comparable journey with a different transfer or at a different time for 32, and no matching journey for 20. Of the 73 sampled Bratislava jour-

neys, the planner offered the same trains within five minutes for 31, a comparable journey with a different transfer or at a different time for 16, and no matching journey for 26. The planner returned a result in 133 of the 136 cases, so the failures reflect disagreement about which trains run, not missing connections. The split by journey type is consistent across both destinations: 23 of 43 direct journeys reproduce exactly, compared with 19 of 93 single-transfer journeys. This is expected, since a transfer journey fails whenever either of its legs has moved. Most mismatches stem from the gap between the pinned snapshot and the live timetable rather than from how the itineraries were constructed. The planner routes through more legs than the computed itinerary in 44 cases.

The domestic results form a coherent pattern. Inbound journey time is an almost deterministic linear function of rail-network distance. Journey efficiency decays hyperbolically, with the steepest decay in the immediate hinterland. Service frequency follows the operational junctions more closely than distance or population size, both of which register only weakly ($r = -0.26$ and $r = 0.29$, together under 18% of the variance). The pipeline reproduces what earlier GTFS studies demonstrated [12–15] and partly extends the scope of intra-urban, single-feed studies to a multi-feed, cross-border setting [13,15,31].

Košice's domestic profile is that of a local regional hub. Direct connections open the city to municipalities holding 27.25% of the national population, yet almost four-fifths of the directly connected stations lie in the economically weaker region of Eastern Slovakia. A third of the directly connected population from the economically stronger part of the country depends on the 5.5 h main line from Bratislava.

A single transfer turns this corridor into a national network that covers 56.0% of the domestic population. At a population-weighted mean journey time of 328 min, however, most potential domestic markets lie beyond a feasible day trip. The pattern mirrors the finding of Székely et al. (2023), from the residents' perspective, that a car-free same-day visit to the regional seat is not feasible from many peripheral municipalities [27]. The weakness of the domestic single-transfer network is its gateway dependence: 68.5% of the municipalities newly reached by one transfer depend on a single transfer station.

Direct international service consists of two main lines to the Czech and Hungarian capitals and a fragment serving three Ukrainian stations, while Poland and Austria have no direct service. With one transfer, the modeled transfer penalty is 56.6 min when the five countries are pooled and 75.8 min once country effects are absorbed; journeys from Poland take more than four hours longer than the norm, and most connections depend on distant Bratislava. The Polish results support Kołodziejczyk's (2020) assessment of the Polish–Czech borderland that poorly coordinated cross-border timetables cut destinations off from visitors without a car [28].

The gap between Hungary and Czechia, which have direct service, and Poland and Austria, which do not, is arguably the more consequential, because, as Gutiérrez et al. (2019) showed, a direct connection weighs more heavily in tourists' choices [25]. Earlier studies linked rail connectivity to growth in tourism demand and to lower seasonality, with the strongest effects in small and medium-sized destinations [20–23]. For Košice, such effects would require systematic improvements in speed and service frequency that the corridors profiled here do not offer. Whereas many studies estimate connectivity effects after the fact [17–22,23,24], the approach demonstrated here provides an ex ante baseline for potential interventions.

Nine years after the adoption of Delegated Regulation (EU) 2017/1926 [3,4], machine-readable data still do not necessarily meet the criteria of analyzable data, and the main gaps concentrate on cross-border services, precisely those that the new EU sustainable-tourism agenda singles out for growth [1,2]. Dedicated EU-level mapping does not close the gap either. The European Commission's inventory of cross-border public-trans-

port routes in border regions omits small Slovak gateway towns for which their role exceeds their size, such as Snina, the urban gateway to Poloniny National Park [83].

The findings agree with single-feed GTFS studies that timetables alone reveal how a national rail system is organized [16], but they depart from that literature in two respects. First, in cross-border analysis, feed availability and cross-feed station identity matter more than any methodological choice made downstream of them. About half of the inbound single-transfer catchment in Czechia (53.5%) and Hungary (50.4%) exists only because the national feed was loaded, and none of the seven feeds came from an official national open-data portal. Second, converting a population catchment into a behavioral quantity shrinks it about sixfold while leaving within-country shares unchanged. This study extends the literature by implementing the two layers that routing engines presuppose: reconciliation of stations across feeds and a harmonized statistical geography to which population can be attached.

For age structure, the conversion rate is 50.7% for ages 15–64 and 48.8% for 65+, and Slovakia is the only one of the five countries with no detectable gradient (−1.9 points, interval −10.2 to +6.3). This reflects data resolution rather than a null effect. The steep gradient lies within the working-age range, where the municipal statistics provide one age band and the survey five, so the binding constraint is the population data, not the survey instrument. Fares are not modeled, but Slovaks are the least cost-sensitive population in the EU-27 when planning journeys (44% against 61%). Five determinants remain open: destination preference, first- and last-mile access, service reliability, border effects, and the composition of the travel party.

Because a destination's inbound and outbound reach can only be measured fully with a multimodal approach, the rail analysis will be combined with earlier work on Košice's road and air connectivity, extended to coach services [84]. A further strand of work is a multimodal transport model that assumes an adjusted rail timetable and a complete highway network connecting Košice directly with Poland, Austria and Ukraine. Such a scenario could address an open question: would Košice benefit more from these links or would the economically weaker neighboring regions?

5. Conclusions

The answers to the four research questions are as follows. RQ1: Open rail timetables were available for all six countries. Only the Slovak and Austrian feeds originate from official open-data portals, and all were obtained through community-maintained aggregators. The analysis windows range from 364 days (Slovakia, Czechia, Ukraine) to 32 days for the all-carrier Polish feed; the Ukrainian feed covers only the three places nearest the border. Loading the national feeds accounts for 53.5% of the Czech, 50.4% of the Hungarian, 34.9% of the Polish, and 14.1% of the Austrian single-transfer catchment. RQ2: Municipalities holding 27.2% of the Slovak base population reach Košice by direct train and 56.0% by a direct train or with one transfer at a transfer penalty of 63.1 min at equal route distance. A same-day return is possible on at least 90% of days for only 15.8%. RQ3: Purchasing power describes who the network reaches, not how much demand it carries. Direct connections reach places wealthier than the national average (1.23 times in Slovakia, 1.69 in Czechia and 2.01 in Hungary), while the single-transfer extension reaches poorer ones (0.95, 0.83 and 0.76). RQ4: Within the available feeds, the inbound cross-border catchment, direct or with one transfer, is 6,068,419 residents in Czechia, 4,193,156 in Poland, 3,844,552 in Hungary, 3,160,473 in Austria, and 240,896 in Ukraine. Of the foreign municipalities newly reached with one transfer, 64.4% depend on a single transfer station.

The methodological contribution is a single reproducible workflow that integrates

multi-feed harmonization, cross-border station matching, and the attachment of municipal population and degree of urbanization. The contribution does not lie in transfer construction, which established routing engines do better.

Empirically, the cascade runs from 5,187,121 Slovak residents to 2,907,245 with a rail connection, 2,132,571 who can make a same-day return, and an expected 837,001 rail travellers (M2; nominal interval 761,711–912,290) among their residents aged 15 and over who live more than 50 km by rail from Košice. Gateway dependence on the strict definition is 68.5% in the domestic and 64.4% in the foreign single-transfer network; the transfer penalty is roughly one hour, and feed availability, rather than railway geography, accounts for between a third and just over half of the measured Czech, Hungarian and Polish catchments.

The results provide a supply-side connectivity baseline under stated feed conditions. They do not measure tourism demand. Future work should hand the routing step to an established engine while keeping the harmonization and opportunity layers and should extend the pipeline to destinations with structured differently feeds.

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Data Availability Statement: The analysis code, environment specification, configuration files, the complete station-match table, the manual override files, and the feed manifest are available at https://github.com/csabasidor/traintranv2(accessed on 17 November 2026).

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Abbreviations

The following abbreviations are used in this manuscript:

API	Application Programming Interface
CRS	Coordinate Reference System
DEGURBA	Degree of Urbanization
DMO	Destination Management Organisation

EPSG	European Petroleum Survey Group (spatial reference identifier)
EU	European Union
EUR	Euro
GDP	Gross Domestic Product
GIS	Geographic Information System
GTFS	General Transit Feed Specification
HSR	High-Speed Rail
km	Kilometer
LAU	Local Administrative Unit
LAU2	Local Administrative Unit, level 2
Mil	Million
MOTIS	Multi-Objective Travel Information System (Routing Engine)
NUTS	Nomenclature of Territorial Units for Statistics
NUTS2	Nomenclature of Territorial Units for Statistics, Level 2
NUTS3	Nomenclature of Territorial Units for Statistics, Level 3
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PKP	Polskie Koleje Państwowe (Polish State Railways)
PKP PLK	PKP Polskie Linie Kolejowe (Polish Rail Infrastructure Manager)
PPS	Purchasing Power Standard
RQ1–RQ3	Research Questions 1 to 3
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
URI	Uniform Resource Identifier

References

1. European Parliament. European Parliament Resolution of 28 April 2026 on Enhancing Connectivity, Preserving Cultural Heritage, and Driving Local Excellence in European Tourism: Destination Management and Regional Tourism Growth (2025/2120(INI)) (P10_TA(2026)0123). 2026. Available online: https://www.europarl.europa.eu/doceo/document/TA-10-2026-0123_EN.html (accessed on 1 May 2026). [Google Scholar]
2. European Parliament. Procedure File 2025/2120(INI): Enhancing Connectivity, Preserving Cultural Heritage, and Driving Local Excellence in European Tourism: Destination Management and Regional Tourism Growth. Legislative Observatory. 2026. Available online: https://oeil.europarl.europa.eu/oeil/en/procedure-file?reference=2025/2120(INI) (accessed on 2 May 2026). [Google Scholar]
3. European Commission. Commission Delegated Regulation (EU) 2017/1926 of 31 May 2017 Supplementing Directive 2010/40/EU of the European Parliament and of the Council with Regard to the Provision of EU-Wide Multimodal Travel Information Services (OJ L 272, pp. 1–13). 2017. Available online: http://data.europa.eu/eli/reg_del/2017/1926/oj (accessed on 2 May 2026). [Google Scholar]
4. European Parliament; Council of the European Union. Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the Framework for the Deployment of Intelligent Transport Systems in the field of road transport and for

Interfaces with Other Modes of Transport (OJ L 207, pp. 1–13). 2010. Available online: http://data.europa.eu/eli/dir/2010/40/oj (accessed on 2 May 2026). [Google Scholar]
5. Hansen, W.G. How accessibility shapes land use. *J. Am. Inst. Plan.* **1959**, *25*, 73–76. [Google Scholar] [CrossRef]
6. Geurs, K.T.; van Wee, B. Accessibility evaluation of land-use and transport strategies: Review and research directions. *J. Transp. Geogr.* **2004**, *12*, 127–140. [Google Scholar] [CrossRef]
7. Shen, Q. Location characteristics of inner-city neighbourhoods and employment accessibility of low-wage workers. *Environ. Plan. B Plan. Des.* **1998**, *25*, 345–365. [Google Scholar] [CrossRef]
8. Hägerstrand, T. What about people in regional science? *Pap. Reg. Sci. Assoc.* **1970**, *24*, 7–21. [Google Scholar] [CrossRef]
9. Kwan, M.-P. Space–time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geogr. Anal.* **1998**, *30*, 191–216. [Google Scholar] [CrossRef]
10. Ben-Akiva, M.; Lerman, S.R. Disaggregate travel and mobility choice models and measures of accessibility. In *Behavioural Travel Modelling*; Hensher, D.A., Stopher, P.R., Eds.; Croom Helm: Kent, UK, 1979; pp. 654–679. [Google Scholar]
11. Handy, S.L.; Niemeier, D.A. Measuring accessibility: An exploration of issues and alternatives. *Environ. Plan. A* **1997**, *29*, 1175–1194. [Google Scholar] [CrossRef]
12. Vannacci, L.; Tartaglia, M.; Navajas Cawood, E.; Rotoli, F. The use of open data for estimating rail accessibility in Europe. *Ing. Ferrov.* **2015**, *70*, 611–634. [Google Scholar]
13. Pourramazani, H.; Gielen, E.; Miralles-Garcia, J.L. Equity-oriented public transport accessibility analysis using GTFS, spatial proximity, and demographic sensitivity. *Sustainability* **2026**, *18*, 4506. [Google Scholar] [CrossRef]
14. Luo, D.; Cats, O.; van Lint, H.; Currie, G. Integrating network science and public transport accessibility analysis for comparative assessment. *J. Transp. Geogr.* **2019**, *80*, 102505. [Google Scholar] [CrossRef]
15. Kujala, R.; Weckström, C.; Mladenović, M.N.; Saramäki, J. Travel times and transfers in public transport: Comprehensive accessibility analysis based on Pareto-optimal journeys. *Comput. Environ. Urban Syst.* **2018**, *67*, 41–54. [Google Scholar] [CrossRef]
16. Huang, Y.; Lu, S.; Yang, X.; Zhao, Z. Exploring railway network dynamics in China from 2008 to 2017. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 320. [Google Scholar] [CrossRef]
17. Campa, J.L.; López-Lambas, M.E.; Guirao, B. High speed rail effects on tourism: Spanish empirical evidence derived from China's modelling experience. *J. Transp. Geogr.* **2016**, *57*, 44–54. [Google Scholar] [CrossRef] [PubMed]
18. Chen, Z.; Haynes, K.E. Impact of high-speed rail on international tourism demand in China. *Appl. Econ. Lett.* **2015**, *22*, 57–60. [Google Scholar] [CrossRef]
19. Campa, J.L.; Pagliara, F.; López-Lambas, M.E.; Arce, R.; Guirao, B. Impact of high-speed rail on cultural tourism development: The experience of the Spanish museums and monuments. *Sustainability* **2019**, *11*, 5845. [Google Scholar] [CrossRef]
20. Boto-García, D.; Pérez, L. The effect of high-speed rail connectivity and accessibility on tourism seasonality. *J. Transp. Geogr.* **2023**, *107*, 103546. [Google Scholar] [CrossRef]
21. Li, L.S.Z.; Yang, F.X.; Cui, C. High-speed rail and tourism in China: An urban agglomeration perspective. *Int. J. Tour. Res.* **2019**, *21*, 45–60. [Google Scholar] [CrossRef]
22. Hou, X. High-speed railway and city tourism in China: A quasi-experimental study on HSR operation. *Sustainability* **2019**, *11*, 1512. [Google Scholar] [CrossRef]
23. Zhou, X.; Chen, S.; Zhang, H. Travel on the road: Does China's high-speed rail promote local tourism? *Environ. Sci. Pollut. Res.* **2023**, *30*, 501–514. [Google Scholar] [CrossRef] [PubMed]
24. Yin, P.; Lin, Z.; Prideaux, B. The impact of high-speed railway on tourism spatial structures between two adjoining metropolitan cities: Beijing and Tianjin. *J. Transp. Geogr.* **2019**, *80*, 102495. [Google Scholar] [CrossRef] [PubMed]
25. Gutiérrez, A.; Miravet, D.; Saladié, Ò.; Anton Clavé, S. Transport mode choice by tourists transferring from a peripheral high-speed rail station to their destinations: Empirical evidence from Costa Daurada. *Sustainability* **2019**, *11*, 3200. [Google Scholar] [CrossRef]
26. Szymańska, E.; Panfiluk, E.; Kiryluk, H. Innovative solutions for the development of sustainable transport and improvement of the tourist accessibility of peripheral areas: The case of the Białowieża Forest region. *Sustainability* **2021**, *13*, 2381. [Google Scholar] [CrossRef]
27. Székely, V.; Novotný, J.; Michniak, D. Without a car and overnight stay, can a visit to a regional centre be an unattainable goal in Slovakia? *Eur. XXI* **2023**, *44*, 141–160. [Google Scholar] [CrossRef]
28. Kołodziejczyk, K. Cross-border public transport between Poland and Czechia and the development of the tourism functions of the region. *Geogr. Pol.* **2020**, *93*, 261–285. [Google Scholar] [CrossRef]

29. Wendt, J.A.; Grama, V.; Ilieş, G.; Mikhaylov, A.S.; Borza, S.G.; Herman, G.V.; Bógdał-Brzezińska, A. Transport infrastructure and political factors as determinants of tourism development in the cross-border region of Bihor and Maramureş: A comparative analysis. *Sustainability* **2021**, *13*, 5385. [Google Scholar] [CrossRef]
30. Masiero, L.; Hrankai, R. Modeling tourist accessibility to peripheral attractions. *Ann. Tour. Res.* **2022**, *92*, 103343. [Google Scholar] [CrossRef]
31. Moragues, A.; Seguí-Pons, J.M.; Ruiz-Pérez, M. Equity in public transportation systems in tourist cities: A comparative study of Palma and Málaga (Spain). In *Advances in Transdisciplinary Engineering*; IOS Press: Amsterdam, The Netherlands, 2024; Volume 63. [Google Scholar] [CrossRef]
32. Delling, D.; Pajor, T.; Werneck, R.F. Round-based public transit routing. *Transp. Sci.* **2015**, *49*, 591–604. [Google Scholar] [CrossRef]
33. OpenTripPlanner. OpenTripPlanner 2 Documentation. n.d. Available online: https://docs.opentripplanner.org/en/latest/ (accessed on 18 November 2026).
34. Pereira, R.H.M.; Saraiva, M.; Herszenhut, D.; Braga, C.K.V.; Conway, M.W. r5r: Rapid realistic routing on multimodal transport networks with R5 in R. *Findings* **2021**. [Google Scholar] [CrossRef]
35. European Union. The Official Portal for European Data [Data Portal]. data.europa.eu. n.d. Available online: https://data.europa.eu (accessed on 9 May 2026).
36. European Union. Datasets: GTFS Train Schedule Search Results [Data Set]. data.europa.eu. 2026. Available online: https://data.europa.eu/data/combined?locale=en&query=GTFS&page=1 (accessed on 9 May 2026). [Google Scholar]
37. Transitous. Sources [Data Set]. 2026. Available online: https://transitous.org/sources/ (accessed on 9 May 2026). [Google Scholar]
38. Železnice Slovenskej Republiky. Train Traffic Chart in GTFS Format [Data Set]. data.europa.eu. 2026. Available online: https://data.europa.eu/data/datasets/ca4cb74c-7192-4198-b074-34acd9d295e7?locale=en (accessed on 9 May 2026). [Google Scholar]
39. Železnice Slovenskej Republiky. Grafikon Vlakovej Dopravy vo Formáte GTFS [Train Traffic Chart in GTFS Format] [Data Set]. Národný Katalóg Otvorených Dát. 2026. Available online: https://data.slovensko.sk/datasety/ebeeedf1-aca2-451a-bdc0-35d536714888 (accessed on 9 May 2026). [Google Scholar]
40. Železnice Slovenskej Republiky. GTFS Info [Data Set]. 2019. Available online: https://www.zsr.sk/sluzby-verejnosti/pre-cestujucich/fgtfs-info (accessed on 9 May 2026). [Google Scholar]
41. Transitous. Železničná Spoločnosť Slovensko (ZSSK) [GTFS Data Set]. n.d. Available online: https://api.transitous.org/gtfs/ (accessed on 4 August 2026).
42. Österreichische Bundesbahnen. Soll Fahrplan [Planned Timetable] [Data Set]. data.europa.eu. 2019. Available online: https://data.europa.eu/data/datasets/919d40b2-031f-430e-bf6c-4183f6dc8b64?locale=en (accessed on 9 May 2026). [Google Scholar]
43. Österreichische Bundesbahnen. Soll Fahrplan [Planned Timetable] [Data Set]. data.gv.at. 2019. Available online: https://www.data.gv.at/datasets/919d40b2-031f-430e-bf6c-4183f6dc8b64?locale=de (accessed on 9 May 2026). [Google Scholar]
44. Österreichische Bundesbahnen. Soll-Fahrplan GTFS [Planned Timetable GTFS] [Data Set]. 2026. Available online: https://data.oebb.at/de/datensaetze~soll-fahrplan-gtfs~ (accessed on 9 May 2026). [Google Scholar]
45. Transitous. Austrian Railway Current Reference Data 2026 [GTFS Data Set]. n.d. Available online: https://api.transitous.org/gtfs/at_Railway-Current-Reference-Data-2026.gtfs.zip (accessed on 4 August 2026).
46. Ministerstvo Dopravy České Republiky. [Public Transport Timetables in the CIS JŘ, NeTEx Format] [Data Set]. data.europa.eu. 2026. Available online: https://data.europa.eu/data/datasets/https-data-gov-cz-zdroj-datove-sady-66003008-1224193768?locale=en (accessed on 9 May 2026). [Google Scholar]
47. Ministerstvo Dopravy České Republiky. [Public Transport Timetables in the CIS JŘ, NeTEx Format] [Data Set]. Národní Katalog Otevřených Dat. 2026. Available online: https://data.gov.cz/dataset?iri=https%3A%2F%2Fdata.gov.cz%2Fzdroj%2Fdatov%C3%A9-sady%2F66003008%2F1224193768 (accessed on 9 May 2026). [Google Scholar]
48. Ministerstvo dopravy České Republiky. Celostátní Informační Systém o Jízdních Řádech (CIS JŘ) [National Information System on Timetables]. 2026. Available online: https://portal.cisjr.cz/ (accessed on 9 May 2026). [Google Scholar]
49. Transitous. Czech Rail (CZPTT) [GTFS Data Set]. n.d. Available online: https://api.transitous.org/gtfs/cz_CZPTT.gtfs.zip (accessed on 4 August 2026).
50. MÁV-START Zrt. [Hungarian Passenger Rail Timetable Dataset] [Data Set]. data.europa.eu. 2026. Available online: https://data.europa.eu/data/datasets/aceaa4d9-cf8b-4bf3-8828-29827a274674?locale=en (accessed on 9 May 2026). [Google Scholar]

51. MÁV-START Zrt. Belföldi és Nemzetközi Személyszállító Vonatok Összeállítási Rendje (SzVÖR) [Composition Order of Domestic and International Passenger Trains] [Data Set]. Nemzeti Adatportál. 2026. Available online: https://kozadatportal.hu/en/dataset/74941842-cf42-4722-961d-8ec5b8237de0 (accessed on 9 May 2026). [Google Scholar]
52. MÁV-Csoport. GTFS Request. 2026. Available online: https://www.mavcsoport.hu/en/gtfs-request (accessed on 9 May 2026). [Google Scholar]
53. Transitous. MÁV (Hungary) [GTFS Data Set]. n.d. Available online: https://api.transitous.org/gtfs/hu_mav.gtfs.zip (accessed on 4 August 2026).
54. European Union. Transport Datasets for Poland: GTFS Search Results [Data Set]. data.europa.eu. 2026. Available online: https://data.europa.eu/data/datasets?locale=en&categories=TRAN&page=1&dataScope=countryData&country=pl&limit=50&query=gtfs (accessed on 9 May 2026). [Google Scholar]
55. Ministerstwo Cyfryzacji. Krajowy Punkt Dostępowy (KPD): Multimodalne Usługi Informacji o Podróżach [National Access Point (NAP): Multimodal Travel Information Services] [Data Set]. dane.gov.pl. 2026. Available online: https://dane.gov.pl/en/dataset/1739,NAP/resource/2194098/table?page=1&per_page=20&q=&sort= (accessed on 9 May 2026). [Google Scholar]
56. Kasznia. Polish Trains [GTFS Data Set]. GTFS kasznia.net. n.d. Available online: https://gtfs.kasznia.net/static/polish-trains.zip (accessed on 4 August 2026).
57. Ministry of Digital Transformation of Ukraine. Open Data Portal of Ukraine. n.d. Available online: chttps://data.gov.ua (accessed on 4 August 2026).
58. Ukrainian Railways. Ukrzaliznytsia [Official Website]. n.d. Available online: https://www.uz.gov.ua/ (accessed on 4 August 2026).
59. Transitous. Ukrzaliznytsia (Ukraine) [GTFS Data Set]. n.d. Available online: https://api.transitous.org/gtfs/ua_ukrzaliznytsya.gtfs.zip (accessed on 4 August 2026).
60. Koňařík, D. JrUtil [Computer Software]. GitLab. 2026. Available online: https://gitlab.com/dvdkon/jrutil (accessed on day month year). [Google Scholar]
61. Kuranowski, M.; Kasznia, M. PolishTrainsGTFS [Computer Software]. GitHub. 2026. Available online: https://github.com/MKuranowski/PolishTrainsGTFS (accessed on day month year). [Google Scholar]
62. Brüchert, J. Generating GTFS Feeds [Blog Post]. Available online: https://jbb.ghsq.de/kde/2026/02/07/Generating-GTFS-Feeds.html (accessed on 9 May 2026).
63. Eurostat. Local Administrative Units (LAU) [Data Set]. European Commission. 2024. Available online: https://ec.europa.eu/eurostat/web/gisco/geodata/statistical-units/local-administrative-units (accessed on day month year). [Google Scholar]
64. Eurostat. Degree of Urbanisation (DEGURBA) [Data Set]. European Commission. 2021. Available online: https://ec.europa.eu/eurostat/web/gisco/geodata/population-distribution/degree-urbanisation (accessed on day month year). [Google Scholar]
65. Eurostat. LAU—NUTS 2024, EU-27 and EFTA/Available Candidate Countries [Data Set]. European Commission. 2024. Available online: https://ec.europa.eu/eurostat/web/nuts/local-administrative-units (accessed on day month year). [Google Scholar]
66. Eurostat. Gross Domestic Product (GDP) at Current Market Prices by NUTS 3 Region (nama_10r_3gdp) [Data Set]. European Commission. n.d. Available online: https://ec.europa.eu/eurostat/databrowser/view/nama_10r_3gdp__custom_15402261/default/table?lang=en (accessed on 4 August 2026).
67. OCHA Field Information Services Section. Ukraine—Subnational Administrative Boundaries [Data Set]. Humanitarian Data Exchange. 2025. Available online: https://data.humdata.org/dataset/cod-ab-ukr (accessed on 4 August 2026). [Google Scholar]
68. State Statistics Service of Ukraine. Chyselnist Naiavnoho Naselennia za Otsinkoiu po Rehionakh, Raionakh, Terytorialnykh Hromadakh [Estimated Resident Population by Region, District and Territorial Community] [Data Set]. Open Data Portal of Ukraine. n.d. Available online: https://data.gov.ua/dataset/46ca2741-b4e8-4939-98ec-83199de5e502 (accessed on 4 August 2026).
69. WorldPop. Degree of Urbanisation (DEGURBA) [Data Set]. University of Southampton. n.d. Available online: https://hub.worldpop.org/geodata/summary?id=125970 (accessed on 4 August 2026).
70. State Statistics Service of Ukraine. *Valovyi Rehionalnyi Produkt u Faktychnykh Tsinakh, mln hrn* [Gross Regional Product at Current Prices, Million UAH] [Data Set]. Open Data Portal of Ukraine. n.d. Available online: https://data.gov.ua/dataset/b5b74954-eb45-4e0b-bdf0-273a881b636e (accessed on 4 August 2026).
71. Český Statistický Úřad. Počet Obyvatel Podle Pohlaví a Základních Věkových Skupin k 1. 1.; 1. 7. a 31. 12. [Population by Sex and Basic Age Groups as at 1 January, 1 July and 31 December] (OBY02ET01) [Data Set]. 2026. Available online: https://data.csu.gov.cz/datastat/data/VYBER/OBY02ET01?vSet=4&vSel=1 (accessed on day month year). [Google Scholar]

72. Központi Statisztikai Hivatal. Éves Településstatisztikai Adatok 2025-Ös Településszerkezetben [Annual Settlement Statistics in the 2025 Settlement Structure] (TA2025_W, Indicators TAAA101, TAAA107, TAAA110, TAAA111) [Data Set]. 2026. Available online: https://statinfo.ksh.hu/Statinfo/themeSelector.jsp?lang=hu (accessed on day month year). [Google Scholar]
73. Statistics Poland. Population. Size and Structure and Vital Statistics in Poland by Territorial Division, as of 31 December 2025 (Table 12) [Data Set]. 2026. Available online: https://stat.gov.pl/en/topics/population/population/population-size-and-structure-and-vital-statistics-in-poland-by-territorial-division-in-2025-as-of-31-december,3,39.html (accessed on day month year). [Google Scholar]
74. Statistik Austria. Bevölkerungsstand zu Jahresbeginn 2026 [Population at the Beginning of the Year 2026] (OGD_bevstandjbab2002_BevStand_2026) [Data Set]. 2026. Available online: https://data.statistik.gv.at/web/meta.jsp?dataset=OGD_bevstandjbab2002_BevStand_2026 (accessed on day month year). [Google Scholar]
75. Štatistický Úrad Slovenskej Republiky. Vekové Skupiny—SR-Oblasť-Kraj-Okres-Obec [Age Groups—Slovak Republic, Region, County, District, Municipality] (om7006rr) [Data Set]. 2026. Available online: https://statdata.statistics.sk/public/api/dc/swagger-ui/index.html (accessed on day month year). [Google Scholar]
76. Statistical Office of the Slovak Republic. Návštevnosť, Tržby a Kapacity UZ—SR, Kraje, Okresy, Obce (13 Ukazovateľov) [Occupancy, Revenues and Capacities of Accommodation Establishments—Slovak Republic, Regions, Districts, Municipalities (13 Indicators)] (Table cr3805qr) [Data Set]. DATAcube. 2026. Available online: https://statdata.statistics.sk/public/api/dc/opendata/cube/dataset/cr3805qr (accessed on 9 November 2026). [Google Scholar]
77. Statistical Office of the Slovak Republic. Návštevnosť UZ—Okresy (Krajiny) [Occupancy of Accommodation Establishments—Districts (by Country of Origin)] (Table cr3804mr) [Data set]. DATAcube. 2026. Available online: https://statdata.statistics.sk/public/api/dc/opendata/cube/dataset/cr3804mr (accessed on 9 November 2026). [Google Scholar]
78. European Commission. *Flash Eurobarometer 499 (Attitudes of Europeans Towards Tourism)*, version 1.0.0, [Data Set] ed.; GESIS: Mannheim, Germany, 2022. [Google Scholar] [CrossRef]
79. European Commission. *Flash Eurobarometer 551 (Multimodal Digital Mobility Service)*, version 1.0.0, [Data Set] ed.; GESIS: Mannheim, Germany, 2025. [Google Scholar] [CrossRef]
80. Anthropic. Claude Code [Computer Software]. 2026. Available online: https://claude.com/product/claude-code (accessed on day month year). [Google Scholar]
81. Sidor, C. Traintranv2. Github Repositorry [Website]. 2026. Available online: https://idoaba.eu (accessed on 4 August 2026). [Google Scholar]
82. Eurostat. Stock of Vehicles by Category and NUTS 2 Region (tran_r_vehst) [Data Set]. 2026. Available online: https://ec.europa.eu/eurostat/databrowser/view/tran_r_vehst/default/table (accessed on 16 November 2026). [Google Scholar]
83. European Commission, Directorate-General for Regional and Urban Policy. Cross-Border Public Transport Routes and Services in EU Border Regions [Data Set]. data.europa.eu. 2022. Available online: https://data.europa.eu/data/datasets/cross-border-public-transport-routes-and-services-in-eu-border-regions (accessed on 4 August 2026). [Google Scholar]
84. Sidor, C.; Kršák, B.; Štrba, Ľ. Basic input data for audiences' geotargeting by destinations' partial accessibility: Notes from Slovakia. *Data* **2023**, *8*, 24. [Google Scholar] [CrossRef]

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