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Ecological Urban and
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Königsbrück / VVO

Linking Survey Data for Spatial Public Transit Analysis – Potentials, Relevant Data and Challenges

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Structure

- Background & Motivation
- Potentials
- Relevant data & studies
- Methodology
- Challenges
- Discussion

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Background & Motivation

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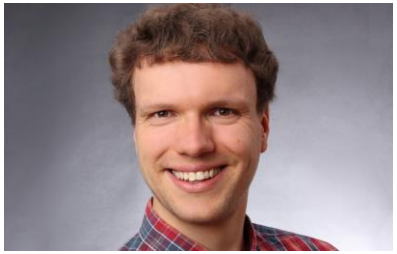
Personal background

Theodor Rieche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- Spatial scientist and cartographer
- Interests
  - Geographic Data Science & GeoAI
  - Data linking & Modelling of uncertainties
  - Open Data, VGI / OpenStreetMap, Open Source, Citizen Science
- Leibniz Institute of Ecological Urban and Regional Development (IOER)
  - Research Area „Spatial Information and Modelling“
  - Related research projects: SoRa+ and GOAT 3.0
- PhD started


IÖR Media

Introduction

Image, you plan to go from Ilmenau to Masserberg

(e.g. for swimming or hiking)

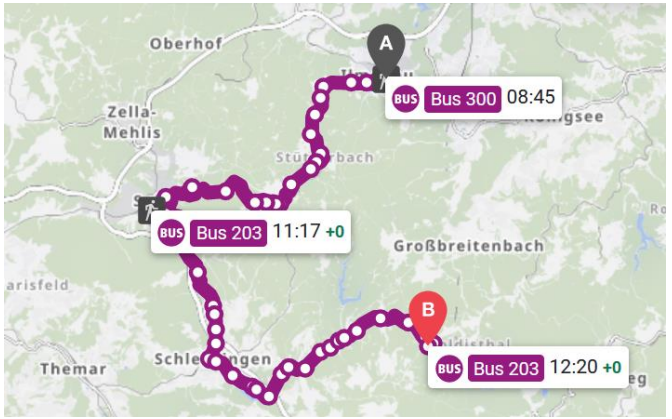
- By car: **31 min (25.2 km)**
- By bus: **at least 2 h 32 min (~ 65 km) via Suhl**

But from Ilmenau to Großbreitenbach (same county)

- By car: **26 min (18 km)**
- By bus: **34 min (18 km)**

Situation in Thuringian Forest region

- Bus often star-shaped network towards main town of each county
- Less cross-county lines
- Railway schedule is organised on federal state level



Kartendaten: © 2024 GeoBasis-DE/BKG (© 2009), Google Maps

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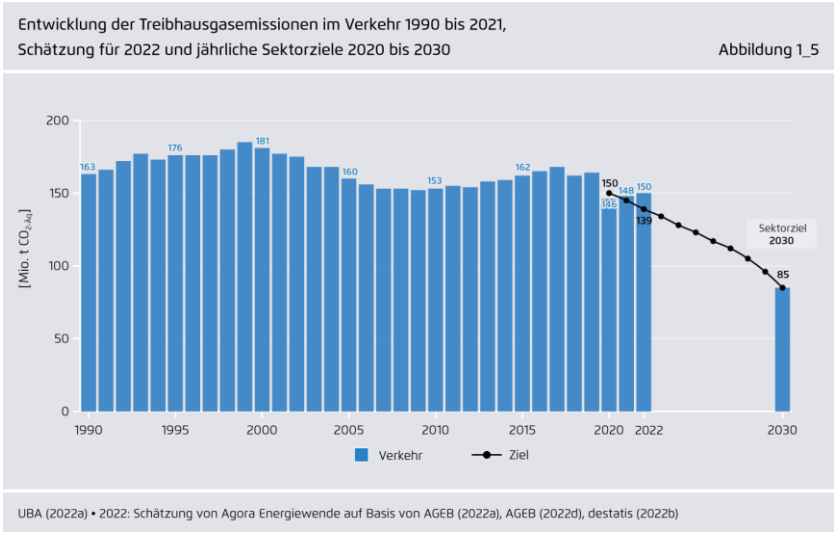
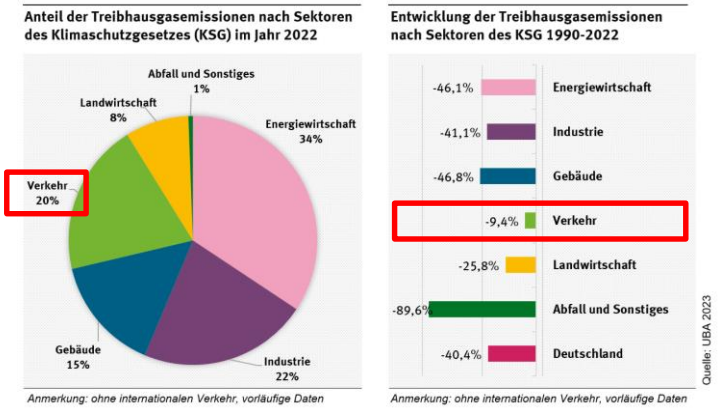
Political goals of mobility turnaround

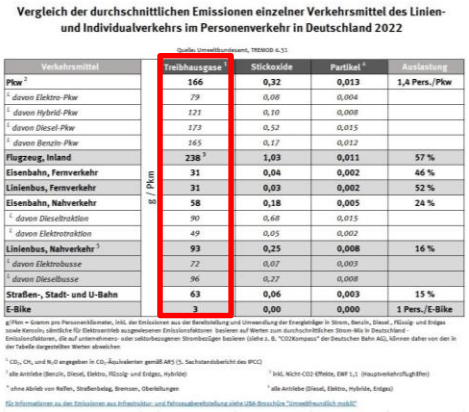
In order to reduce CO2 emissions



Development of greenhouse gas emissions for Germany in the transport sector (including goals until 2030) (UBA 2022a)



Share of greenhouse gas emissions for Germany in 2022 by sectors and its dynamics between 1990 and 2022 (UBA 2023)



Vergleich der durchschnittlichen Emissionen einzelner Verkehrsmittel des Linien- und Individualverkehrs im Personenverkehr in Deutschland 2022

Quelle: Umweltbundesamt, TREMOD 6.51

Verkehrsmittel	Treibhausgase [1]	Stickoxide	Partikel [1]	Auslastung
	g / Pkm			
Pkw [2]	166	0,32	0,013	1,4 Pers./Pkw
[1] davon Elektro-Pkw	79	0,08	0,004	
[1] davon Hybrid-Pkw	121	0,10	0,008	
[1] davon Diesel-Pkw	173	0,52	0,015	
[1] davon Benzin-Pkw	165	0,17	0,012	
Flugzeug, Inland	238 [3]	1,03	0,011	57 %
Eisenbahn, Fernverkehr	31	0,04	0,002	46 %
Linienbus, Fernverkehr	31	0,03	0,002	52 %
Eisenbahn, Nahverkehr	58	0,18	0,005	24 %
[1] davon Dieseltraktion	90	0,68	0,015	
[1] davon Elektrotraktion	49	0,05	0,002	
Linienbus, Nahverkehr [3]	93	0,25	0,008	16 %
[1] davon Elektrobusse	72	0,07	0,003	
[1] davon Dieselbusse	96	0,27	0,008	
Straßen-, Stadt- und U-Bahn	63	0,06	0,003	15 %
E-Bike	3	0,00	0,000	1 Pers./E-Bike

g Pkm = Gramm pro Personenkilometer, bzw. der Emissionen aus der Bereitstellung und Umwandlung der Energieträger in Strom, Benzin, Diesel , Flüssig- und Erdgas sowie Kerosin, sämtliche für Elektrizität ausgewiesenen Emissionsfaktoren basieren auf Werten zum durchschnittlichen Strom-Mix in Deutschland

Emissionsfaktoren, die auf unternehmens- oder sektorbezogenen Strombezügen basieren (siehe z. B. "CO2Kompass" der Deutschen Bahn AG), können daher von den in der Tabelle dargestellten Werten abweichen

[1] CO_2, CH_4, und N_2O angegeben in CO_2-Äquivalenten gemäß AR5 (5. Sachstandsbericht des IPCC)

[2] alle Antriebe (Benzin, Diesel, Elektro, Flüssig- und Erdgas, Hybrid)

[3] inkl. Nicht-CO2-Effekte, ENF 1,1 (Hauptverkehrsflughöhen)

[4] ohne Abrieb von Reifen, Straßenbelag, Bremsen, Oberleitungen

[5] alle Antriebe (Diesel, Elektro, Hybride, Erdgas)

Für Informationen zu den Emissionen aus Infrastruktur- und Fahrzeugherstellung siehe UBA-Broschüre "Umweltfreundlich mobil!"

Average greenhouse gas emission per passenger kilometer by transport mode (UBA 2022b)

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Borders of local public transit planning

- Many different actors of local public transit planning in Germany draw a heterogeneous picture
- Planning of service/schedule or pricing on different spatial levels:
  - County
  - Traffic association
  - Federal state
  - Country

→ planning organization leads to border areas

Verkehrsverbünde: Maximilian Dörrbecker (Chumwa), NJ Giggie, CC BY-SA 4.0 - Eigenes Werk

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Research questions

- Has defining (artificial) boundaries of local public transit planning an impact on the offered service?
- Does it have an impact for daily choice of transport mode (e.g. car or bus) or car density for the people living within the border areas?
- And who is living in those border areas?
  - socio-demographic or socio-economic variables

Potentials

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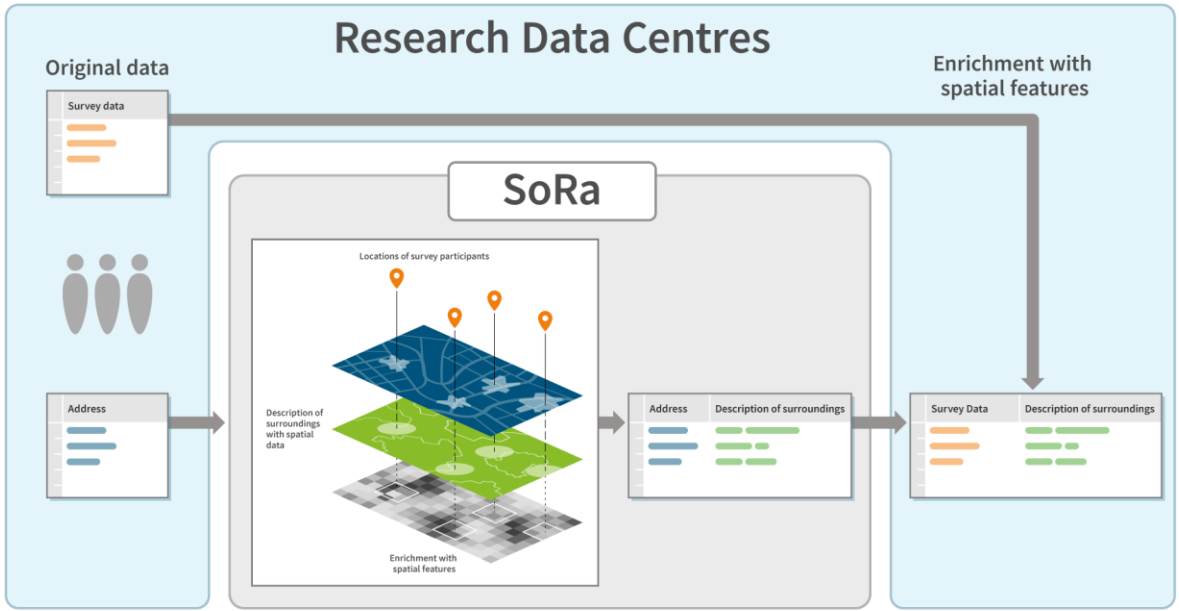
Potentials

- Long-term panel survey data exists, partly with small-scale spatial reference (like adress or INSPIRE grid cell)
- More and more spatial data is publicly available, such as schedule data including departures, stops, journeys per day
- German-wide small-scale spatial indicators are available (e.g. IOER Monitor)
- Linking to gain more precise small-scale understanding of aspects in mobility sector
- Comparing individual perspective with status quo from spatial data

Data linking of survey and spatial data

General approach in the Sora+ project



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Relevant data & studies

Relevant data & studies

Spatial data

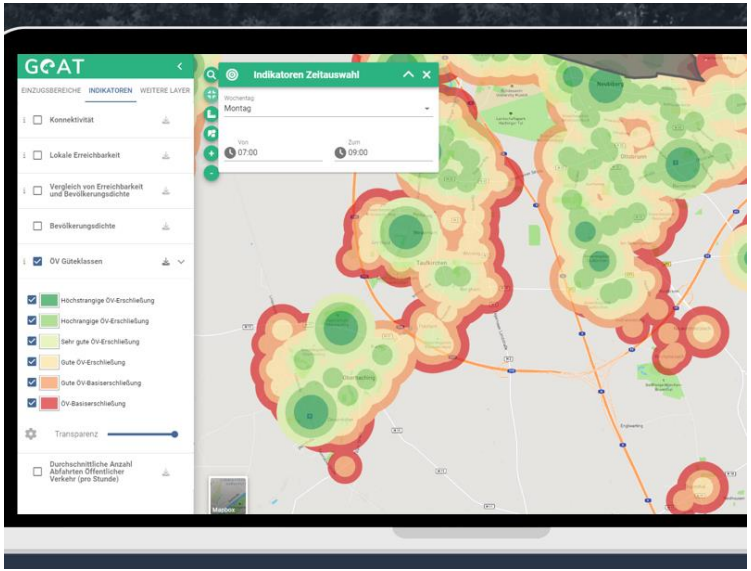
Dataset	A	B	C	D	E	F
						
Name	Deutschland gesamt / **schedule data in GTFS format**	**Public transit routes**	VG25 / **Administrative boundaries**	GeoGitter INSPIRE **Grid**	**POIs**	**Spatial indicators** from **IOER Monitor of Settlement and Open Space Development**
Provider	DELFI e.V.	OpenStreetMap	BKG	INSPIRE / BKG	OpenStreetMap, BKG	IOER Monitor
Spatial information	Stops as points	Polyline	Polygons	Polygons	POIs as points	Raster or Vector for whole Germany

Relevant data

Based on schedule data

Typical indicators:

- Acessibility of local public transit stops
- Frequency of services
- ÖV Güteklassen
- Operating period (from … to …)
- Number of trips per day
- Number of stops in admin unit
- Number of lines in admin unit
- Deriving disparities
- …



ÖV Güteklassen with frequency and accesibility / Plan4Better GmbH / GOAT 3.0

Literature:

Agora Verkehrswende; Nationalatlas 1999; Plan4Better / GOAT 3.0; Uddin (2022); Schlott (2022); Shkurti (2022); Sikder (2020); Zogg (2023)

Relevant studies

In the field of mobility turnaround

- Agora Verkehrswende
  - Public transit (ÖV) Atlas 2021, 2022 and 2023
  - 2023: Mobility guarantee in Germany
- BBSR
  - 2018: Accessibility quality of public transit
  - 2019: Accessibility of public transport stops
- Acatech / Plan4Better
  - 2023: Modal Split / Active mobility Munich / MVV

Relevant data & studies

Based on survey (or statistical) data

Panel data	Smallest spatial reference	Socio-demographic	Socio-economic	Satisfaction with local public transit	Daily choise of transport mode
ALLBUS (GESIS)	INSPIRE grid	X	X		
SOEP Core (SOEP Panel)	Adress	X	X		(X)
INKAR (BBSR)	County / Municipality	X	X		(X) Car density etc
Regionaldatenbank (destatis)	County / Municipality	X	X		(X) Car density etc
Census 2011 & 2022	100m grid	X			
Mobility in Germany (BMDV / DLR)	1km grid (not everywhere)	X			X
Environmental awareness in Germany (UBA)	Federal state + city size	X	X		X

State of the art

- Various indicators of local public transit are applied mostly on municipality or county level
- Focus often on frequency or accessibility of the service
- Cross-border traffic is less in focus
- German-wide small-scale spatial indicators are missing

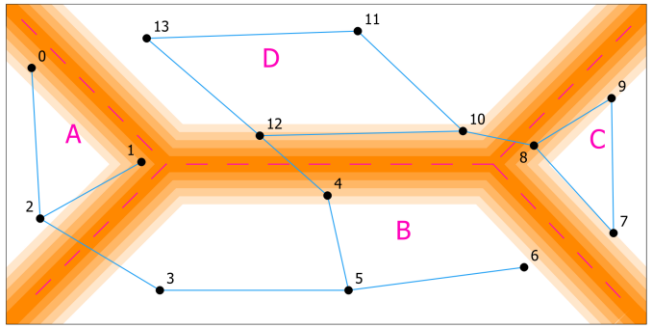
Methodology

Methodology

- Involving experts from mobility research and planning
- Creating spatial multi-level indicator
  - **Border area layer** (describing border areas)
  - **Connectivity layer** (analysing barriers in graph network)
  - **Destination / traveltime layer** (comparing reachable destinations / POIs by different transport mode e.g. private motor vehicle versus local public transit)
- Linking survey and spatial data using the SoRa approach
- Improve input data (e.g. POI data or schedule data)
- Model uncertainties in quantitative manner
- Test spatial indicators within model regions → later: Germany

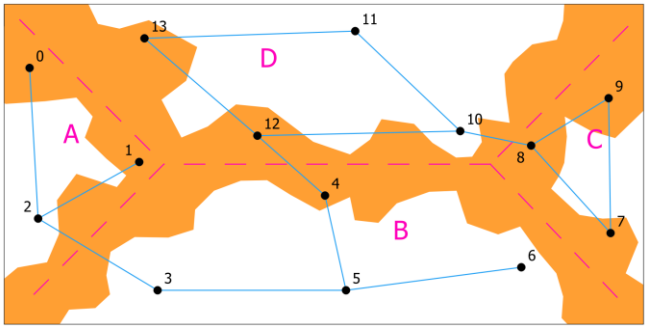
Dimension: Border area

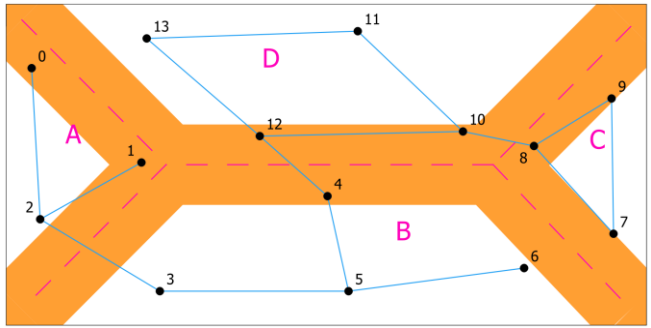
How to define the border area?



Buffer: graded border region with weighting ($0 \leq w \leq 1$)

(or using IDW to cover every area without gaps?)





Buffer: hard threshold

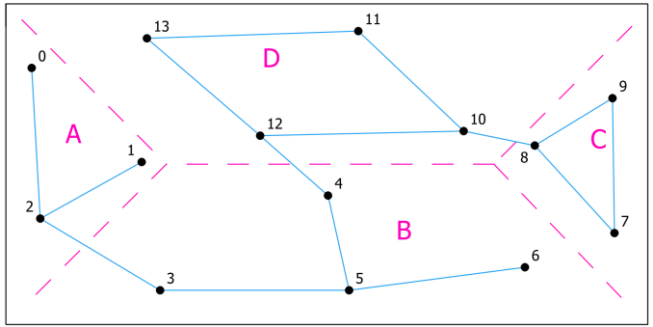
Using adjacent municipalities next to borders as a definition?

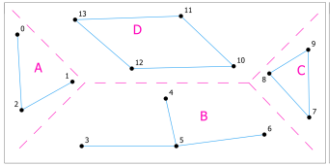
Border areas will be derived **for all relevant spatial levels**, e.g. counties, traffic associations, and federal states

stop — border — public transit route

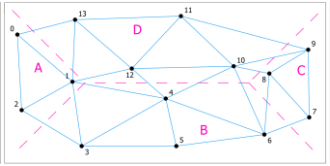
Dimension: Connectivity

How to detect gaps in a node-edge-model (graph theory)?

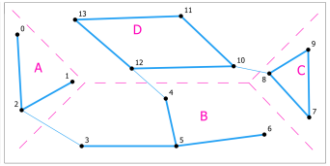




worst case
(no cross-border service)

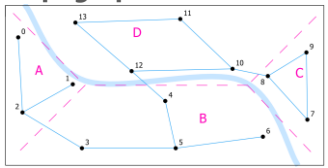


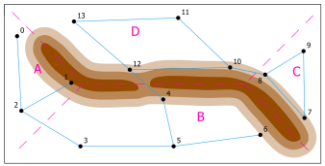
(almost) best case
(triangulation)



Low number of cross-border trips per day

Topographic barrier: rivers or mountains





Measures for cross-border services:

Edge (Public transit route)

- Crossing a border (yes/no)

Point (Stop)

- Ratio directly (without changing service) reachable stations in other areas versus all stops
- Number of adjacent edges

Comparison of two networks: public transit versus road network?

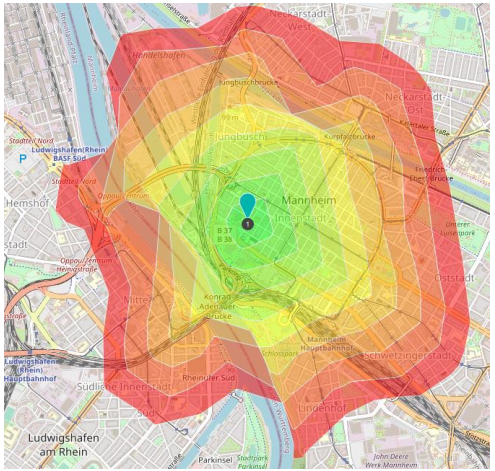
stop — border — public transit route

Dimension: Reachable destinations

Ratio of reachable destinations by different transport mode

- E.g. reachable POIs within one hour by car or local public transit
- As a measure to understand choise of transport mode
- Isochrones (profile: car or public transit)
- Could be derived in a small-scale raster grid
- POI data as relevant input (e.g. BKG, OSM)
  - Selection of POI type is still not defined

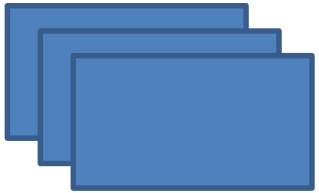
$$p = \frac{\sum reachable\ POIs\ by\ local\ public\ transit}{\sum reachable\ POIs\ by\ private\ motor\ vehicle}$$



https://openrouteservice.org/

Usage of SoRa workflow

For linking survey and spatial data



survey data, adressing …

- … daily choise transport mode
- … satisfaction with local public transit
- … socio-demography
- … socio-economy

And others

spatial data

Multi-level indicator containing multiple small-scale raster layer

- **Border area**
- **Connectivity**
- **Reachable destinations**

Analysing correlation to answer research questions

Challenges

Challenges

Important terms and its usage

- Data protection compliant processing → solution: SoRa data linking service
- Size of sample in survey data big enough? Representativeness?
- Positional accuracy / shift of survey data (if no adress data)
- From point to area: how to visualize survey data in a small-scale map without de-anonymize the survey participants?
  - Using dynamic buffer etc. based on population grid to keep statistical confidentiality?
  - Idea: detect changes of choise of transport mode or car density over time to explain it in spatial context?

Discussion

Discussion

Possible questions

- Further relevant georeferenced (survey) data for the analysis?
  - Hints for data of **Austria** or **Switzerland** to analyse cross-country region?
- How to define border areas related to planning borders?
- Any hints or further interesting aspects for my conceptional framework?

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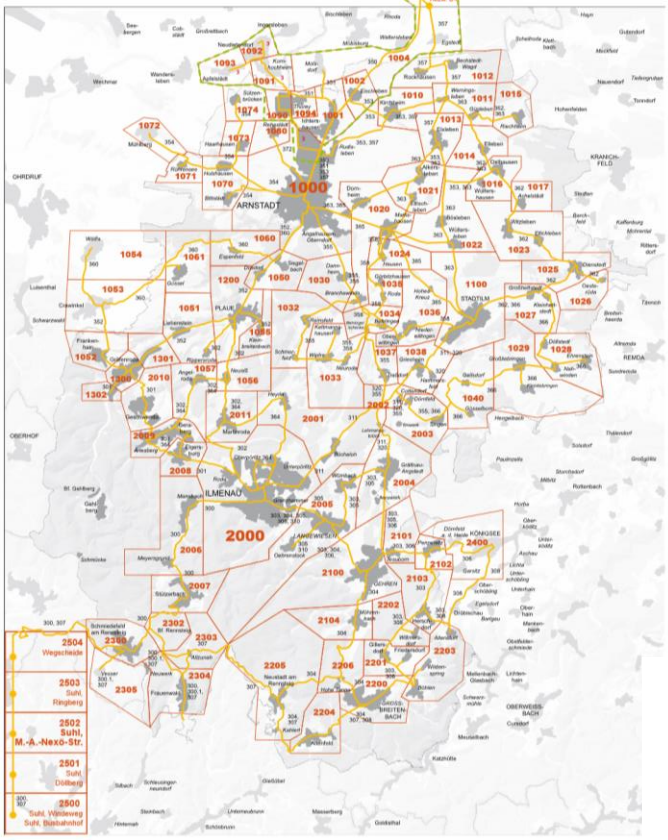

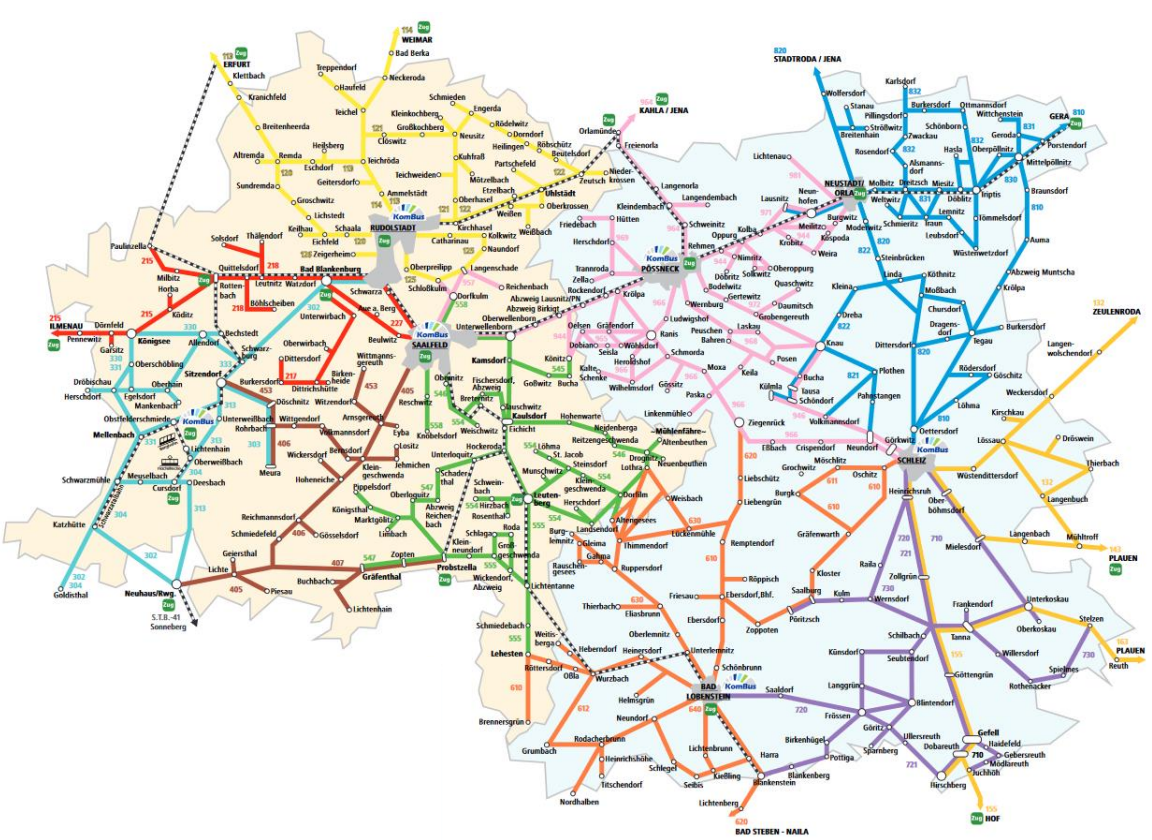

Source: https://www.bus-bahn-thueringen.de/

Thank you for your attention!

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