Project report

Geospatial Data Analysis for Smart Communities, FS24

Project Title: Public Transportation Visualizer

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1 Motivation and goals

Switzerland boasts one of the most efficient and extensive public transportation systems globally, renowned for its punctuality, cleanliness, and connectivity. Its dense transport network, with approximately 70’000 kilometers of roads and a 5’100-kilometer railway system, positions it as a global leader in transportation infrastructure. The Swiss Federal Railways (SBB) is a key player in public transport, alongside other rail operators like BLS AG, while regional bus services, often operated by private companies or PostAuto, connect remote areas. Responsibility for different transport modes varies between federal, cantonal, and municipal levels.

Population growth, particularly among the elderly demographic, underscores the importance of assessing transit systems' capacity to meet evolving needs. With a 0.8% increase in the overall population between 2020 and 2021 and a notable 1.9% rise in the number of individuals aged 65 and over during the same period, there's a heightened demand for transit services that cater to the mobility requirements of older residents. Efficiently visualizing population data against transit patterns becomes crucial for evaluating the system's adequacy in accommodating these demographic shifts.

By correlating population growth with transit usage patterns and considering factors like accessibility, frequency, and coverage, authorities can identify areas where the aging population may face challenges in accessing transportation services. This data-driven approach enables policymakers to implement targeted measures such as enhanced accessibility features, specialized services for seniors, and optimized routes to ensure that Switzerland's transit infrastructure remains inclusive and responsive to the needs of its evolving population.

As such, we aim to build a dashboard app to provide insights into public transportation patterns within Switzerland. Our data-driven approach aims at providing a comprehensive visualization platform for evaluating transit data, facilitating the optimization of routes, schedules, and infrastructure investments to elevate the efficiency and accessibility of public transportation systems.

Interactive visualizations will be utilized to depict key patterns and statistics, including heat maps indicating areas with high transit usage, charts showing the distribution of transit modes. Additionally, popular routes and destinations are highlighted, showcasing the busiest transit corridors, and frequently visited locations by commuters and tourists alike. The app may additionally provide data on the frequency and punctuality of public transit services, presenting average wait times and on-time performance for different transit lines.

Demographic insights will offer further understanding, revealing how factors such as age, income, and location influence transit preferences. Comparative analysis across different cities and regions within Switzerland identifies best practices and areas for improvement. Educational content could round out the app's offerings, promoting awareness of the importance of public transportation and sustainable mobility practices for individuals and communities.

2 Data source

To pursue the defined goal, data regarding both population and transportation is required. Fortunately, both are freely available in Switzerland.

2.1 Transit data

The main source of data for the app has been obtained from opentransportdata.swiss, which corresponds to transportation nodes of Switzerland and neighboring countries, encompassing a large range of node types spanning over 53’869 observations. The basis of the project will be a subset of the original file obtained by filtering the items by their ISO country code CH, for Switzerland, with a size of 55 columns and 6’762 rows.

The structure of the file can be summarized as follows:

Field Type	Data Type	Description
Identification Data	Integer	Unique identifiers like "numberShort" and "sloid" with additional check digits
Validity and Dates	Date	Columns such as "validFrom" and "validTo" indicate periods of validity, while "creationDate" and "editionDate" mark timestamps
Geolocation	Float	Coordinates such as "lv95East" and "wgs84North" specify locations, with "height" denoting elevation
Organizational Information	String	"businessOrganisation" includes name, abbreviation, and descriptions in various languages
Transportation Details	String	Information like "meansOfTransport" and "categories" describe transportation types and service categories
Location Information	String	Hierarchical location details within Switzerland, such as "cantonName" and "municipalityName"
Operating Point Attributes	Boolean	Characteristics like "operatingPoint" and "stopPointType" are represented by true/false flags
ISO Country Code	String	Identifies the country, primarily filtering data by country code
Numeric Data	Integer/Float	Various numerical values such as distances and organizational numbers
Boolean Flags	Boolean	Indicate true/false values for attributes like "operatingPoint" and "hasGeolocation"
Comments	String	"fotComment" offers additional textual information or comment

Table 1: Description of the Transit Dataset.

2.2 Data enrichment: demographic data

Additionally, the first dataset has been enriched with demographic data from "Statistik der Bevölkerung und der Haushalte (STATPOP) ab 2010" with the aim of providing more comprehensive insights. This source is structured into several csv datasets, of which we will concentrate on STATPOP2022_GMDE.csv, which contains population statistics, as well as additional demographic descriptors, and a standardized Swiss municipality ID number. This field will serve as the merging variable between both sets.

The table is composed of 79 columns and 2'145 rows, which are summarized in the following figure:

Field Type	Data Type	Description
GMDE	Integer	Gemeinde Code
BJJBTOT	Integer	Total permanent resident population in the year JJ (Example: total population year 2023: B23BTOT)
BjjB11	Integer	Total number of Swiss citizens in the year JJ
BjjB12	Integer	Total number of foreign residents in the year JJ
BjjB13:	Integer	Quantity of EU/EFTA State in year JJ
Nationality of an EU/EFTA state	Integer	Represents the number of residents from EU/EFTA countries.
BjjB14 - BjjB16:	Integer	BjjB14 - BjjB16: Further breakdowns of nationality by EU/EFTA states, non-European states, and unspecified or unattributable nationalities in the year JJ
BjjB21 - BjjB30	Integer	Breakdowns of permanent residents by birthplace, including those born in Switzerland, in the same municipality, in the same canton, in another canton, abroad, and further breakdowns by specific regions or unspecified locations in the year JJ

Table 2: Description of the STATPOP2022_GMDE Dataset

As part of the preliminary study for the project, we initially developed a concept that extended the scope to the entire country of Switzerland. However, recognizing that the volume of work might become unattainable, we considered the possibility of narrowing the focus to a specific region of interest. Additionally, during this preliminary phase, we determined that the choice of tools for cartographic representations would necessitate the use of shapefiles for the geometries of municipalities and cantons.

Another dataset, "Service Points," provides additional data regarding stops. This dataset includes stops of all types from Switzerland and the surrounding countries. To facilitate international data exchange, the dataset uses the isoCountryCode column, which abbreviates the countries using two letters (e.g., CH for Switzerland). This column is essential for filtering stops to only include those in Switzerland.

"SLOID" stands for Swiss Location ID. It is used to standardize the representation of stops and also includes objects such as stop platforms and stop areas, facilitating international data exchange. The basic format of a SLOID is <Country>: <Authority>: <IDName>: <Location>: <Components>. The <Components> part can be further divided into <StopArea>:<StopPlatform>. (Lutz Richard, o. J.)

Additionally, the dataset includes the MunicipalityName, which specifies the name of the municipality, and localityName, which gives a more precise description of the stop's location within the municipality. The MeansOfTransport column describes the type of transport associated with each stop, such as whether it is a train or bus stop. Exact coordinates are provided in wgs84east and wgs84north, representing longitude and latitude, respectively. Another important attribute in the dataset is height, which indicates the elevation above sea level.

Field name Export	Title	Description	Example values
Sloid	Swiss Location ID (SLOID)	Unique key for service centres in accordance with the Swiss ID for Public Transport specification, which is used in the customer information.	Ch:1:sloid:8795
isoCountryCode	County	The code of the country	CH
MunicipalityName	Name of municipality	Name of the municipality	Hasliberg
localityName	Name of the locality	Name of the locality	Haliberg Wasserwendi
MeansOfTransport	Mode of transport	Means of transport for which a stop is in use.	TRAIN,BUS,TRAM,BOAT,CABLE_CAR,CHAIRLIFT,CABLE_RAILWAY,METRO,ELEVATOR,UNKOWN
wgs84east	WGS 84 EAST	East coordinate in the WGS84 coordinate system (longitude).	7.431841427
wgs84north	WGS 84 North	North coordinate in the WGS84 coordinate system (latitude).	47.40368793
height	Height	Altitude above sea level	516
fsoNumber	Number of municipality	Number of the municipality	783

Table 3: Description of Public transport stops dataset.

3 Methods

For an initial overview, QGIS was utilized to quickly and easily display the maps and to test a wide range of shapefiles related to transportation.

In a subsequent step, an interactive dashboard was created using Tableau.

This allows viewers to customize and visualize their own map concerning transportation in Switzerland, enhancing user engagement and providing tailored insights.

For a preliminary analysis, the geoprocessing tool “QGIS” was used. One of the significant advantages of QGIS is that it is free and open-source, eliminating licensing costs and allowing users to start mapping datasets quickly. QGIS supports a wide variety of vector data formats, including PostgreSQL/PostGIS, Shapefiles, GPX, GeoJSON, and SQLite. Its extensive functionality is enhanced by a rich ecosystem of plugins, enabling advanced spatial analysis, data visualization, and geoprocessing.

QGIS also benefits from strong community support, ensuring continuous development and improvement. The active user and developer community provides extensive documentation, tutorials, and forums, making it easier for new users to learn and solve problems. This collaborative environment fosters innovation and regular updates, making QGIS a powerful and flexible tool for various geospatial applications. (Moyroud & Portet, 2018)

For these reasons, QGIS was used to create the initial maps and gain an overview of the data. QGIS's powerful geospatial capabilities allow for visualizing and analyzing attributes like population density, transportation stops, and coordinates. This initial exploration helps identify patterns and trends within the data, leading to new research questions.

With a solid understanding of the data from QGIS, insights can then be further explored using Tableau. Tableau's advanced visualization tools enable the creation of interactive dashboards and detailed analyses. This complementary approach—using QGIS for initial mapping and Tableau for in-depth exploration—ensures a robust and thorough analysis of the dataset.

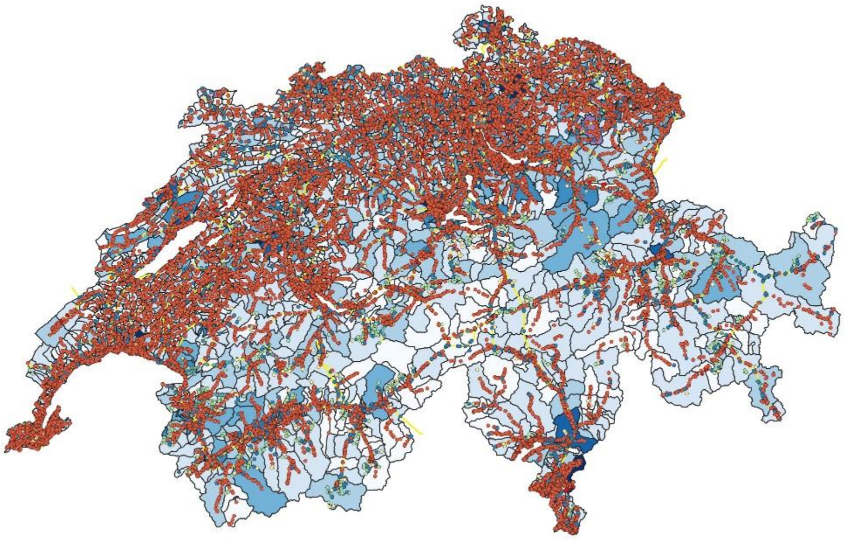

Figure 1: general map of Switzerland with all relevant layers.

In this image, Switzerland is depicted with various layers. One layer shows the municipalities with their boundaries, and the color indicates how populous specific regions are. Dark blue represents the municipalities that are the most densely populated, while white indicates that these have very few or no inhabitants. Additionally, a shapefile with train and tram lines has been added to the map. Furthermore, the stops of public transport are displayed on the map in different colors.

For the first part, the municipal boundaries were displayed on a map of Switzerland. The depth of the colors, ranging from blue to white tones, represents the total population of each municipality, with deeper blue indicating a higher population. This information was sourced from the file STATPOP2022_GMDE. Subsequently, a Shapefile containing Switzerland's railway network, shown in yellow, was added. From the dataset "Service Points," all stops for various public transportation modes were plotted in different colors, as depicted in Figure 1. These colors represent different types of transport, such as boat, train, bus, and tram, etc. and also indicate multi-modal stations like those that serve train, bus, tram, etc.

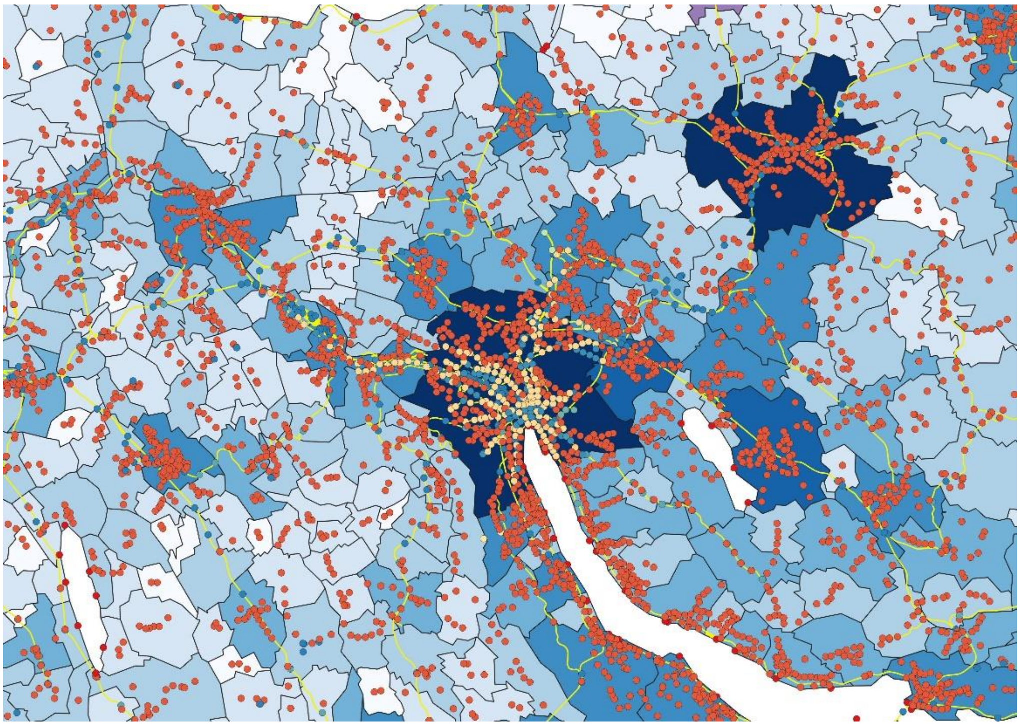

Figure 2: close-up of the Zürich metropolitan area.

In this additional image, the region around the city of Zurich is depicted. The various stops are shown in different colors to provide an overview of the density of each mode of transport. The subsequent illustration provides a detailed description of the respective colors and stops.

This figure is a zoomed-in view from Figure 1, focusing on the metropolitan area of Zurich. The center of Zurich is shown in dark blue, indicating a high population density. It is evident that municipalities with larger populations have a higher density of public transport stops. In the city of Zurich, it is also clear that various modes of transport are available, such as the tram, which is depicted in an orange-yellow color.

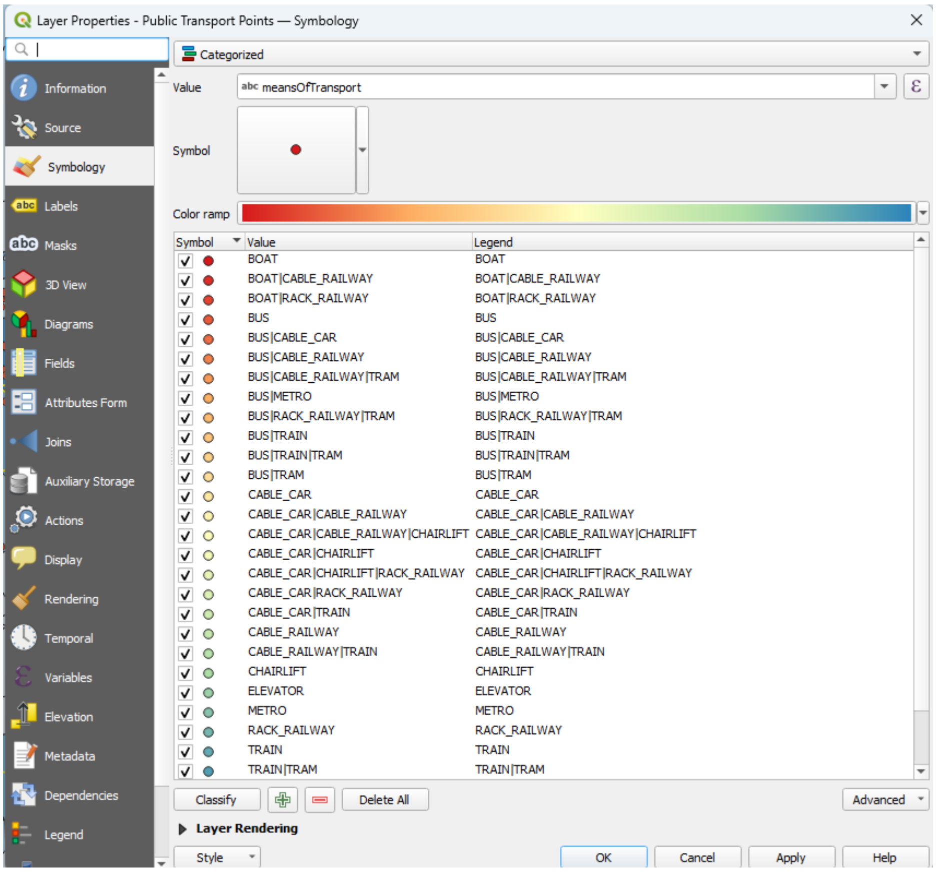

Figure 3: transit node symbols legend.

In this figure, the points displayed on the map are shown in greater detail. Each color represents a different type of transport, with some colors indicating multiple modes of transport. The color gradient ranges from dark red to blue, signifying various transport categories.

3.1 Tableau

We have chosen Tableau as our visualization tool because it offers enhanced interactivity between plots and provides users with an accessible interface, including the ability to implement filters. The following visualizations and findings are presented through Tableau dashboards, which can be accessed on the Tableau Cloud via the provided link.

3.2 Missing data and anomalies

The dataset contains also data from neighboring countries as well as null values associated with various variables. Filters within the tableau plots are used to isolate the relevant ones and provide a more cohesive interpretation.

For the QGIS parts, there were some missing values due to the following reasons. The base map of Switzerland used a shapefile from 2023, whereas the dataset "STATPOP2022_GMDE.csv" is from 2022. During this time, some municipalities merged, leading to missing values when joining the datasets. Another reason for missing values is found in the "Service Points" dataset, where some municipalities do not have any stops, resulting in missing values, as seen in Figure 11. Examples of merged municipalities include Neckertal in the canton of St. Gallen and Andelfingen in the canton of Zurich. In the context of this work, these missing values were left as they were.

4 Visualizations and key figures

The visualization created in Tableau can be divided into two main chapters:
Firstly, a look into the commercial activity in the Swiss transit network, including the following topics:
The number of nodes which provide freight services, as well as transport companies, to identify regional markets and behaviors.
Logistic corridors can be identified along the low Alpine valleys, connections from North to South, part of larger European logistic corridors.

Secondly, the Means of transportation and their accessibility to population are analyzed.
The **density of population** is compared to the **Number of transit nodes and available modes of transportation.**
Filtering by height above sea level allows to identify recreational transit systems, such as ski lifts and touristic trains.

4.1 Population

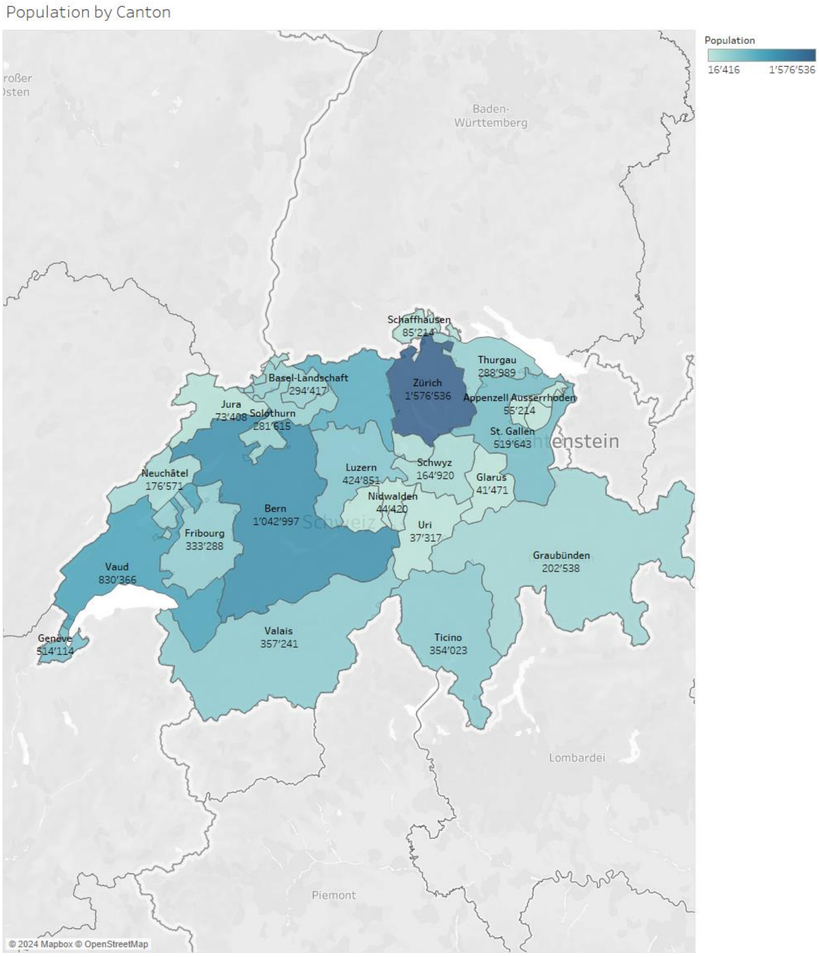

Figure 4: Population of the Swiss cantons.

The image is a thematic map of Switzerland, displaying population distribution by canton, with each canton shaded in varying shades of blue to represent different population sizes. Zurich has the highest population (1,576,536), indicated by the darkest blue, while Appenzell Innerrhoden has the lowest population (16,416), shown in the lightest blue. The central and northern regions, particularly Zurich, Aargau, and Basel-Landschaft, have higher population densities compared to the southern and eastern regions like Graubünden and Uri. Switzerland is often divided into three regions: the Jura, the Central Plateau (Mittelland), and the Alps. This map clearly shows that the Central Plateau is the most densely populated region, with cantons such as Vaud, Bern, Aargau, and Zurich. The Jura region, including cantons like Jura and Neuchâtel, is less densely populated. Similarly, the cantons in the Alpine region, such as Valais, Uri, and Graubünden, also have lower population densities. This depiction accurately reflects the population distribution across these three regions.

4.2 Means of Transport

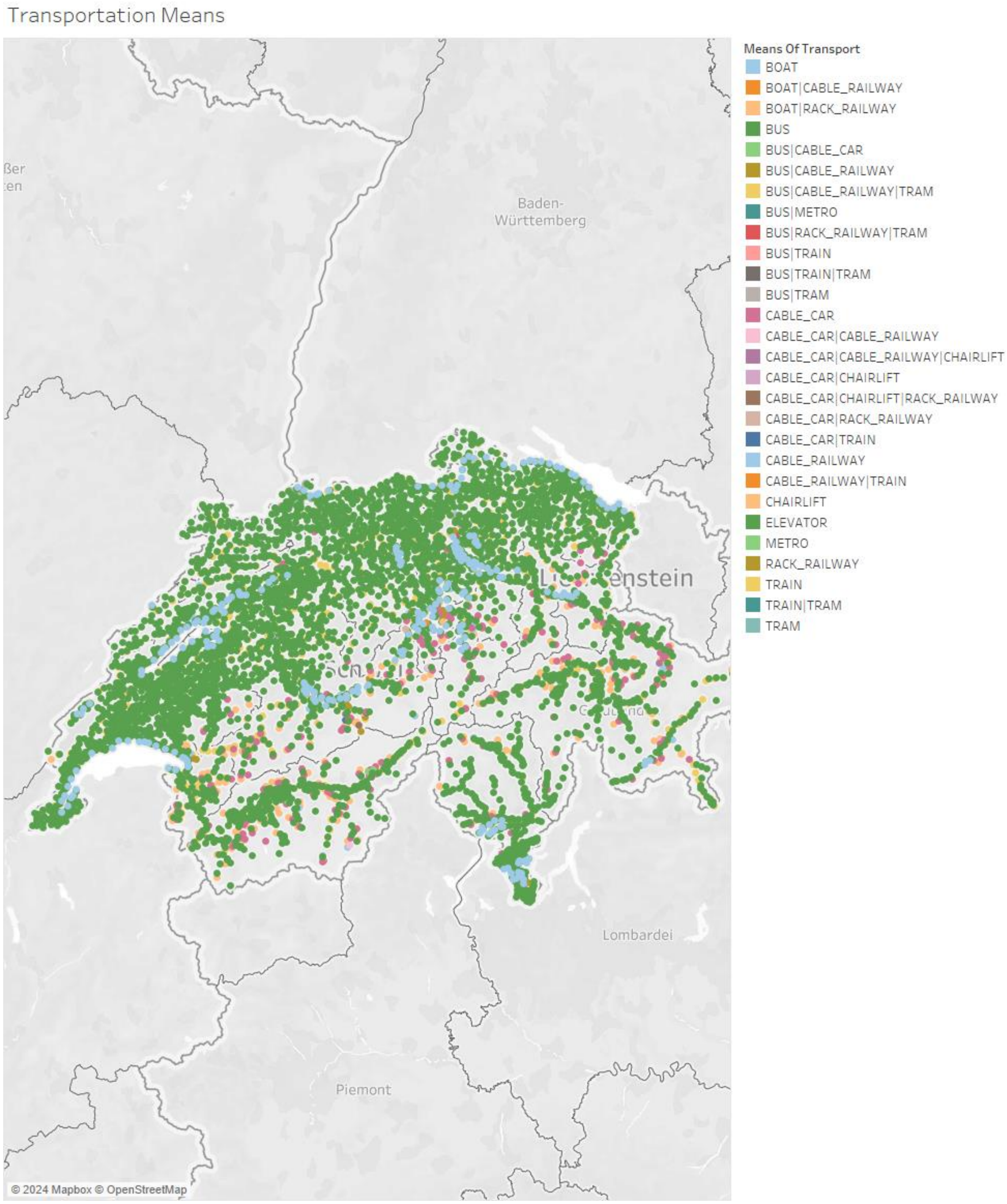

Figure 5: Public transport stations, color coded by means of transport.

This map illustrates the various means of transportation across Switzerland, showcasing a wide range of transport modes with different colored points. Each color corresponds to a specific type of transport, as indicated in the legend. A point on the map indicates that the locality has at least one transportation stop. However, these points do not represent the exact locations of the stops within Switzerland. If a locality has multiple bus stops, only a single point is shown for that locality. However, a locality can have multiple points if it has different types of transportation, such as buses and cable cars. The green dots represent bus stops, which are widespread across the country, particularly dense in the Central Plateau and urban areas. The pink dots indicate cable cars, prevalent in mountainous regions. The map also highlights Switzerland's extensive network of waterways, evident from the turquoise points scattered across the country. These points represent boat stops, which are found even on smaller lakes such as Lac de Joux in Vaud, Murtensee in Fribourg, and Greifensee in Zurich. Despite their modest size, these lakes have boat stops, showcasing the widespread and integrated nature of Switzerland's public transport system. Other colors represent combinations of transport modes, such as train and tram (orange) or boat and cable car (yellow). This distribution underscores the accessibility and connectivity provided by various modes of transportation throughout the nation, from urban centers to remote alpine areas.

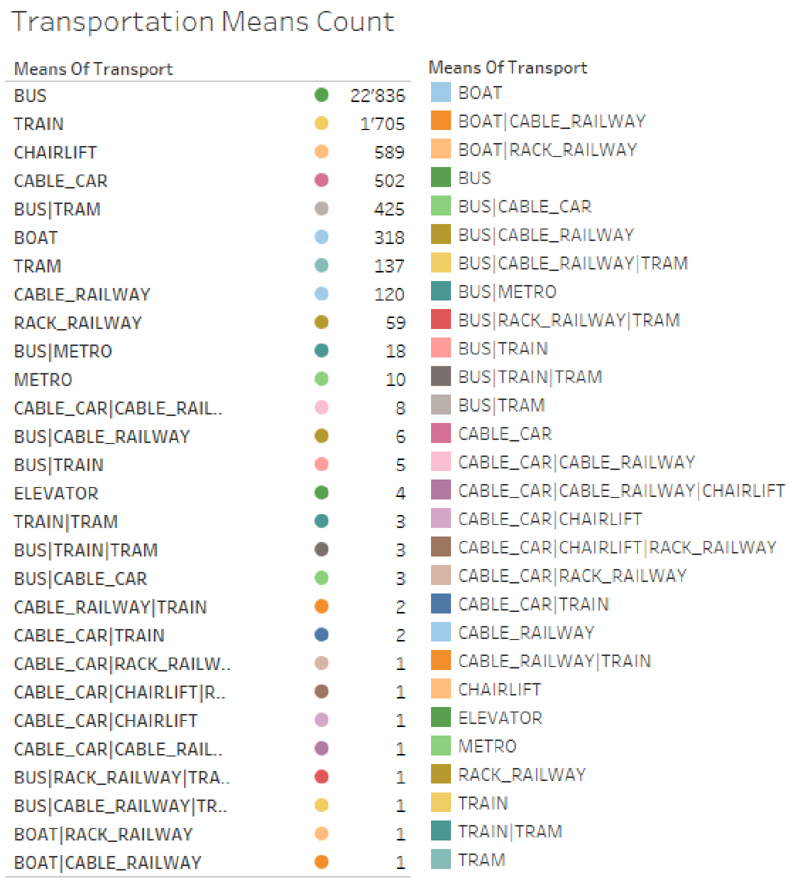

Figure 6: No. Public transport stations.

This plot provides a detailed count of various means of transportation in Switzerland, categorized by type. The green dot, representing bus stops, has the highest count with 22,836 stops. Train stops, marked in brown, are the second most frequent with 1,705 stops. Other notable categories include chairlifts (589), cable cars (502), and combinations like bus/tram (425). Less common transport modes include metro (10 stops), rack railway (59 stops), and unique combinations such as cable car/cable railway (8 stops). The diverse color coding helps to distinguish between the different modes and combinations of transport available throughout the country.

4.3 Dominant mean of transport i.r. to station availability

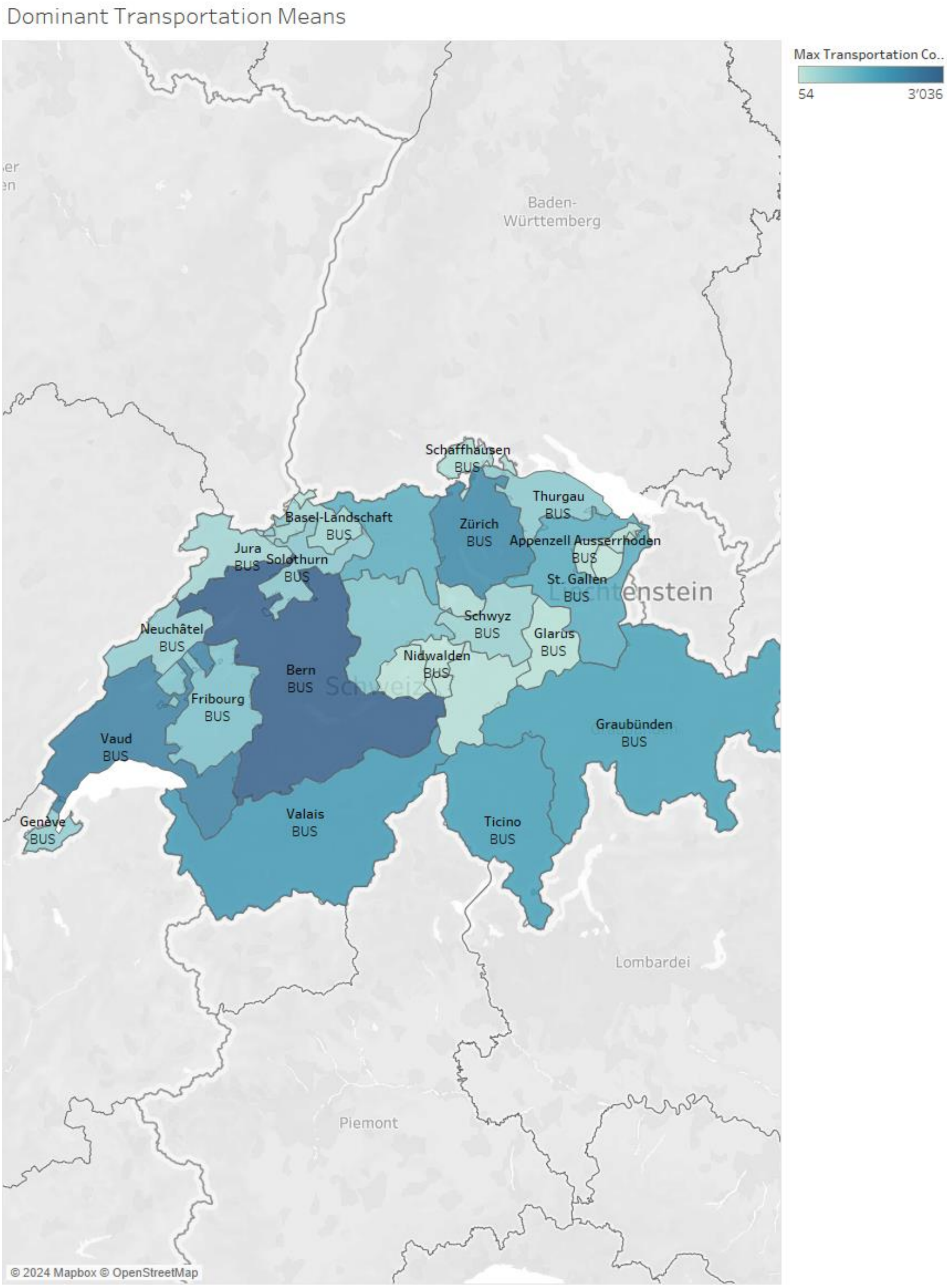

Figure 7: Dominant mean of transport per canton.

This map shows the dominant means of transportation across various cantons in Switzerland. Each canton is labeled with the predominant mode of transport, which in this map is consistently "BUS." The shades of blue represent the count of the dominant transportation mode within each canton, with darker shades indicating higher counts. This suggests that buses are the most common mode of public transportation throughout the country, highlighting their extensive network and importance in connecting different regions, from urban centers to rural and alpine areas. The legend on the right indicates the range of bus stop counts, with a lighter blue for fewer stops and a darker blue for a higher number of stops, showing significant variation in bus stop density across different cantons. It stands out that the canton of Bern relies heavily on buses, as do the Alpine cantons like Valais, Ticino, and Graubünden, although to a lesser extent. In contrast, the Central Swiss cantons such as

Nidwalden, Uri, and Schwyz have a relatively lower reliance on buses compared to the rest of Switzerland.

4.4 Providers of public transport

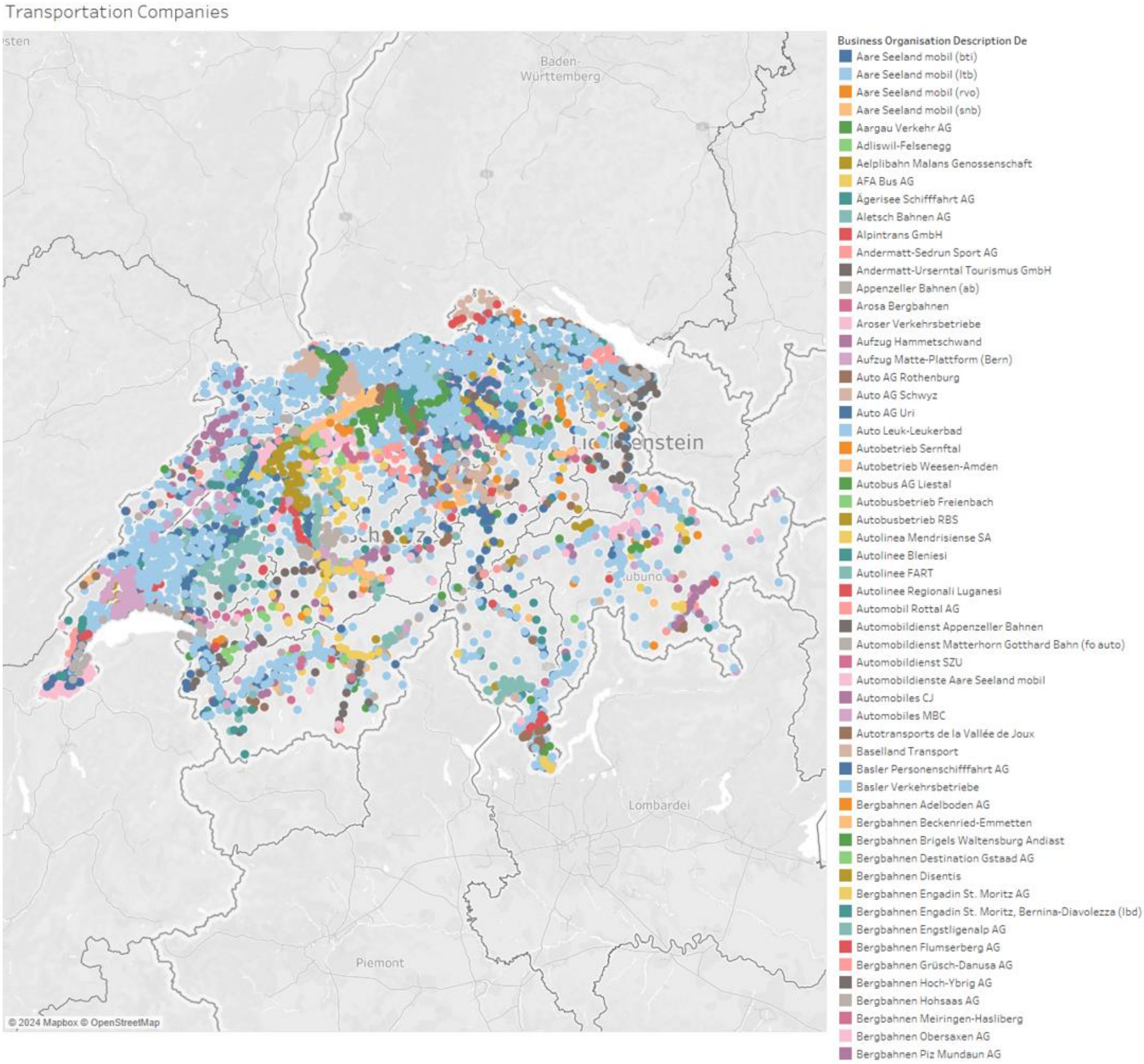

Figure 8: Public transportation providers.

The points in the graphic indicate the presence of various transportation companies within each locality. A single municipality can host multiple transportation companies. As observed in other figures, buses predominantly prevail, evidenced by the numerous turquoise points representing PostAuto. It is also notable that each region has its own transportation companies, particularly in areas like Bern, Solothurn, and Aargau. In the mountainous regions, such as Valais, there are numerous cable car companies, each unique to their respective localities. This map highlights the regional diversity of transportation companies, as well as the prevalence of bus services across the entire country.

4.5 Freight train availability

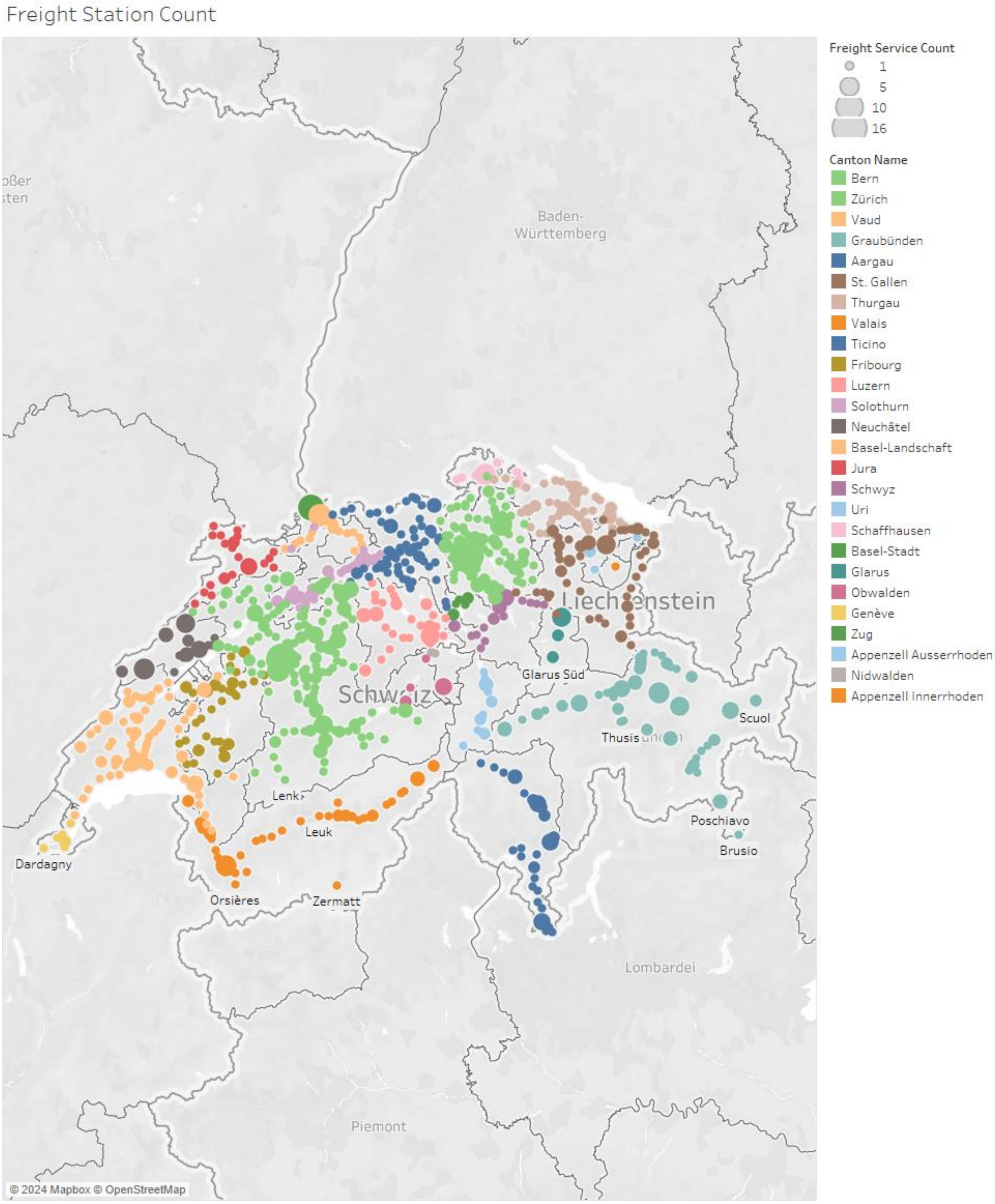

Figure 9: Availability of freight train stations.

This illustration shows the number of transportation companies within each municipality. The larger the point, the more transportation companies are present in that municipality. It is not surprising that major hubs such as Zurich HB, Bern, and Basel are represented with large points. The colors indicate the canton to which each municipality belongs. Notably, the major cities of Lausanne and Geneva each have only two transportation companies, despite their size.

4.6 Transit stop density

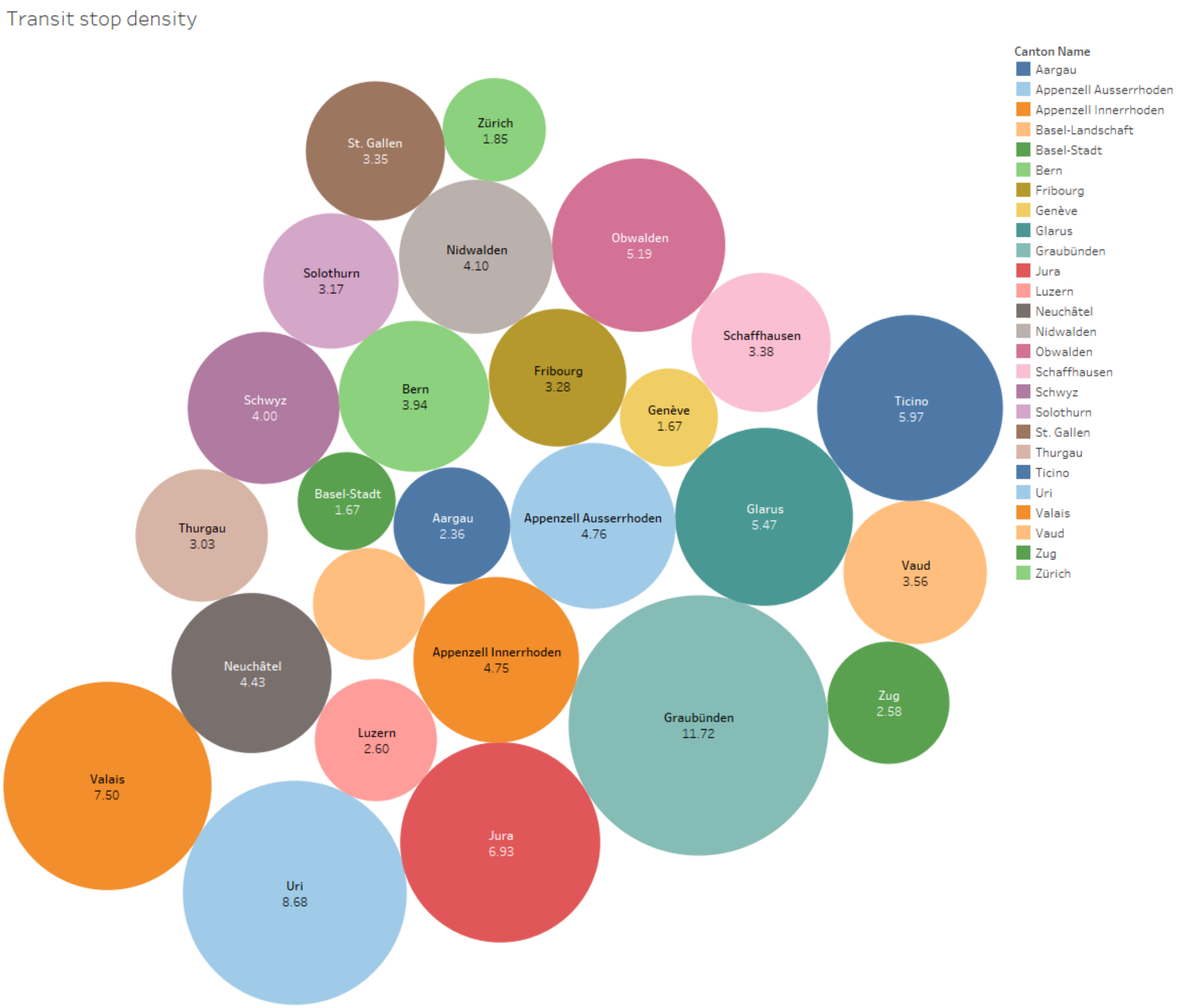

Figure 10: Transit stop density per 1'000 inhabitants.

In this figure, the number of stops per 1’000 inhabitants for each canton is calculated. There is a clear trend showing that less densely populated cantons, such as Graubünden, Uri, and Valais, have a high density of stops. Conversely, densely populated cantons with smaller areas have fewer stops per 1’000 inhabitants. This trend includes cantons such as Basel-Stadt, Geneva, and Zurich. While the canton of Zurich is geographically larger than the other two, it is still very densely populated due to major cities like Zurich and Winterthur.

4.7 Stops per 1,000 people per municipality

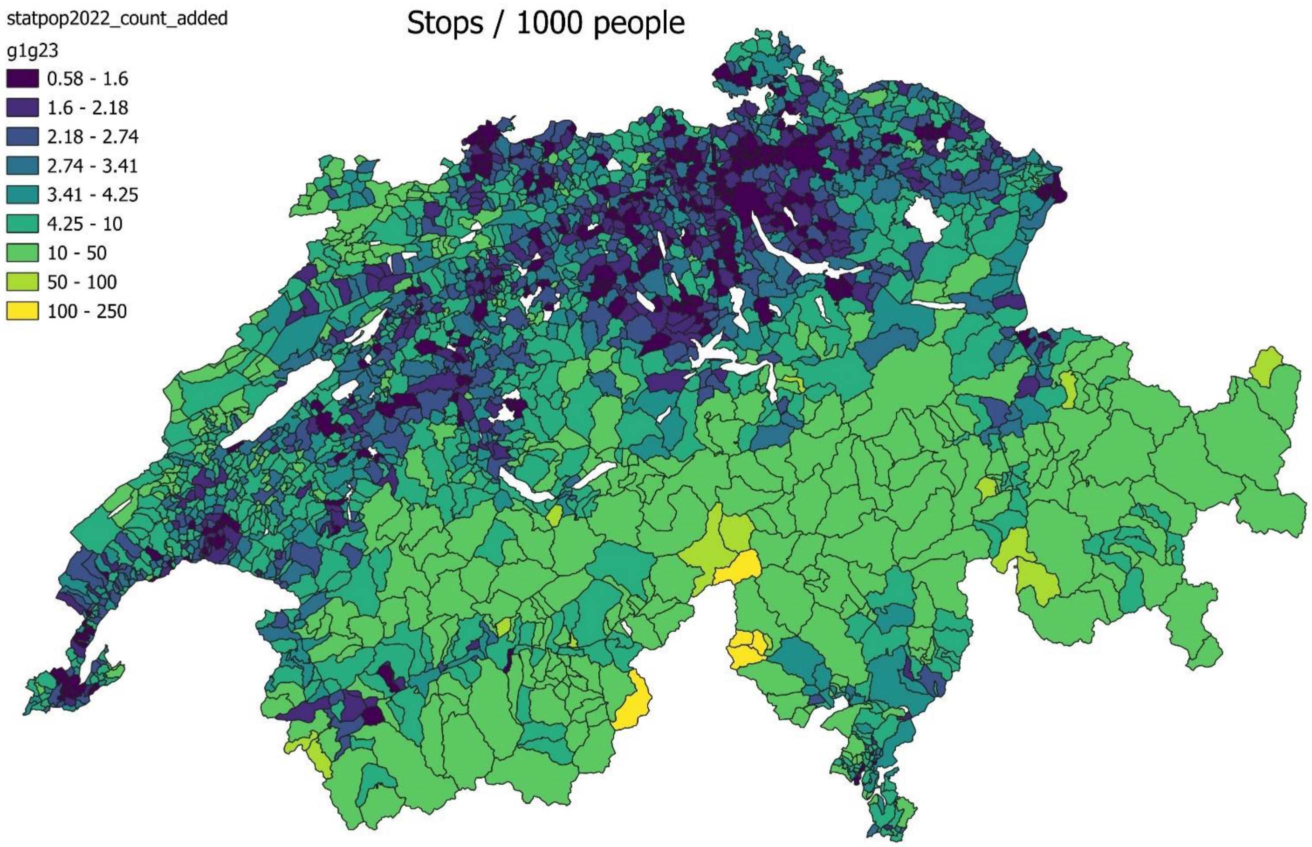

Figure 11: Stops per 1000 inhabitants per municipality.

This illustration fundamentally shows the same information as Figure 10, but the difference is that it displays the density at the municipal level, also per 1'000 inhabitants. Similar to Figure 10, it is evident that densely populated cities and urban areas have approximately 0.6 stops per 1,000 inhabitants. In contrast, regions like Graubünden and Valais stand out with about 10-50 stops per 1'000 inhabitants. The highest value is found in the municipality of Cerentino, which boasts 250 stops per 1'000 inhabitants. This exceptionally high value is due to Cerentino's small population of just 36 residents, yet it has 9 stops.

5 Conclusion

Our analysis of Switzerland's public transit system reveals several key insights, particularly regarding the correlation between population density and transportation infrastructure. As a breakdown of the previously showcased visualizations and insights, we now go over some of the key findings.

It is found that there is a strong correlation between regions with higher population densities and significant transportation routes used for both freight and passenger travel. Notably, even regions with lower population concentrations exhibit a high availability of transit options. Using elevation filters, it becomes apparent that many recreational transportation systems and networks are concentrated in mountainous areas, supporting ski resorts and various winter and summer sports activities.

When examining the absolute number of public transport stops, a distinct diagonal line from St. Gallen to Geneva becomes evident, highlighting a dense concentration of stops. This observation aligns with the Swiss newspaper NZZ's report that a third of the Swiss population resides within a five-kilometer-wide corridor along the railway line covered by Intercity 1 in just over four hours. It is logical that the highest number of stops are located where the population is most dense.

The number of stops per 1,000 inhabitants also reveals an interesting pattern: less populous cantons such as Graubünden and Uri have a relatively higher number of stops compared to densely populated cantons like Zürich or Geneva. Plotting these cantons against these two factors demonstrates a clear exponential decrease in the number of stops per 1,000 inhabitants with increasing population density. This suggests a deliberate strategy by public transportation authorities to ensure access to transit for as many people as possible, even in areas with lower absolute populations.

The project underscores the exemplary nature of Switzerland's transportation network, demonstrating its extensive reach and efficiency. By filtering data by elevation, insights are gained into the operational use and purpose of transit nodes, revealing that even with reduced population density, certain regions maintain an efficient network of nodes. This ensures a basic level of connectivity despite lower concentrations of localities and people. In an ageing and evolving society, maintaining a robust transportation network is crucial to enabling all citizens to participate fully in the economy and leisure activities.

Overall, these findings highlight the effectiveness and inclusivity of Switzerland's public transit system, emphasizing its role in supporting both densely and sparsely populated regions.

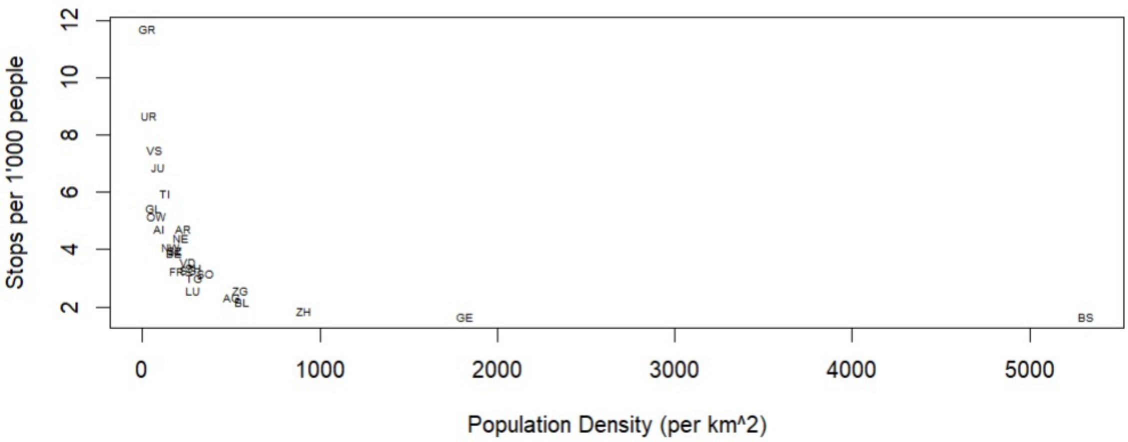

Figure 12: Cantons by population density and No. public transport stops per 1'000 people.

Accessibility appears to be a main concern of the Federal Office of Transport. Not only is for example the expansion of the railway networks a constant concern, but also the accessibility of public transport services to the disabled.

As a final note, this project provided an invaluable opportunity for our team of four, all new users of GIS tools, to explore this technology. Coming from diverse professional backgrounds, with some of us more acquainted with spatial data and its applications than others, we successfully bridged the gap between quantitative data analysis and spatial interpretation. Utilizing visualizations to convey our findings in an intuitive and engaging manner, this project has also been a rewarding experience in teamwork, marked by an efficient division of tasks and active involvement from all members.

6 References

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7 Figures and Tables