Local transport mobility analysis and emissions estimation in the Municipality of Trento

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`https://github.com/SanzioMeh/PublicTransportEmissions_Trento`

1 Abstract

This work aims to quantify urban public transit emissions using GTFS data and combining it with some aspects of mobility analysis for the municipality of Trento. This approach should allow us to estimate emission levels over distinct spatial and temporal intervals. Our methodology employs geospatial modeling to identify areas of elevated transit coverage that correlate with elevated emissions, thereby uncovering insights for sustainable urban planning, such as the choice of employing vehicles with lower emissions. The resulting emission efficiency metric, alongside simple visualization tools, should empower local policy maker in balancing mobility and environmental sustainability.

2 Data sources and description

This work is going to be based on publicly available data. The first, and most important, dataset is the General Transit Feed Specification (GTFS) file of all local transportation routes for the municipalitiesof both Trento and Rovereto. It is publically available and can be found here [3]. It follows Creative Commons Attribution 4.0 International so it can be shared and adapted, provided that the original source is credited.

The second source of data is Trentino Trasporti, the public utility company that provides public transport services in the province of Trento. It periodically publishes an Environmental Sustainability Report that can be freely consulted. Additionally, they also provides, on their website, some information on the composition of their fleet of buses, allowing for better estimation of emissions. These documents don't have a specific license, therefore we are going to utilize only the data within it and always provide suitable credit.

Finally, as far as emission estimation is concerned we are going to be utilizing the *gtfs2emis* package, "an R package to estimate the emission levels of public transport vehicles based on General Transit Feed Specification (GTFS) data" (github del pacchetto). This software utilizes the EMEP/EEA Air Pollutant Inventory Guidebook standardized exhaust emission factors to estimate emissions. This guidebook is maintained by the European Monitoring and Evaluation Programme (EMEP) and the European Environment Agency (EEA). Both sources do not specify their license, so we are going to follow the specified citation guidelines.

3 Mobility analysis

The first step in our workflow was to clean the GTFS data obtained from (source), which includes information on all public transport services across the province of Trento. Since our analysis focuses solely on the municipality of Trento, we manually removed all routes belonging to other municipalities, as there was no municipality-specific identifier in the dataset. This manual approach was feasible because the number of routes was relatively small; otherwise, a more advanced filtering method—such as using route coordinates, which would still require human judgment—would have been necessary. The routes can be visualized in Figure 1.

We then conducted some basic mobility analysis tasks, which required further processing of the original GTFS data. First, the *stop times* and *trips* dataframes were merged on the *route id* column to associate each stop event with its corresponding route. Next, stop frequencies were calculated using the *stop id* column and stored in a new dataframe. This dataset was subsequently merged with the *stops* dataframe, providing the spatial coordinates of each stop alongside its service frequency. We then transformed the result into a GeoDataFrame and

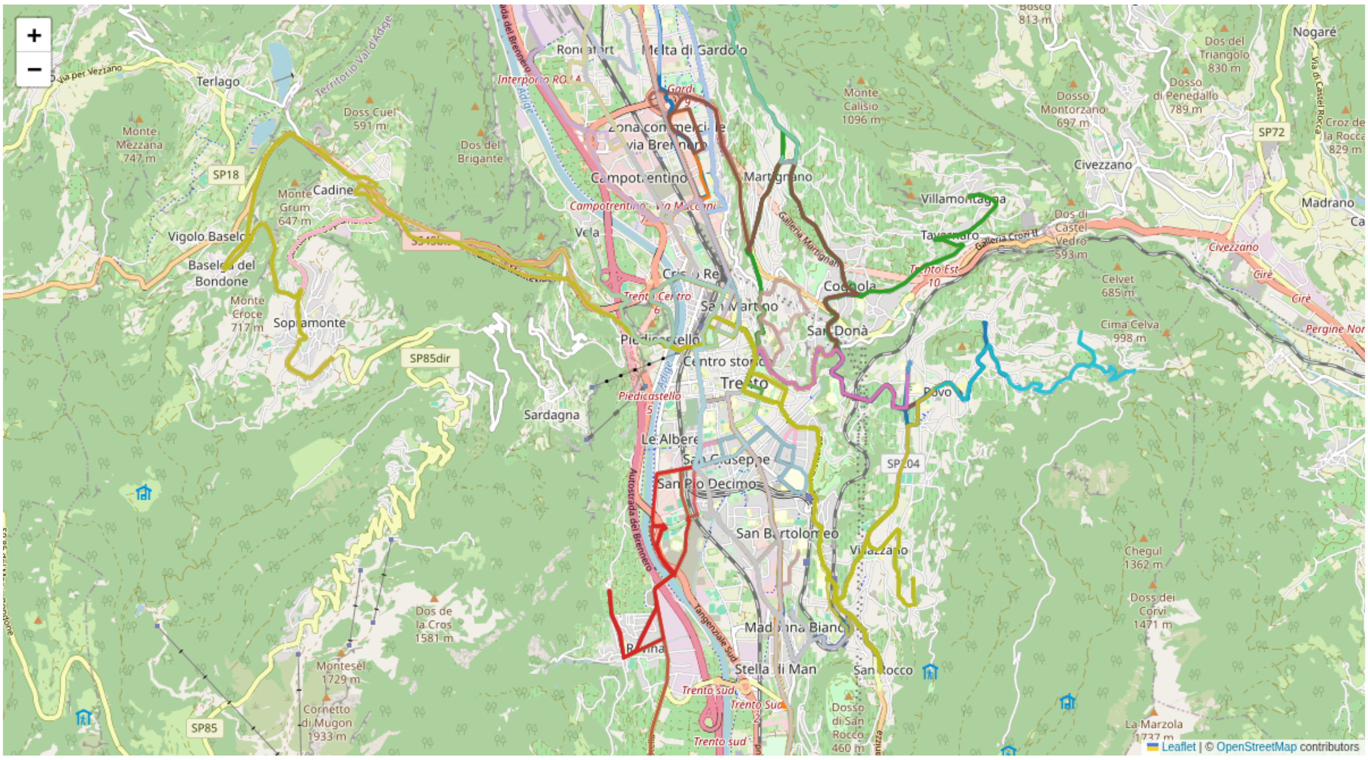

Figure 1: Local public transport routes in the municipality of Trento

defined a spatial grid for analysis. A grid cell size of 500 meters was selected, as smaller cells would overemphasize the area immediately surrounding individual stops, while larger cells would encompass multiple stops and reduce the spatial resolution of the analysis. Each stop is then assigned to the grid according to their spatial coordinates, and the stop counts for each area are computed. We the utilize the *Folium* library to plot the results (Figure 2).

It is clear that this map provides limited insight due to the high concentration of stops near the train station, which causes all other areas to be classified as inactive. To address this issue, we apply a logarithmic scale to the frequencies, reducing the dominance of high-frequency areas. The difference is illustrated in Figure 3, which has been zoomed out for clarity.

This logarithmic map is clearly more informative, enabling us to identify areas with varying levels of public transportation coverage. While the areas around the train station remain the most served, reflecting the passage of most routes, additional neighborhoods such as Povo and Mesiano (home to universities), as well as Sopramonte, Ravina, Madonna Bianca, and Gardolo, now emerge as highlighted zones.

Next, we analyze different time intervals to investigate potential changes in frequency distribution throughout the day. Figure 4 presents the logarithmic frequencies of bus stops between 7 AM and 2 PM, aiming to reveal shifts near school and university areas. However, the pattern remains largely unchanged from the full-day distribution, indicating that the public transportation coverage across the city remains consistent during this period.

Consequently, to identify more nuanced patterns, we adopt a different approach. First, we use the website [1] to obtain the spatial coordinates of specific points of interest. We then construct square polygons of variable size around these points and compute the number of stop events occurring within these zones throughout the day. This method allows us to compare the distinct temporal distributions associated with different locations.

Our initial analysis focuses on the train station, which is the primary bus hub in the municipality. Figure 5 illustrates the hourly bus stop events within a 500-meter-sided square centered on the train station (latitude = 46.055569, longitude = 11.132340).

The pattern aligns with expectations, showing three modest peaks in the early morning, midday, and around 6 PM. These peaks likely correspond to school start and end times, as well as typical workday completion. Given the train station's role as a major transit node, observing such predictable temporal trends in bus stop events is unsurprising.

The same pattern is observed around the Museum of Sciences (Muse) (lat = 46.063259, lon =

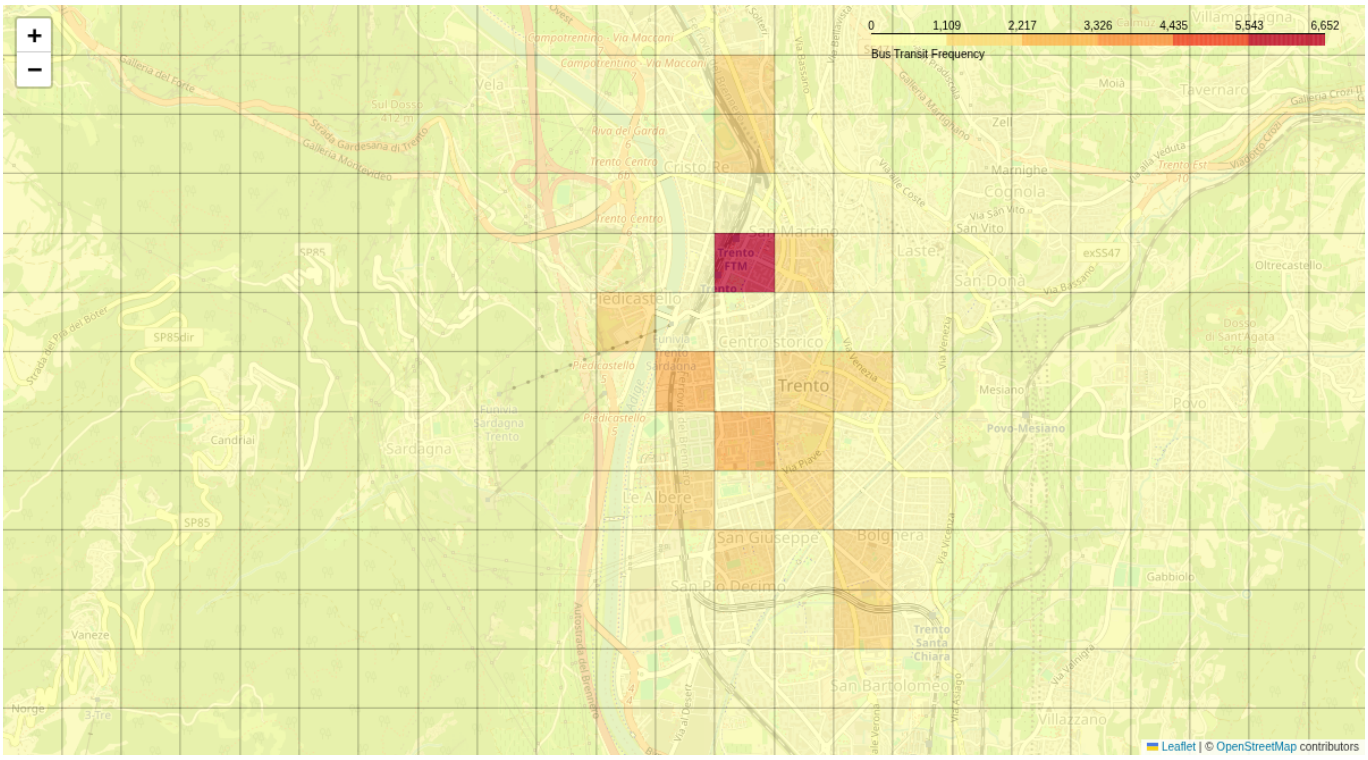

Figure 2: Bus stops absolute frequencies in the municipality of Trento

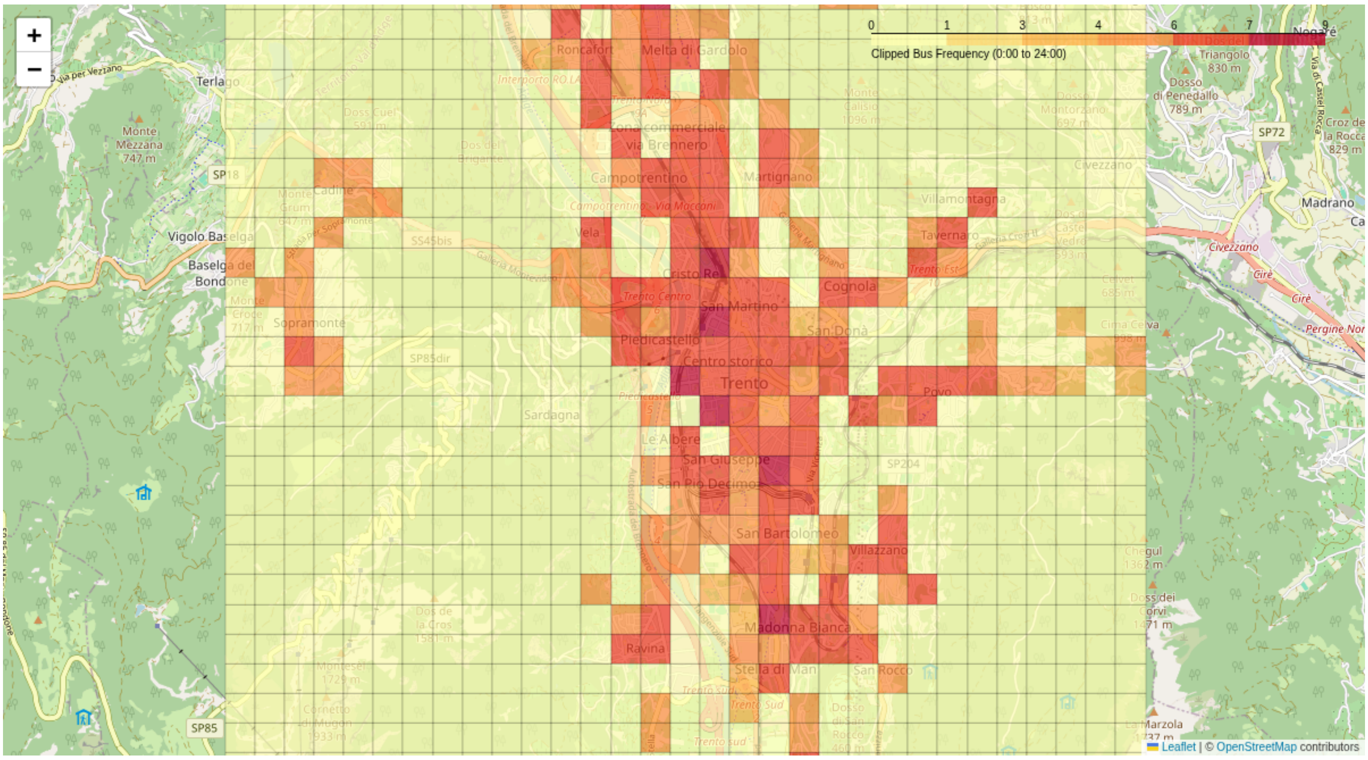

Figure 3: Bus stops logarithmic frequencies in the municipality of Trento

11.113125). Figure 6 shows a slightly higher peak in the late afternoon. This might indicate that the museum area doesn't require any particular transportation pattern, resulting in a more generic schedule.

A completely different pattern emerges around school areas. In Figure 7 we show the number of stops in the 500 meters square around the Galileo Galilei high school (lat = 46.06325, lon = 11.13631), one of the biggest in Trento. The plot shows an expected distribution with a tall peak early in the

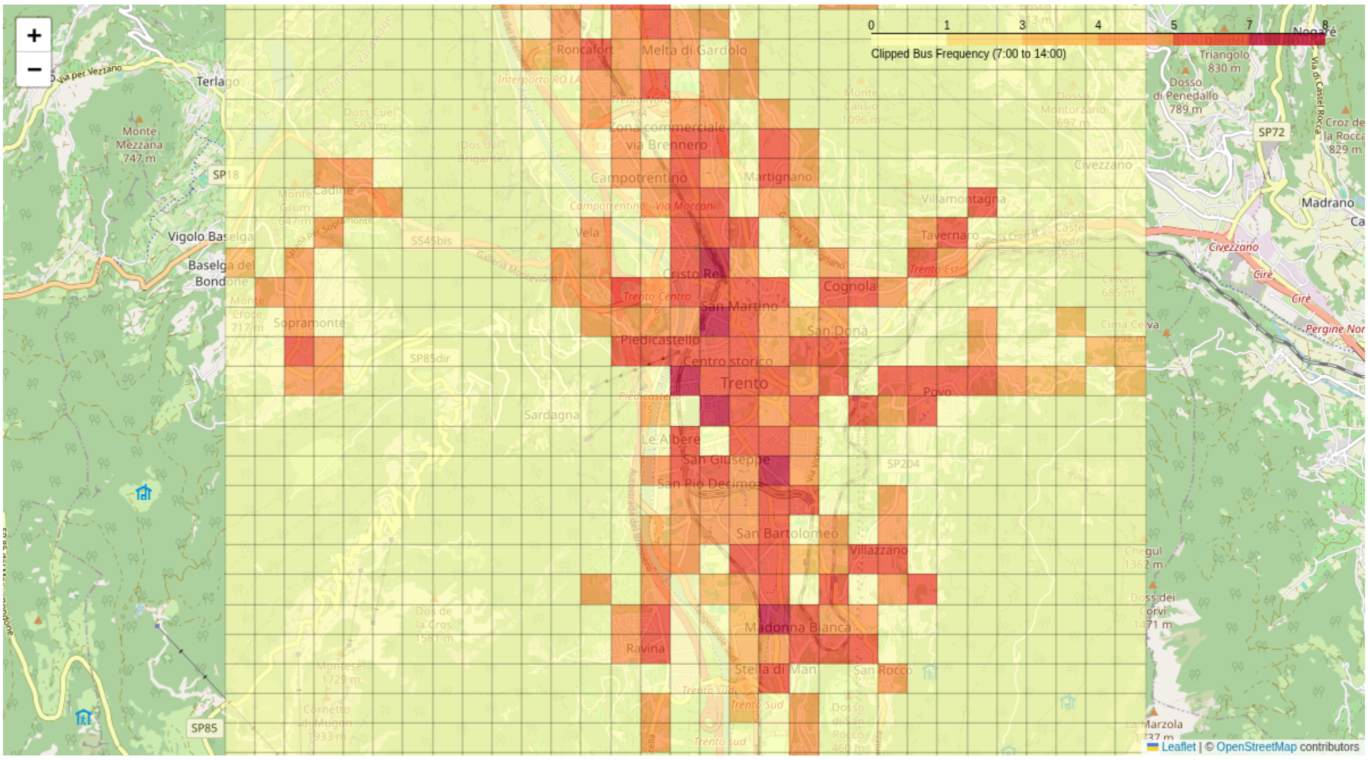

Figure 4: Bus stops logarithmic frequencies in the municipality of Trento between 7 AM and 2 PM

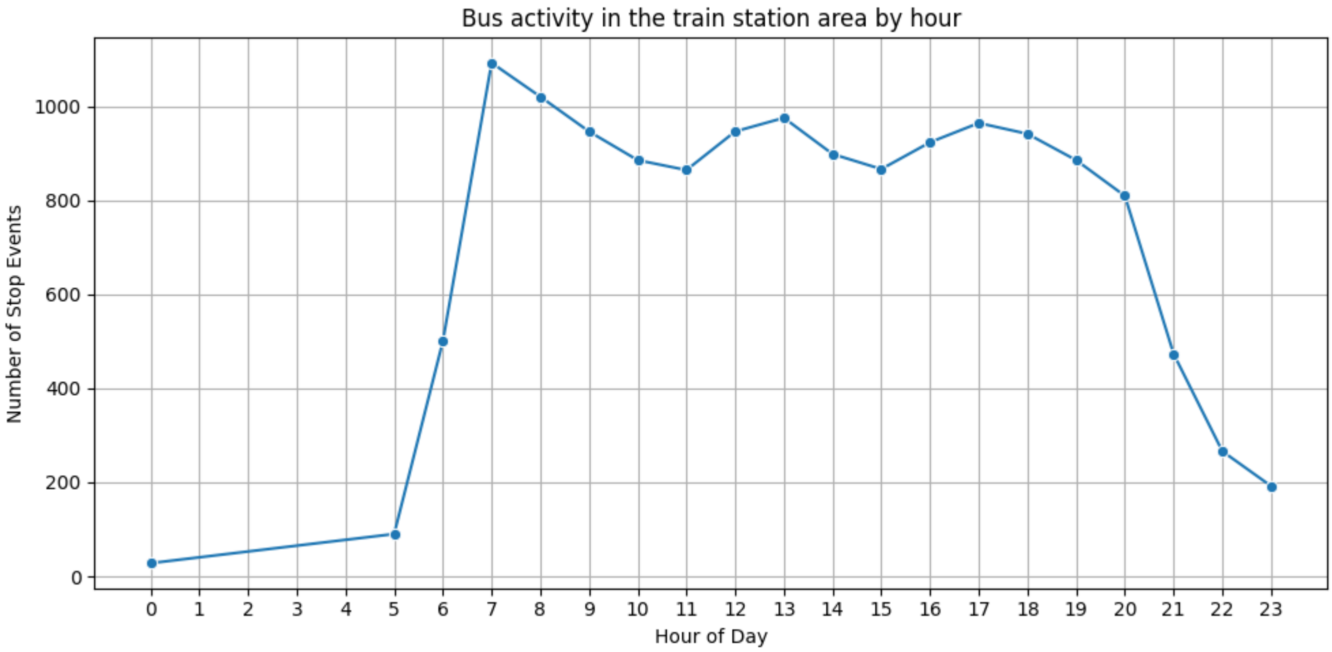

Figure 5: Bus stop events by hour in the train station area

morning (7AM) and a small peak around midday. Notably, there is no peak around workday completion as stops in the area mainly serve a morning-only school.

A different pattern is observed around the University in Povo (lat = 46.067527, lon = 11.150486), as per figure ??. This graph shows two very tall peaks around 8AM and 5-6PM. The early peak occurs slightly later, compared to the previous location, as university students are expected to begin their lessons later than high schoolers. Then the second peak is also justified by the fact that most students either have lessons in both morning and the afternoon, or choose to spend their day around the various university buildings. Finally, a

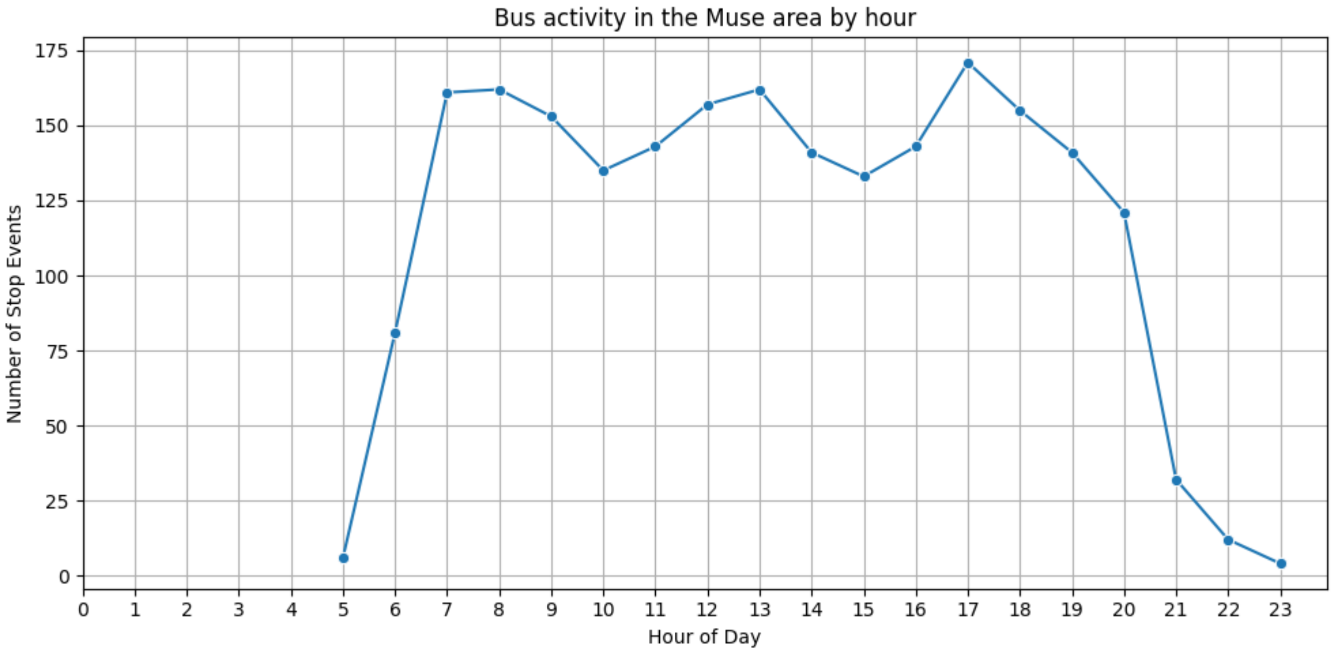

Figure 6: Bus stop events by hour in the Muse area

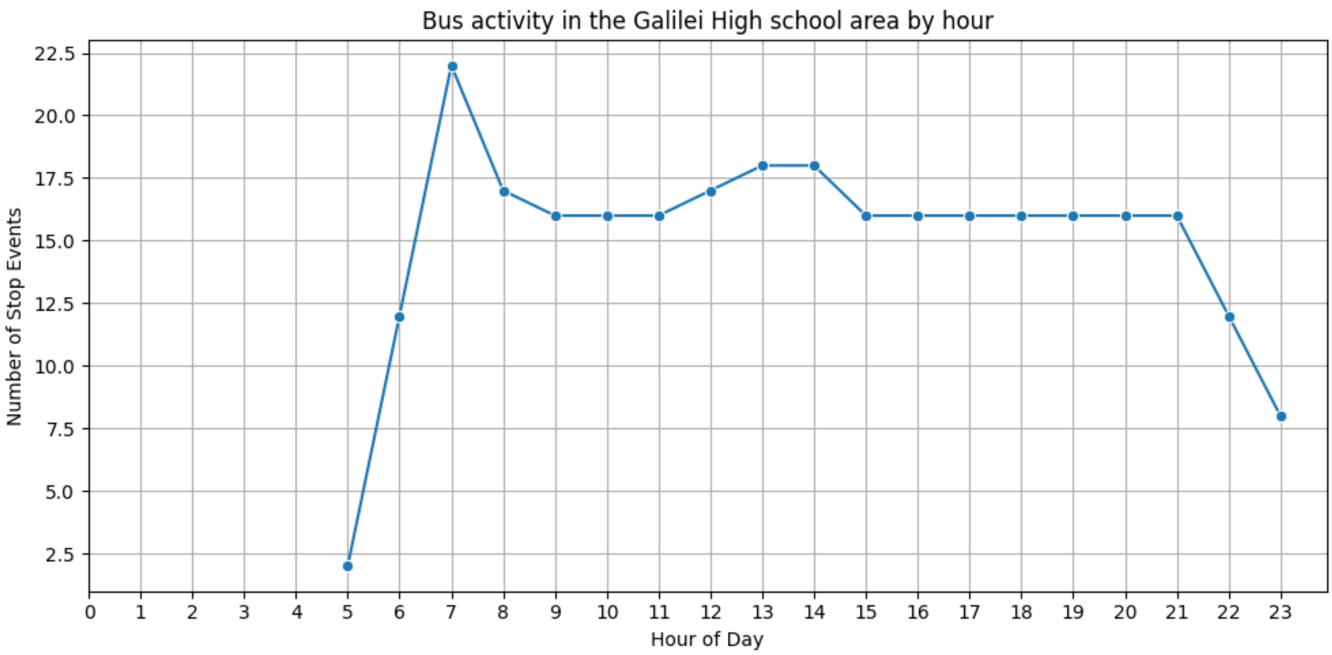

Figure 7: Bus stop events by hour in the Galilei High school area

different pattern is seen around the hospital (lat = 46.055569, lon = 11.132340), seen in Figure 9. Besides a small peak around 8AM, which can be justified by the generally higher bus activity during early morning, the plot is almost constant, reflecting the intent of providing a consistent connection to a critical facility.

3.1 Conclusions

Our analysis delineates a local transport net centered around the train station and manages to serve all areas in the municipality to a reasonable extent. When analyzing patterns of service for different areas of the day, the distribution of bus stops across the day seems coherent with the functions of different areas. This suggests that the bus schedules were developed with care and sensibly.

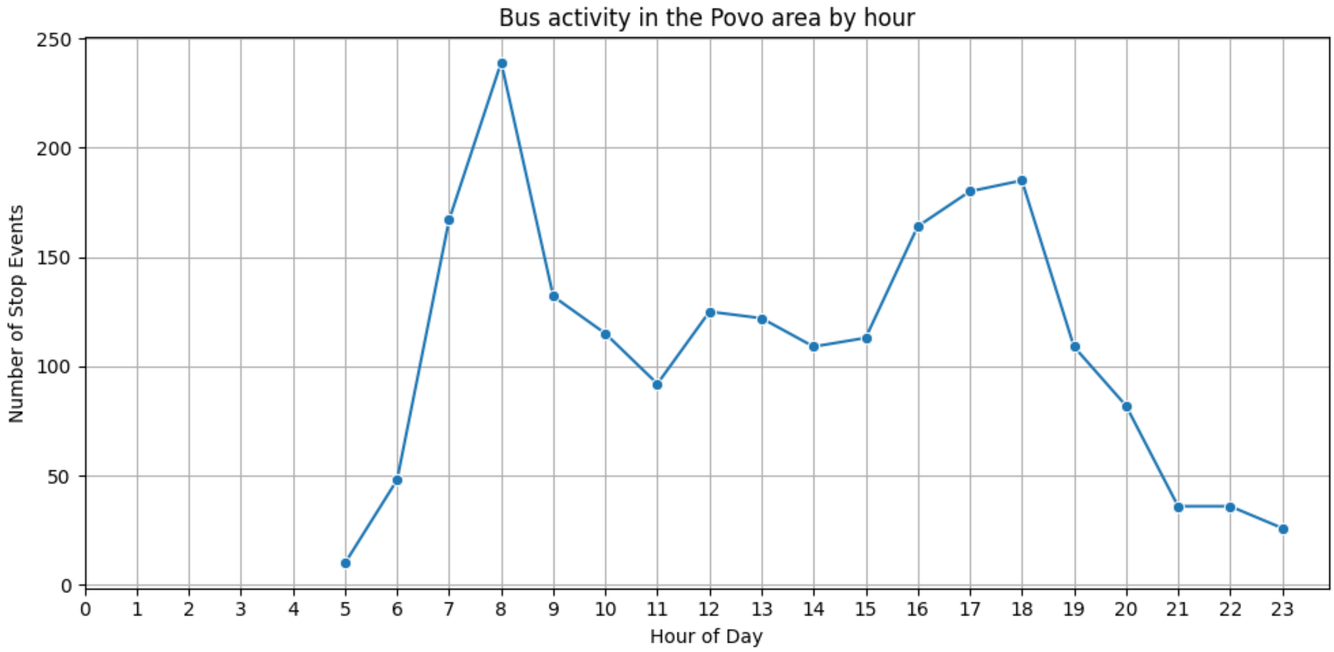

Figure 8: Bus stop events by hour in the Povo area

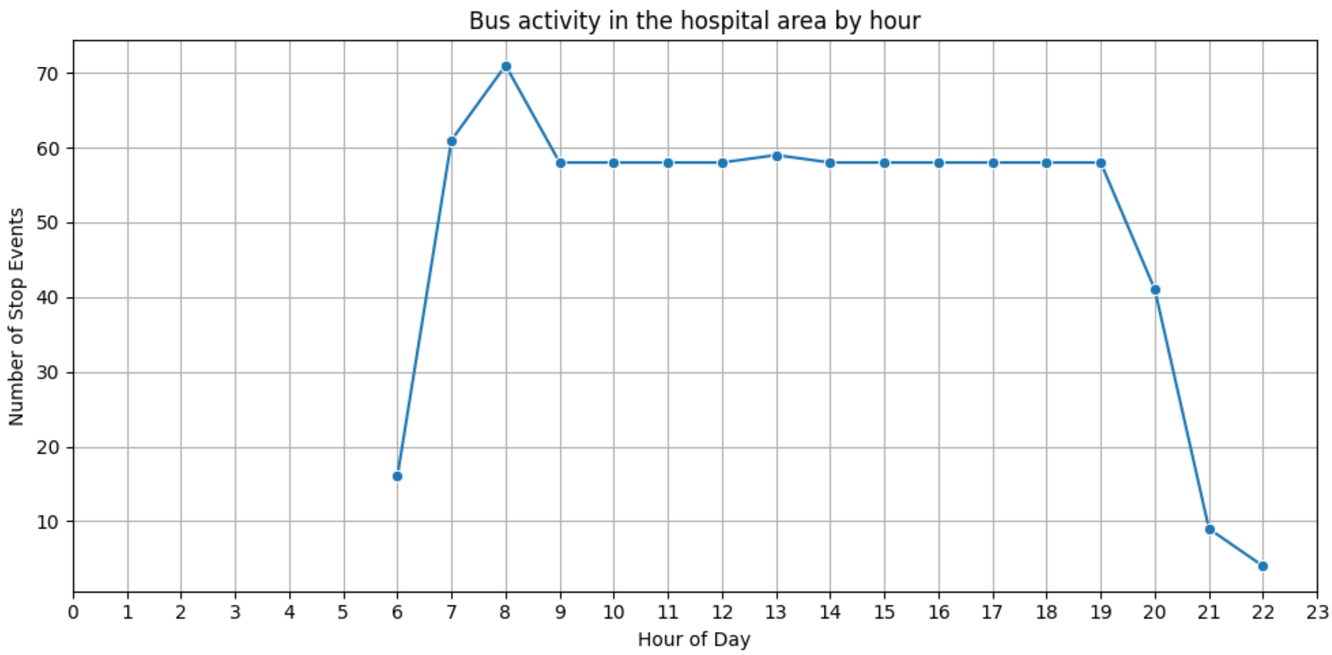

Figure 9: Bus stop events by hour in the hospital area

4 Emission prediction

4.1 The gtfs2emis package

The emission prediction is going to be made utilizing the gtfs2emis package [[2]]. It was developed to estimate hot-exhaust emission of public transport system in data-poor context. It only uses widely available GTFS transit data and a table of simple fleet specifications. It can then utilize different emission factor models from Europe (EMEP/EEA), United States (MOVES/EPA & EMFAC/CARB), and Brazil (CETESB).

The model utilizes two steps. First, the GTFS schedules are converted to GPS-like vehicle trajectories that account for speed, distance and elevation by interpolating between stops. Then, they are combined with vehicle fleet data and emission factor models to compute emission estimations.

Table 1: Updated fleet composition by vehicle type, EURO standard, fuel, and technology

Vehicle Type	**EURO**	**Fuel**	**N**	**Fleet Composition**	**Technology**
Ubus Std 15–18 t	I	CNG	25	0.119	-
Ubus Std 15–18 t	III	D	32	0.152	-
Ubus Std 15–18 t	IV	D	1	0.005	SCR
Ubus Std 15–18 t	V	D	9	0.043	SCR
Ubus Std 15–18 t	VI	D	72	0.343	DPF+SCR
Ubus Std 15–18 t	V	BD	9	0.043	SCR
Ubus Std 15–18 t	II	CNG	67	0.319	-

This model presents a main limitation: the paper shows that accuracy is within 26% to 42% compared to actual GPS data, proving it should only be utilized when such data is unavailable.

4.2 Estimation

To apply the estimation model we gathered data regarding the bus fleet of Trentino Trasporti, the public service provider of the province of Trento. Since there is no publicly available table containing a complete list of every vehicle, extensive interpolation between different sources was necessary. The four main sources utilized were [4], [5], [6] and [7].

The estimated local transport fleet composition for the municipality of Trento is shown in Table 1.

The first column indicates vehicle size, which was the category with the least amount of data. Documents and personal experience indicate the existence of an unknown number of articulated buses over 18 tons, which would require separate classification. However, since exact figures are not reported, to avoid arbitrary assumptions, we assigned the standard 15–18 ton bus size to all entries.

The second column represents the euro class of the vehicle. In this case a lot more information was available, but some guesswork was still required due to the age and incompleteness of the information, especially in combination with other categories. Additionally, different fuels have different Euro classification systems: for example, all compressed natural gas (CNG) vehicles belong to Euro class I and II (a different scale from diesel vehicles). Finally, electric vehicles are classified as part of the CNG fuel class.

The third column represent fuel types, with CNG standing for compressed natural gas and D for diesel. The fourth and fifth column represent the absolute and relative number of each vehicle type. The information on these entries should be reliable as it can be directly found in the Environmental Declaration [[4]].

The last column depicts the technology standard, with SCR standing for Selective Catalytic Reduction, EGR for Exhaust Gas Recirculation and DPF for Diesel Particulate Filter. In this case we used a combination of standard technologies related to the Euro level and specific vehicle type information when that was available.

We tested the model using three different pollutants: NOx, PM10 and CO. The yearly results are shown in Table 2

The results appear reasonable overall; however, some peculiarities emerge. The compressed natural gas vehicles, even considering their large number, seem to be producing the lion's share of NOx and CO, despite producing less PM10. Similarly, the electric vehicles seem to produce more NOx and CO per unit than the Euro VI diesel. These apparent inconsistencies may arise from the model's estimating nature, issues in the original data (e.g., short trips between stops reported as simultaneous, affecting speed calculations), or the personal estimations involved due to limited data and expertise.

5 Conclusion

Overall, our work has derived some interesting insights into local public transportation in the municipality of Trento. Our mobility analysis identified areas that are more or less covered by public transport, with the train station emerging as the main hub for most bus lines.

We were also able to understand that the current policies employed by the service provider take into account particular points of interest, such as schools, universities, and hospitals, and their needs.

Our emission estimation analysis, despite being much less robust and precise due to the assumptions made by the author, still provides some rough estimates. Moreover, the code implementation of our model could be easily adapted by the public service

Table 2: Emissions by Euro Class and Fuel Type (in grams)

Pollutant	Euro I CNG	Euro III D	Euro IV D	Euro V D	Euro VI D	Euro EEV	Euro II CNG
NOx	92387.99 g	79563.48 g	1544.84 g	16838.37 g	9539.67 g	8051.87 g	225147.21 g
PM10	111.99 g	1574.53 g	12.44 g	128.96 g	102.94 g	22.19 g	150.10 g
CO	47033.89 g	20034.99 g	326.09 g	6035.79 g	4769.26 g	1957.69 g	40526.50 g

provider and utilized with more precise fleet data.

Finally, combining the two analyses could allow the identification of areas that are more impacted by public transit pollution. However, this estimate could be made more accurately with more data regarding which vehicle is responsible for which route.

References

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