Final Project Paper

Abstract

Urban mobility is not only a matter of infrastructure and efficiency but also of **social equity and territorial justice**. This paper investigates bike-sharing and public transport integration in Trento, adopting a computational social science perspective. Three research questions guide the study: (1) How are bike-sharing stations distributed in relation to the public transport network (GTFS, 2025)? (2) Which urban areas are underserved in terms of intermodality, i.e., lacking bicycle stations near high-frequency transit nodes? (3) How did weather conditions (ERA5, 2020–2022) shape mobility patterns captured by Google Mobility Reports, and who was most affected?

By combining geospatial analysis, Generalized Additive Models (GAM), and equity-oriented interpretations, we show that while central districts benefit from dense multimodal access, peripheral areas remain disadvantaged. Weather shocks exacerbate these inequalities, disproportionately impacting commuters and low-mobility groups. These findings highlight the importance of integrating **social justice, planning, and climate resilience** in urban mobility policy.

Introduction

Urban mobility lies at the intersection of **social behavior, environmental constraints, and infrastructural design**. In European mid-sized cities such as Trento, the integration of bike-sharing systems with public transport can promote sustainable commuting. Yet, accessibility is not evenly distributed: some neighborhoods remain underserved, amplifying social inequalities in access to mobility. At the same time, weather fluctuations — increasingly extreme in the context of climate change — impose further vulnerabilities.

This project leverages open data (Google Mobility Reports, ERA5 weather data, GTFS transport feeds, and local bike-sharing stations) to explore how spatial distribution, equity, and climate jointly affect mobility. Our aim is to frame bike-sharing not merely as a technical innovation but as a **social infrastructure** with consequences for fairness and resilience.

Literature Review

- **CSS and weather–mobility models (WISE 2016):** Demonstrates the value of integrating meteorological factors with mobility datasets using computational methods, grounding our modeling approach.
- **Equity and environmental impact (APAT):** Stresses how urban mobility choices shape environmental justice, underlining why underserved areas matter for both emissions and fairness.
- **Weather and bike-sharing (Remote Sensing):** Shows empirical evidence of weather's impact on bike-sharing demand, providing a comparative lens for our RQ3.

Together, these works guide our methodology and frame our contribution as a **historical-structural analysis**: we study pandemic-era (2020–22) behavioral data in relation to current (2025) infrastructure, showing how past vulnerabilities inform today's planning.

Research Questions

- **RQ1 (Distribution and accessibility):** How are bike-sharing stations distributed with respect to the public transport network (GTFS 2025)?
- **RQ2 (Underserved areas):** Which urban zones lack intermodal connections, i.e., bike stations near high-frequency transit stops?
- **RQ3 (Weather and social impact):** How do weather conditions (ERA5 2020–2022) affect urban mobility (Google Mobility Reports), and which groups are most impacted?

Data and Methods

- **Bike-sharing stations:** Geolocated points (2025).
- **Public transport (GTFS):** Urban + extra-urban routes (2025).
- **Weather (ERA5):** Daily series for Trento, 2020–2022.
- **Mobility (Google):** Community Mobility Reports, 2020–2022.

Methods

- **Spatial accessibility:** Buffer analysis (300m and 500m) around stations, accessibility indices.
- **Underserved areas:** Cross-referencing bike stations with high-frequency transit stops.
- **Mobility–weather models:** GAMs with smoothers for temperature/precipitation, categorical controls for weekdays, weekends, and holidays.
- **Equity framing:** Interpreting gaps not only technically but socially (which groups and neighborhoods are affected).

Results

RQ1 — Distribution and accessibility

Histograms and boxplots of intermodality indices (Figure 1, Figure 2) reveal strong centralization: central stations show high connectivity (top 5 stations have >15 stops within 300m), while peripheral ones cluster near zero. Maps (Figure 3) confirm that **central Trento is multimodally rich**, while suburban nodes lack access.

Table 1 lists the top 5 and bottom 5 stations by intermodality index, highlighting inequalities across neighborhoods.

RQ2 — Underserved areas

Spatial overlays (Figure 4) highlight underserved areas where **bus hubs lack bike-sharing integration**. Peripheral zones (north and south corridors) remain structurally disadvantaged. This spatial inequity points to **territorial justice concerns**: residents in peripheral districts face higher mobility costs and lower modal alternatives.

RQ3 — Weather and social impact

GAM results (Figure 5, Figure 6) show:
- **Temperature:** Moderate increases boost transit and workplace mobility, but extreme heat reduces it.
- **Precipitation:** Rain depresses both categories, with stronger effects on transit mobility.

Boxplots (Figure 7, Figure 8) confirm: heavy rain days see significantly lower mobility, with a disproportionate effect on commuters dependent on transit. Socially, this means **those with fewer alternatives (low-income, peripheral workers) bear the brunt of weather shocks**.

Discussion

1. **Equity and territorial justice:** The uneven distribution of bike-sharing reflects broader spatial inequalities. Peripheral residents, often with fewer resources, face systemic disadvantages in access to sustainable mobility.
2. **Integration and planning:** A coordinated expansion of bike-sharing near high-frequency transit nodes could close gaps and promote multimodal resilience.
3. **Climate adaptation:** Weather amplifies existing inequities, highlighting the need for adaptive infrastructure (covered bike docks, flexible schedules, incentives for resilient commuting).

Conclusions

This study demonstrates that **urban mobility in Trento is structured by inequities in space, access, and climate vulnerability**. Central zones enjoy dense intermodality, while peripheral districts remain underserved; weather shocks further marginalize commuters with few alternatives.

From a policy perspective, the findings argue for:
- **Equitable redistribution** of bike-sharing stations.
- **Targeted integration** at underserved transit hubs.
- **Climate-resilient mobility strategies** that protect vulnerable groups.

Ultimately, bike-sharing should be recognized not only as an environmental measure but as a **social justice instrument** shaping urban equity and collective well-being.

Figures & Tables

- **Figure 1.** Histogram of intermodality index (300m).
- **Figure 2.** Boxplot of intermodality index (500m).
- **Figure 3.** Map of bike-sharing stations and intermodality (300m).
- **Table 1.** Top 5 and bottom 5 stations by intermodality index.
- **Figure 4.** Spatial overlay of underserved transit hubs (no nearby bike-sharing).
- **Figure 5.** GAM partial effects of precipitation on transit mobility.
- **Figure 6.** GAM partial effects of temperature on workplace mobility.
- **Figure 7.** Boxplot of transit mobility under rain vs no rain.
- **Figure 8.** Boxplot of workplace mobility under heavy rain conditions.