Mobility in the Turano Valley: Understanding Movement Patterns Using Smartphone Data

1. Introduction

Human mobility is a fundamental aspect of modern life, influencing how cities are planned, how tourism is promoted, and how local economies develop. People's movements shape the way cities evolve, determine the efficiency of transportation systems, and influence the success of local businesses. The ability to understand human mobility patterns has significant implications for local authorities, urban planners, tourism stakeholders, and researchers alike.

Traditionally, human mobility has been studied using methods such as surveys, population censuses, and manual counts of travelers at specific points (like train stations or tourist hotspots). While these methods provide useful insights, they have several limitations. They only capture information at specific points in time, they are resource-intensive to conduct, and they struggle to capture the dynamic nature of human movement. In reality, people's movement is fluid and influenced by daily routines, seasonal changes, and special events.

This consideration is of key importance, as understanding the way people move within and across regions is a powerful indicator of social, economic, and tourism-related activities. It offers policymakers insight into how spaces are used, which can guide decisions on infrastructure development, tourism promotion, and sustainable planning.

In the context of tourism, understanding mobility patterns can inform more effective strategies for marketing, infrastructure development, and resource allocation. Knowing how tourists move, where they come from, and how long they stay enables local authorities to tailor experiences that attract and retain more visitors. The case of the **Turano Valley** in Italy provides an ideal use case for this type of analysis, as it is a scenic area known for its natural beauty, small villages, and historical charm. The valley relies on tourism as a key economic driver, and understanding human mobility in the region can support smarter planning and enhance the tourist experience.

1.1. Types of Mobility Data

The analysis of human mobility relies on the collection of large datasets that track the location and movement of people. Over the years, several methods have been developed to capture mobility data, each with its own strengths and limitations. The choice of data type depends on the nature of the study, the objectives of the analysis, and the level of detail required. Below are the main types of mobility data used in modern mobility studies.

Mobile Network Data is one of the most widely available sources of mobility data, as it is collected by mobile network operators. Every time a mobile phone connects to a cellular tower to make a call, send a message, or use mobile internet, the phone's location is recorded. This data provides information about a person's general location within a specific coverage area. However, the spatial accuracy of mobile network data is relatively low compared to other methods. This is because the phone's location is inferred from the location of the nearest cell tower, not the precise position of the user. In areas where cell towers are spaced far apart, such as rural or suburban areas, the location accuracy can range from 200 to 500 meters. For instance, in a small village, a person could be anywhere within a radius of several hundred meters from the tower, making it difficult to know their

precise position. Despite this limitation, mobile network data is useful for tracking large-scale regional and inter-city movements, particularly where higher precision is not required.

Another method for tracking human mobility is **Public Transport and Ticketing Data**, which comes from ticketing systems, fare card taps, and entry/exit records at transport hubs like bus stations, subway platforms, and train terminals. This type of data is especially useful for understanding commuter flows and public transport usage. It provides insights into how and when people use public transportation, which can inform improvements in transport schedules, capacity planning, and congestion management. However, public transport data only tracks the points where people enter and exit the system (like train platforms or bus stops), not their full journey. For example, if a person taps their card at a subway station and then exits at another station, only the entry and exit points are recorded — not the movement between these points. Moreover, this data excludes people who use private cars, bicycles, or walk, leading to a limited view of total human mobility.

Social Media and Crowdsourced Data is a newer and less conventional source of mobility data. When users post geotagged photos, share location-based status updates, or “check in” at specific places (like restaurants or tourist attractions), this information can be collected and analyzed. Social media platforms such as Instagram, Facebook, and Twitter are common sources of geotagged mobility data. This type of data is particularly valuable for identifying popular tourist spots, places of interest, and tracking event-driven movement, as people often post about festivals, parades, and public gatherings. However, the major limitation of social media data is that it is voluntary. Only users who actively post geotagged content are included, and many people do not share their location on social media. Furthermore, the data is sporadic, as users may only post once or twice during a trip, making it difficult to establish a continuous movement pattern.

The most accurate and widely used source of mobility data today is **GPS Mobility Data**, which is collected through GPS-enabled devices, primarily smartphones. Location-based applications like Google Maps, navigation tools, and weather apps track the precise position of users in real time. This data is collected continuously, providing a detailed record of where people move, at what time, and for how long. GPS data has high spatial accuracy, often within 1 to 20 meters, which makes it far superior to mobile network data in terms of precision. Unlike cell tower triangulation, GPS provides exact coordinates of a user's location, allowing for street-level tracking of movement. GPS mobility data can follow a person's movement in real time, making it possible to analyze how people navigate specific areas, such as parks, pedestrian walkways, and tourist hotspots. While this data has enormous potential, it requires users to enable GPS tracking on their devices, which may reduce the sample size. Privacy is also a key consideration, as continuous tracking of individual movements raises privacy concerns, but anonymization and data aggregation can address these issues.

1.2. A New Era of GPS-Driven Mobility Analysis

With the rise of smartphones, a new era of mobility analysis has emerged. Smartphones, equipped with GPS sensors, can track user locations in real time. Every time a person opens a navigation app, searches for nearby restaurants, or uses weather apps, their location is recorded. This data, aggregated and anonymized to protect privacy, becomes a powerful tool to analyze human movement. By analyzing this information, researchers and policymakers can now capture highly detailed and up-to-date views of how people move through cities, towns, and rural areas.

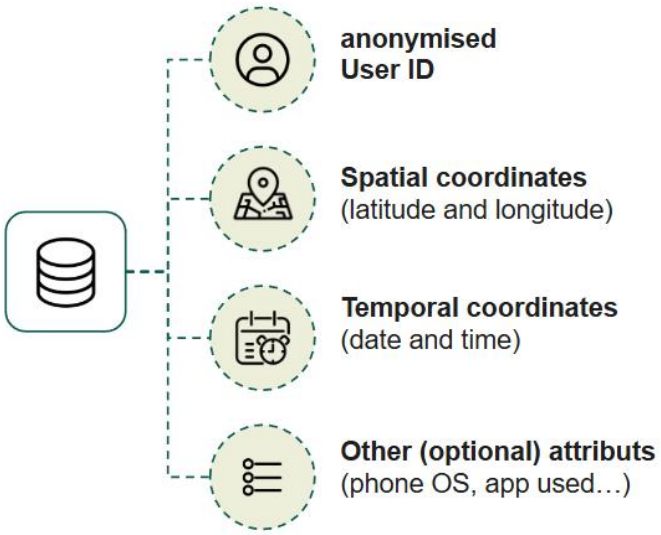
Unlike traditional surveys, this approach allows for **continuous, large-scale, and granular data collection**. Mobility data from smartphones provides several benefits. The **real-time insights** offered by GPS tracking allow for analysis of how movement patterns change daily, weekly, and seasonally. For example, researchers can observe how tourist numbers peak on weekends or how

traffic increases during weekday rush hours. The **high spatial precision** of GPS data enables precise location tracking at the street or building level, making it possible to identify the most visited tourist sites or areas of heavy foot traffic. Moreover, because this data comes from thousands or even millions of users, it provides a **large and diverse dataset** that captures the behavior of a broad cross-section of the population, as opposed to survey data, which relies on small sample sizes.

Generally speaking, GPS mobility data contains a raw collection of “pings” or data points. Each data point includes:

- **User ID** (anonymous and unique)
- **Spatial coordinates** (latitude and longitude)
- **Temporal coordinates** (date and time of the location)
- **Other optional attributes** (e.g., phone operating system, app used, etc.)

This data has high temporal frequency (up to every minute) and spatial accuracy (ranging from 1 to 20 meters), making it possible to analyze how people move in real-time.



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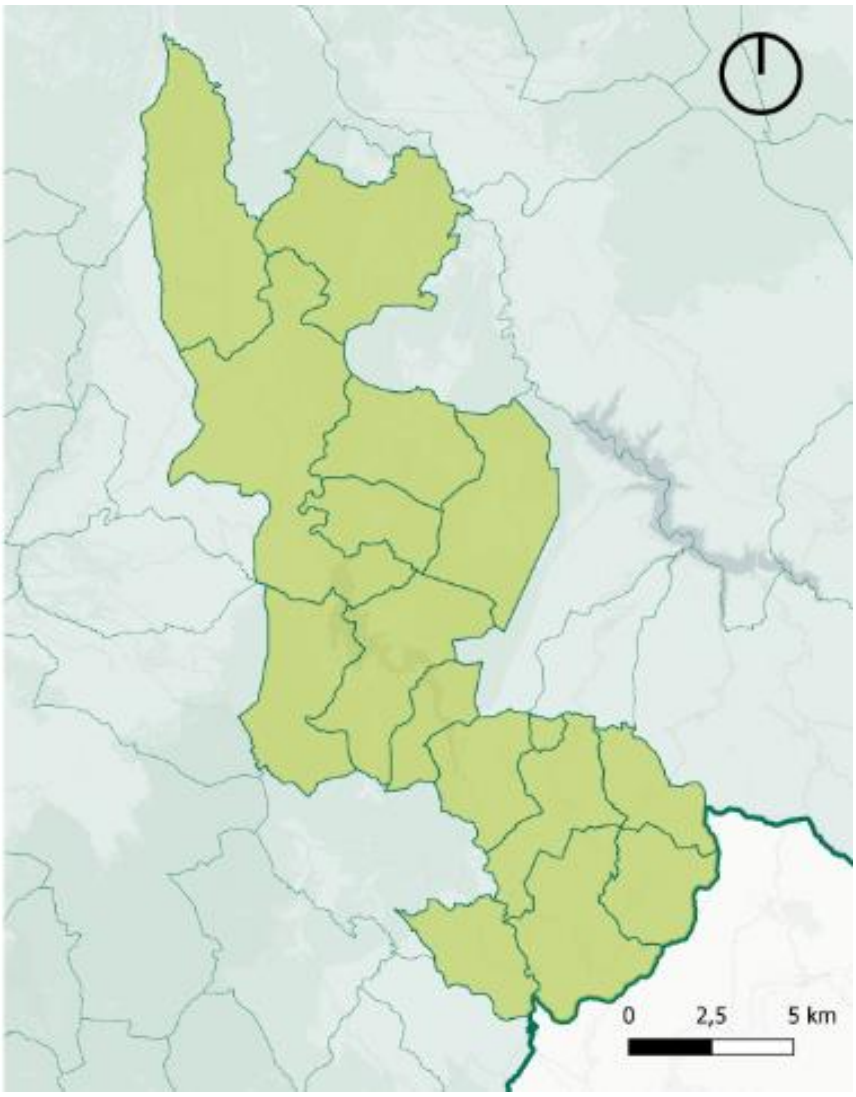
1884	38.90124	-77.0042	2022-03-22 02:11:55
1884	38.90084	-77.0042	2022-03-22 02:11:55

The continuous and accurate tracking provided by GPS data offers unique opportunities for tourism-related studies. In tourist destinations like the **Turano Valley**, local authorities and tourism boards can track visitor flows in real time, identify the most frequented tourist attractions, and determine how long visitors stay. This insight helps local governments and businesses tailor tourism services, such as improving facilities near high-traffic areas or creating personalized itineraries for tourists. GPS mobility data is also crucial for **sustainable mobility planning**, as it shows how people move within the valley and reveals whether they rely on private cars, bicycles, or pedestrian routes. This knowledge allows for better infrastructure planning, encouraging alternative modes of transport like walking paths, cycling routes, or shuttle buses.

2. Analysing Mobility in the Turano Valley

Known for its natural beauty, scenic landscapes, small villages, and historical charm, the Turano Valley, located in the Lazio region of Italy, attracts a diverse mix of tourists, weekend travelers, and local residents seeking a peaceful escape from urban life, making it an ideal setting to explore human mobility through smartphone GPS data. Indeed, this data allows for a fine-grained understanding of

which specific areas within the valley are most visited, how people navigate between municipalities, and how movements differ during weekdays, weekends, and seasonal holidays. This is crucial for several reasons. First, it enables local authorities to make informed decisions on tourism promotion, infrastructure planning, and economic development. By identifying the most visited areas, local governments can improve services such as parking facilities, transport options, and visitor centers. Secondly, it allows tourism operators to enhance visitor experiences by offering tailored services like guided tours, local events, or suggested itineraries. Thirdly, the information is essential for sustainable development, as it helps to manage tourism flow, reduce congestion, and promote the use of alternative transport methods.



2.1. The use case

The study of mobility in the Turano Valley is centered around a detailed analysis of movement patterns within and between the **11 municipalities** in the region, covering a total surface area of **210.55 km²**. These municipalities include small towns, rural settlements, and natural areas, each of which plays a unique role in shaping the overall mobility dynamics of the valley. While, according to census data, these municipalities host a population of **4,438 people** (which results in a low population density of **16.61 inhabitants per km²**), yet the area experiences significant inflows of

tourists and visitors throughout the year. This influx of people alters the movement landscape significantly, particularly on weekends and during special events. Given this context, it is particularly important to understand how external visitors (primarily tourists) contribute to the activity in the valley. This is why the analysis tracks not only local residents but also short-term visitors and tourists who come to the area for leisure, sightseeing, and cultural events.

2.2 The data

To capture the full range of movement patterns, the study used **GPS-based smartphone data collected over an 8-month period from April to December 2023**. The scale of this dataset is substantial, with approximately **964,960 unique users** recorded per month across Lazio, which accounts for **13% to 22.5% of Lazio's population**. Within the Turano Valley specifically, **72,111 unique users** were captured monthly, reflecting both resident movements and incoming visitors, and offering an unparalleled view of how people move in and out of the area. These figures highlight the valley's role as a prominent destination for visitors, with tourist numbers far exceeding the local resident population.

The use of GPS-based smartphone mobility data for the Turano Valley study was conducted with strict adherence to ethical principles and privacy regulations. By anonymizing personal data, aggregating user movements, and complying with the GDPR, this analysis ensures that no individual can be identified. Through transparency, oversight, and secure data handling, this approach achieves a balance between privacy protection and the need for valuable, actionable insights. For mode details on Privacy and Ethical considerations on the use of Mobility data, please refer to Section 5 of the current report.

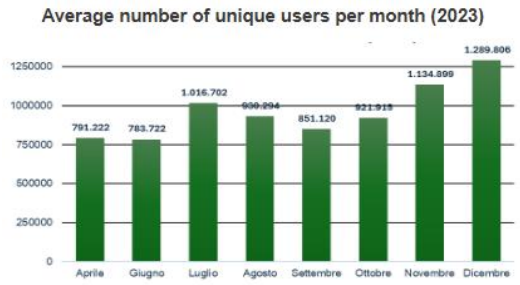
Mobility Data in Lazio for 2023:

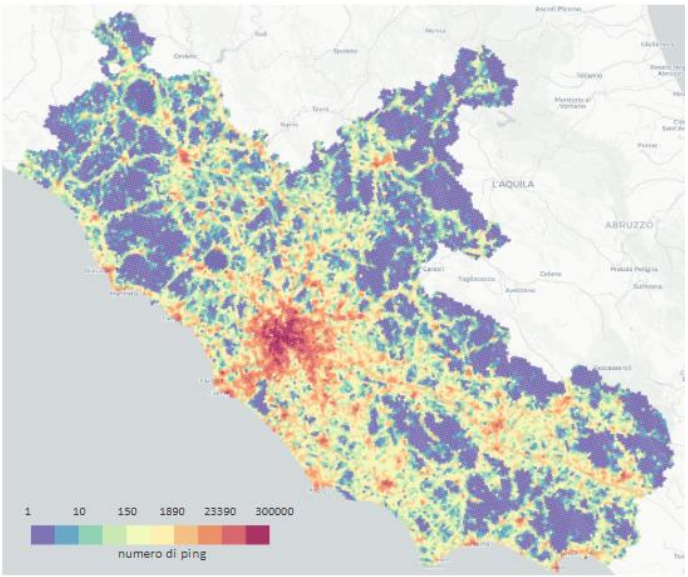
8 months of data (April - December 2023)

around 964,960 unique users per month

Representing 13% - 22.5% of the actual population of Lazio

72111 unique users in turano valley.





2.3 Key questions

To better understand the nature of human mobility in the Turano Valley, several core research questions were addressed. These questions target key aspects of human movement, focusing on the distinctions between **residents**, **visitors** and **tourists**. Residents are those whose daily movements are primarily within the valley, while tourists and visitors are those whose journeys typically start and end outside the valley and their permanence in the area might vary from few hours to few days. Each question is explored in detail in later sections of this report.

1. **Tourist Behavior: How long do tourists stay in each municipality?** Understanding the duration of tourist stays is crucial for tourism development and hospitality services. It reveals whether tourists are staying for short, one-day visits or longer multi-day stays. This insight is useful for local businesses, such as hotels, restaurants, and event organizers, as it indicates potential demand for accommodation and other visitor services.

2. **Resident Behavior: How do resident movement patterns differ from tourist patterns?** Resident movements typically reflect daily activities like commuting to work, school runs, and accessing local amenities. Understanding how residents move within and between municipalities helps local governments design better transport routes, create local bus services, and prioritize infrastructure development.

3. **Commuting Patterns: Where do residents of the Turano Valley go for work?** This question explores the role of commuting in shaping daily movement patterns. For instance, do most residents stay within the valley for work, or do they commute to nearby cities such as Rome or Rieti? This analysis provides valuable input for regional planning and transport policy. Commuter patterns can also inform decisions on the placement of new public transport routes or carpooling initiatives.

4. **Visitor Origins: Where do visitors to the Turano Valley come from?** By analyzing visitor origins, local authorities can better understand the "pull factor" of the valley. Are visitors coming from nearby cities, neighboring regions, or international destinations? This insight informs marketing campaigns and helps identify priority markets for tourism promotion.

5. **Seasonal and Event-Driven Mobility: How do seasonal trends, weekends, and special events influence the number of people in the area?** This question examines the impact of holidays, festivals, and special events on mobility. The analysis tracks how foot traffic changes during events like **Turano DiVino** or the **Sagra degli Strigliozzi**, revealing the role of tourism-driven events in boosting local economic activity. Seasonal analysis also identifies peak and off-peak tourism periods, helping businesses and local authorities manage demand and prepare for crowd surges.

3. Mobility in the Turano Valley: results of the analysis

3.1. Tourist Behavior: How Long Do Tourists Stay in Each Municipality?

Tourist behavior is a crucial indicator of the **economic impact of tourism** on the local economy. This is driven by multiple factors, including the availability of tourist accommodations, the presence of natural or cultural attractions, and the type of tourism activity taking place (such as leisure, nature-based exploration, or participation in local festivals and events).

3.1.1. Tourist Behavior by Day of the Week

Tourist behavior in the **Turano Valley** changes significantly between weekdays and weekends. The number of visitors increases sharply on Saturdays and Sundays, reflecting the influence of **weekend leisure travel** from cities like **Rome and Rieti**. However, certain municipalities maintain a steady flow of visitors even on weekdays, especially those with stronger tourism infrastructure or access to natural attractions. This distinction between weekday and weekend tourist activity reflects broader patterns of leisure tourism, family visits, and the movement of semi-residents returning to their second homes.

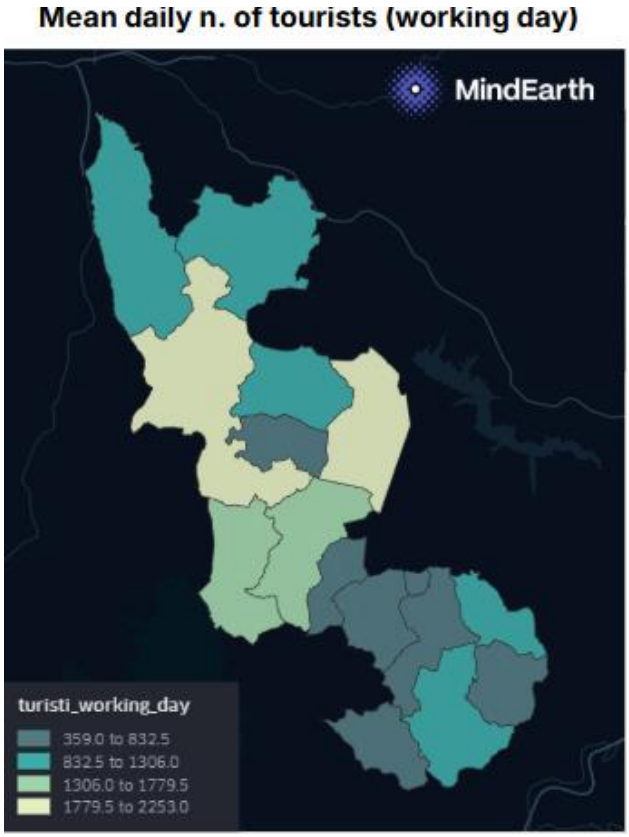
On **weekends**, tourist activity peaks, with more visitors arriving compared to weekdays. The **most visited municipalities during weekends are Rocca Sinibalda and Castel di Tora**, which see large crowds of visitors drawn by leisure activities, cultural events, and their proximity to **Lago del Turano**. These municipalities serve as major focal points for tourists looking for natural getaways, outdoor activities, and scenic views. Following Rocca Sinibalda and Castel di Tora, the municipalities of **Ascrea and Colle di Tora** also experience high visitor numbers during weekends.

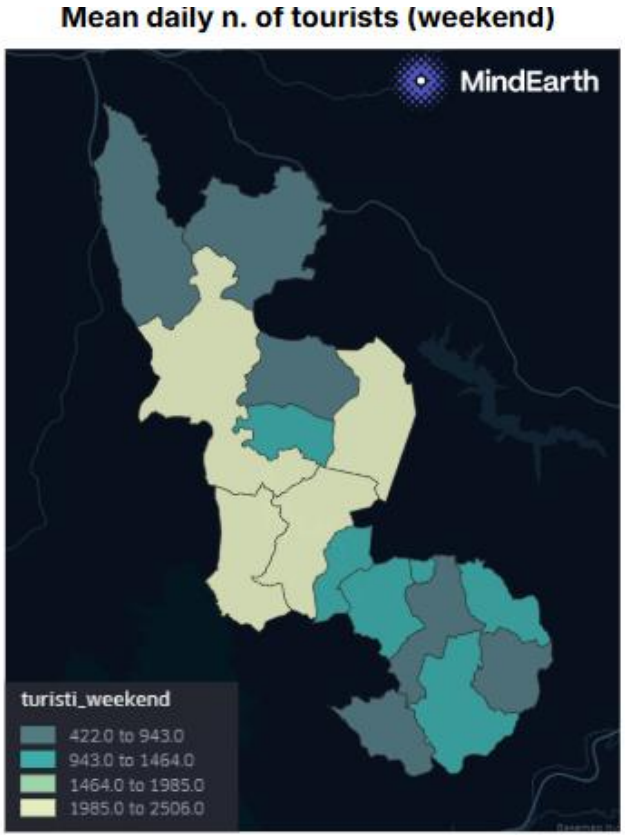
On **weekdays**, tourist activity is substantially less intense but remains consistent in several municipalities. The most visited municipalities during the week continue to be **Rocca Sinibalda and Castel di Tora**, followed by **Colle di Tora and Ascrea**. These areas maintain steady tourist activity during weekdays, although the volume of visitors is lower than during weekends.

This can be explained by several factors:

1. **Weekend Leisure Travel:** The increase in visitor numbers on weekends can be attributed to the role of the Turano Valley as a **weekend escape** for residents of **Rome, Rieti, and other nearby urban areas**. Many tourists visit the valley on Fridays or Saturdays, stay for one or two nights, and return home on Sunday. Municipalities like **Rocca Sinibalda, Castel di Tora, and Colle di Tora** are prime locations for this type of weekend tourism due to their proximity to the **Lago del Turano**, scenic views, and natural beauty.
2. **Role of Tourist Infrastructure:** Municipalities with better-developed tourist infrastructure, such as **holiday homes, agritourism facilities, and short-term vacation rentals**, experience higher numbers of tourists and longer stays. For example, **Castel di Tora** offers a wider range of lodging options, including hotels like **Hotel Turano** and several **Airbnb vacation rentals**, providing tourists with choices for 1-2 night stays. **Colle di Tora** has fewer accommodation options, with notable examples like the **C'era Una Volta Guest House** while **Rocca Sinibalda** features **rental properties and second homes** available on Airbnb, such as the **Almond Tree House**, which caters to longer stays and eco-tourism. In contrast, municipalities with fewer accommodation options see fewer multi-day tourists and rely more on day-trippers.
3. **Event-Driven Tourism:** The presence of **local festivals, fairs, and seasonal events** also explains the influx of visitors on weekends. While tourists may visit the valley for nature-based activities, local events can provide additional motivation for tourists to plan weekend visits. **Ascrea and Colle di Tora** often see spikes in visitor activity during community festivals, while municipalities like **Rocca Sinibalda** may host larger-scale events. Event-driven tourism tends to concentrate tourists over a short period, particularly on weekends, leading to large peaks in visitor numbers.
4. **Second Home owners:** Some visitors to the Turano Valley are not tourists in the traditional sense but rather **semi-residents** who return to their family homes on weekends. Many residents of larger cities, such as **Rome**, maintain second homes or family properties in the valley. These individuals may work in the city during the week but return to the valley on

weekends or during holiday periods. As they predominantly “live” in Rome, their movements resemble those of tourists, which increases the observed volume of weekend visitors.





3.1.2 Tourist Behaviour by duration of stay

The duration of a tourist's stay determines their level of interaction with local businesses, such as hotels, restaurants, cafes, and shops. Longer stays generally lead to greater contributions to the local economy, while shorter stays (e.g., day trips) result in lower spending. Typically, municipalities with more tourist accommodations (like hotels, agritourism stays, and holiday rentals) see longer stays, while areas with fewer accommodation options attract more day-trippers.

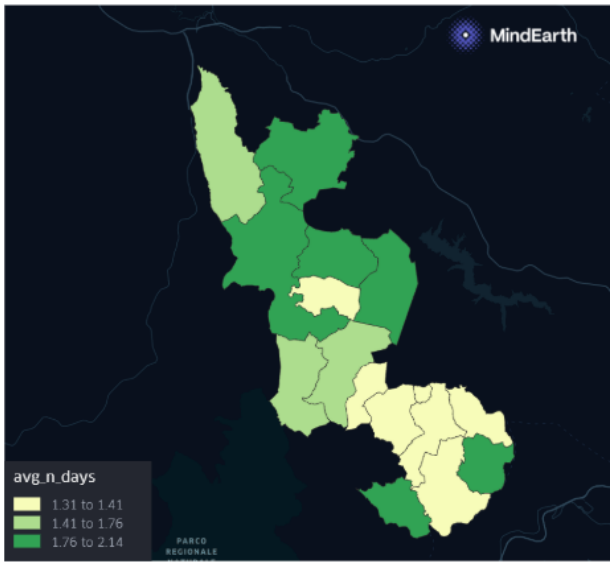
Tourist stay patterns in the **Turano Valley** differ significantly across its 11 municipalities, influencing the extent to which tourists engage with local businesses, such as hotels, restaurants, and shops. The duration of stay directly impacts the local economy, as longer stays lead to greater tourist spending on lodging, dining, and leisure activities. The analysis divides tourist stays into three categories based on the average length of stay: 1) **Day-tripper destinations** — municipalities where tourists stay for less than 1 day on average; 2) **Weekend getaways** — municipalities where tourists stay for more than 1 day but no more than 2 days; and 3) **Longer stays** — municipalities where tourists stay for more than 2 days.

Day-tripper destinations are typically associated with quick visits where tourists arrive, explore, and leave on the same day. However, according to the data, **none of the 11 municipalities in the Turano Valley have an average stay of less than 1 day**. While day-trippers certainly visit the area, they do not dominate the tourism landscape in any of the municipalities. This means that, on average, tourists spend more than one day in each of the municipalities, with no municipality falling into the day-tripper category.

The most common type of tourist stay in the valley is the **weekend getaway**, where tourists stay for 1 to 2 days. Eight municipalities fall into this category: **Ascrea** (1.33 days), **Belmonte in Sabina** (1.76 days), **Castel di Tora** (1.42 days), **Collalto Sabino** (1.41 days), **Colle di Tora** (1.46 days), **Collegiove** (1.31 days), **Paganico Sabino** (1.41 days), **Turania** (1.77 days). In these municipalities, the average tourist stay ranges from **1.3 to 1.8 days**, which means that most tourists spend at least one night in the area. This pattern aligns with typical weekend tourism, where visitors arrive on a Friday or Saturday, stay overnight, and leave on Sunday. In municipalities like **Collegiove (1.31 days)** and **Ascrea (1.33 days)**, tourists tend to stay for just one night. On the other hand, municipalities like **Belmonte in Sabina (1.76 days)** and **Turania (1.77 days)** experience longer stays closer to the 2-day mark, suggesting that tourists are staying for a full weekend before departing.

The final category, **longer stays**, includes municipalities where tourists stay for more than 2 days. Only three municipalities fall into this group: **Longone Sabino** (2.00 days), **Nespolo** (2.02 days) anf **Rocca Sinibalda** (2.14 days). These municipalities exhibit the longest stays in the Turano Valley, with tourists remaining for an average of **2 or more days**. Unlike short-term stays seen in other areas, tourists in these municipalities often remain for multiple nights. This suggests a deeper, more immersive engagement with the destination. While most tourists stay for only a weekend in the rest of the valley, tourists in these municipalities may stay for several nights, allowing for a broader range of activities and experiences.

Municipality	Average Stay (day)
Ascrea	1.33
Belmonte in Sabina	1.76
Castel di Tora	1.42
Collalto Sabino	1.41
Colle di Tora	1.46
Collegiove	1.31
Longone Sabino	2.00
Nespolo	2.02
Paganico Sabino	1.41
Rocca Sinibalda	2.14
Turania	1.77



Average Duration of Stay (days) of non-resident visitors

Several factors explain why no municipalities are dominated by day-trippers and why tourists stay for longer periods in certain areas of the Turano Valley. These factors include the nature of tourism in the area, the availability of accommodation, the influence of weekend leisure travel, and the impact of local residents who behave like tourists.

1. **Weekend Getaways, Not Day Trips:** Unlike typical tourist hotspots near large cities, the Turano Valley is seen as a place for **weekend escapes** rather than quick day trips. While day-trippers from **Rome and Rieti** certainly visit the area, many choose to stay for at least one night. This is due to the nature of the activities available in the valley. Visitors are drawn to experiences like hiking, lake activities, and rural relaxation, all of which require more than a few hours to fully enjoy. Instead of rushing to complete everything in one day, tourists are more likely to book a **weekend stay**. Destinations like **Castel di Tora** and **Colle di Tora**, which are close to **Lago del Turano**, encourage this type of tourism, as visitors are naturally drawn to stay overnight and enjoy the lake the following day. As a result, the recorded stay

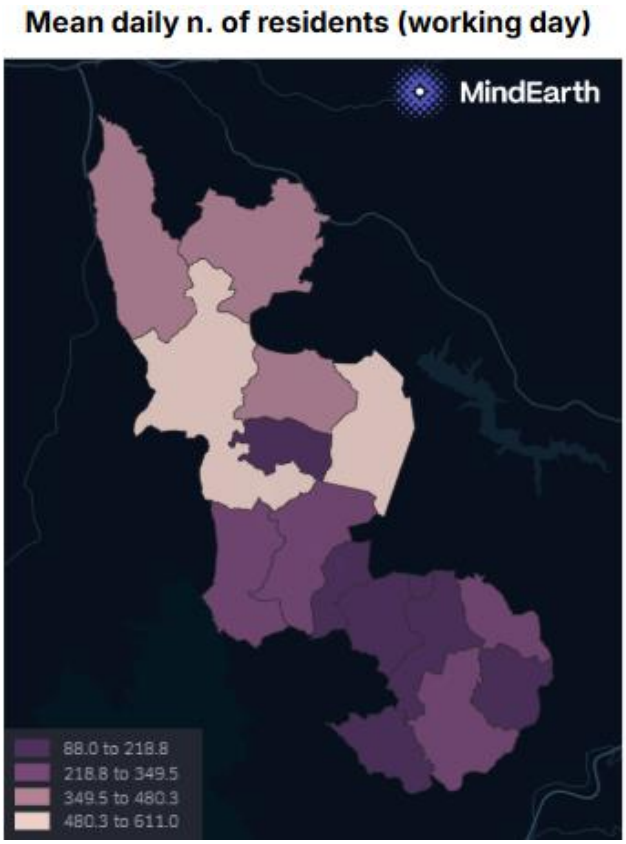
durations in these municipalities exceed one day, placing them in the "weekend getaway" category.

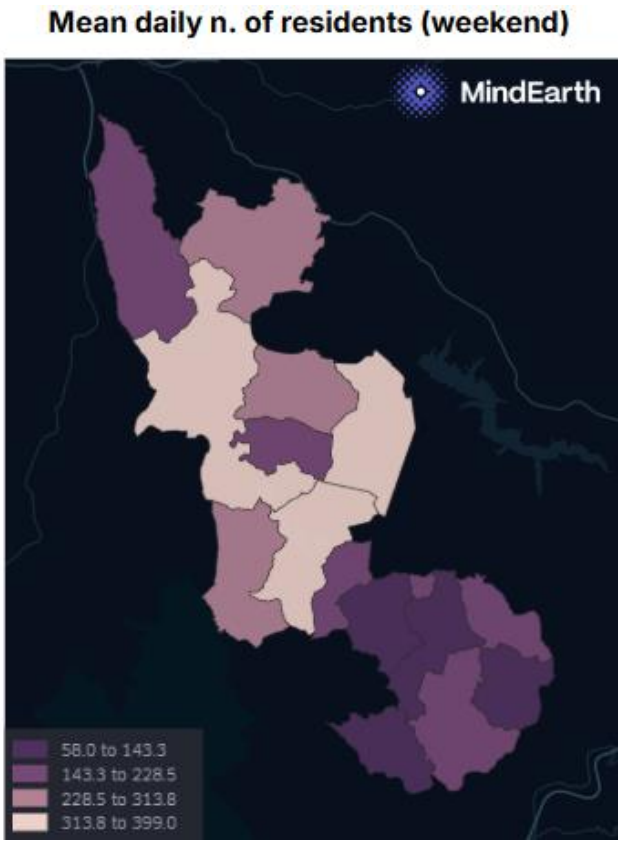
2. **Nature-Based Tourism Encourages Longer Stays:** The **nature-based tourism** model seen in the Turano Valley naturally promotes longer stays. Unlike visits to a single landmark, like a monument or a museum, nature-based tourism encourages slow, immersive exploration. Tourists may hike a trail on one day, relax by the lake on another, and then explore scenic viewpoints on the third day. These types of nature-focused experiences take more time to complete, leading tourists to book multi-day stays. This explains why tourists remain for **2 or more days** in municipalities like **Rocca Sinibalda (2.14 days), Nespolo (2.02 days), and Longone Sabino (2.00 days)**. Tourists who stay for multiple nights may also be more likely to explore several nearby municipalities, further increasing the average stay duration across the valley.
3. **Tourists May Stay in Nearby Municipalities:** Even in municipalities with few or no tourist accommodations, visitors may still spend multiple days in the Turano Valley. This is possible because tourists can stay overnight in one municipality while spending their day exploring others. For instance, a tourist might spend the day in **Collegiove** but sleep in **Castel di Tora**. Tourist mobility data often captures the presence of tourists in multiple municipalities, which can inflate the calculated stay durations in places where tourists do not actually sleep. This behavior makes it difficult to identify “day-tripper” municipalities because tourists may appear in several locations even if they only sleep in one. As a result, some municipalities may appear to have longer tourist stays than they actually do.
4. **Limited Accessibility for Day Trips:** For a location to attract high numbers of day-trippers, it must be easy to access for quick visits. However, the **Turano Valley is not well connected by public transport**, and access roads are not direct, making day trips less practical. Visitors from **Rome or Rieti** may find it inconvenient to visit and return home in a single day, especially if they want to enjoy activities like hiking or swimming. This discourages day-trip behavior and instead promotes weekend or multi-day stays. If tourists find it difficult to leave on the same day, they are more likely to stay overnight, thereby pushing the average stay duration for each municipality beyond the one-day mark.
5. **Not All "Tourists" Are True Tourists:** some of the people identified as "tourists" may not be tourists in the traditional sense. Mobility data captures movements of individuals between locations, but it does not distinguish between **true tourists** (people visiting a place for leisure) and **semi-residents** (people with local connections - e.g. family in the area, second homes - who regularly move between their home in a city and a residence in the valley) or even **part-time residents** (people who live and work in the city during the week but return "home" for extended weekends). This is a common pattern in rural areas close to major cities. Many individuals who work in larger cities, like **Rome**, maintain **second homes** or family residences in the Turano Valley. During the workweek, they live in the city, but on weekends, they return to their homes in the valley. While these people are not tourists, their presence is recorded as tourist activity since they are seen as "arriving" in the valley from a different location. Their movement is tracked in the same way as that of tourists. Since they often stay for one or more nights, their presence increases the average tourist stay duration.

3.2 Resident Behavior: How do resident movement patterns differ from tourist patterns?

Resident movements typically reflect daily activities like commuting to work, school runs, and accessing local amenities. Understanding how residents move within and between municipalities helps local governments design better transport routes, create local bus services, and prioritize infrastructure development. The movement patterns of **residents** in the Turano Valley differ significantly from those of tourists. While tourists primarily move during weekends or holidays, residents exhibit more **consistent movement patterns** throughout the week.

Certain municipalities, such as **Rocca Sinibalda, Belmonte in Sabina, Castel di Tora, and Longone Sabino**, have higher populations of permanent residents compared to others which show more fluctuation due to the arrival of short-term visitors. Few key points are observed throughout: first, that only a small population lives in the Turano Valley year-round; second that the number of *permanent* residents is lower than the number of visitors and third that there are residents that mask their behaviour as that of "*tourists*", returning only for short stays, resulting in fewer permanent residents remaining on weekends compared to weekdays.





3.3. Commuting Patterns: Where Do Residents of the Turano Valley Go for Work?

Commuting refers to the regular movement of people between their place of residence (home) and their place of work, typically following a daily or weekly pattern. This movement is a key aspect of human mobility and the analysis of commuting patterns offer valuable insights into **regional economic integration** and the connection between rural areas and larger employment hubs. For the Turano Valley, where local job opportunities are limited, this type of analysis plays a crucial role in understanding the relationship between rural and semi-rural areas like and nearby urban employment centers where many residents travel to for employment.

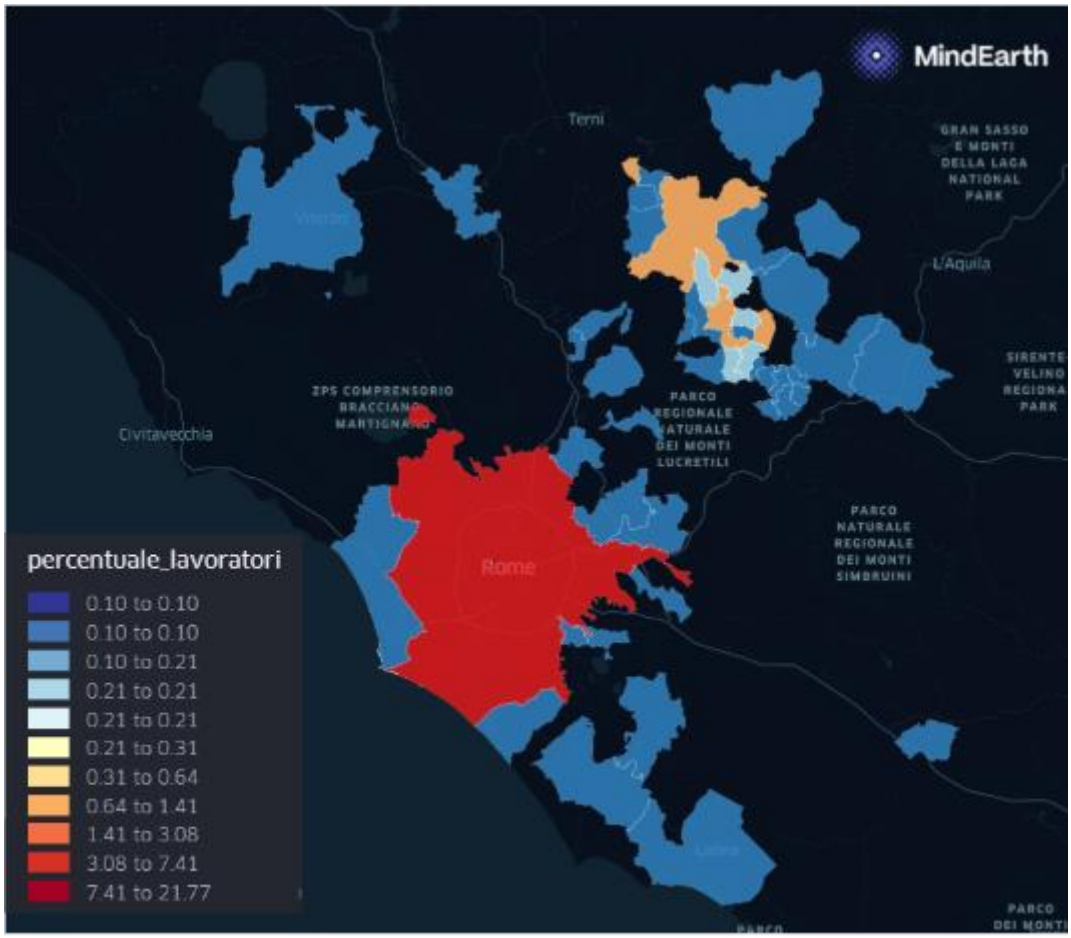
The analysis reveals that residents have two primary employment pathways: on the one hand, the reliance of the Turano Valley's workforce on **external employment hubs** and, on the other the

continued importance of **local job opportunities** within the valley itself. The largest share of commuting residents (21.7%) travel to **Rome**, the main economic hub of the Lazio Region. Rome offers job opportunities across a wide range of sectors, including **public administration, finance, education, retail, and services**. While commuting to Rome requires significant travel time and cost, it is justified by the variety of employment opportunities available. After Rome, Rieti serves as a secondary **provincial employment hub**, with approximately **13.3% of residents** commuting there for work. Because of its proximity to the Turano Valley, commuting to Rieti is easier, shorter, and more affordable than commuting to Rome. The analysis shows that only a **small share of residents** commute to other large cities in the Lazio Region, such as **Viterbo (0.3%)** and **Latina (0.2%)**. This is likely because these cities are located farther from the valley and would require significantly more travel time. While many residents commute to urban areas, a portion of the workforce is employed within the valley itself. Local employment opportunities are concentrated in **Rocca Sinibalda (14.6%)**, **Longone Sabino (8.0%)**, **Colle di Tora (7.2%)**, **Castel di Tora (7.1%)**, and **Belmonte in Sabina (6.55%)**.

While the analysis provides valuable insight into the employment destinations of Turano Valley residents, there are two important limitations that should be acknowledged. First, this analysis only considers employment destinations within the **Lazio Region**. As a result, commuting to areas outside of Lazio, particularly the nearby **Abruzzo Region**, is not included. Since **Abruzzo is geographically close to the Turano Valley**, it is possible that some residents travel there for work, but their movements would not be captured in this data. This limitation highlights the potential for **underestimation of work-related movement** to Abruzzo, especially in municipalities closer to the regional border. For a complete view of commuting patterns, future studies should consider including cross-regional mobility data.

The second limitation is that the present analysis assumes that commuting patterns are based on the classic definition of **"home-to-work"** commutes, as used in many mobility studies. This refers to the movement between a person's primary residence (home) and their place of work, usually captured by observing the most frequent start and end locations of daily trips during the week. However, in the context of the Turano Valley, this general assumption has limitations.

As seen before, many people in the Turano Valley may live in urban centers like **Rome during the week** (for work) but return to their homes in the valley on weekends. This group of people would not be captured by a standard "home-to-work" commute analysis because their weekday home is in a city, not in the Turano Valley, where they return to only on weekends. As these individuals behave like tourists, their commuting patterns may be misrepresented. This is especially relevant for municipalities with high numbers of second homes or weekend residents, such as **Rocca Sinibalda, Longone Sabino, and Castel di Tora**. Recognizing these limitations is essential for **transport planning and local development policies**, especially in supporting weekend flows of semi-residents and cross-regional commuting.



Destinations of Turano Valley Residents for Employment

3.4. Visitor Origins: Where Do Visitors to the Turano Valley Come From?

The origins of visitors reveal the **pulling power of the Turano Valley** as a tourist destination. By identifying where visitors originate, local tourism boards can design targeted marketing campaigns to attract even more tourists from high-potential regions.

The analysis of visitor origins reveals that the vast majority of people visiting the Turano Valley come from within the **Lazio Region**, with the largest shares of visitors coming from the **Rome Metropolitan Area (45.78%)** and the **Municipality of Rieti (12.12%)**. Together, these two areas account for over **half of the total visitors**, making them the most significant sources of tourism demand. Visitors from other municipalities across Lazio contribute smaller shares, with most municipalities accounting for between **0.1% and 5%** of total visitors. This distribution highlights the impact of **distance, transport access, and familiarity** on visitor flows to the valley.

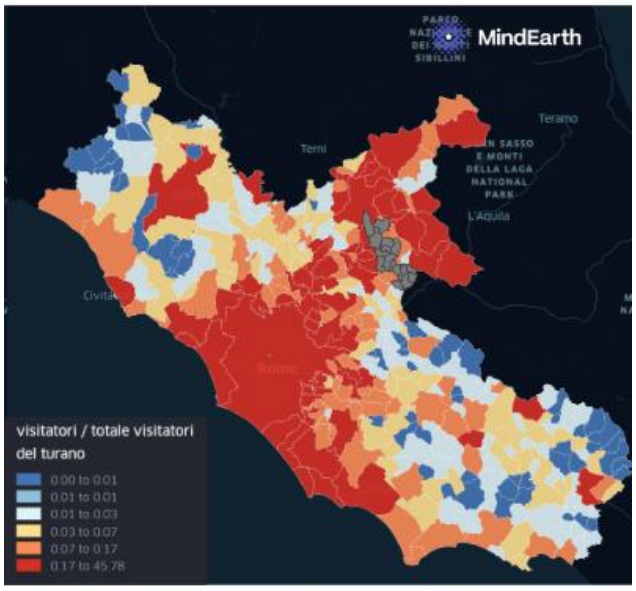
A complementary perspective on visitor origins can be gained by examining the **visitation rates relative to the populations of the municipalities** that send visitors. While municipalities with larger populations, like Rome and Rieti, naturally contribute higher absolute numbers of visitors, the relative engagement of smaller municipalities reveals another important dynamic. Small municipalities near the Turano Valley may send fewer visitors in total numbers, but when measured as a percentage of their local populations, the visitation rates are much higher. In some cases, as much as **5% to 100% of a municipality's population** has visited the valley at least once during the study period. This

perspective highlights the **dual role of the Turano Valley** as both a **weekend tourist destination for urban populations** and a **local recreational area for nearby communities**.

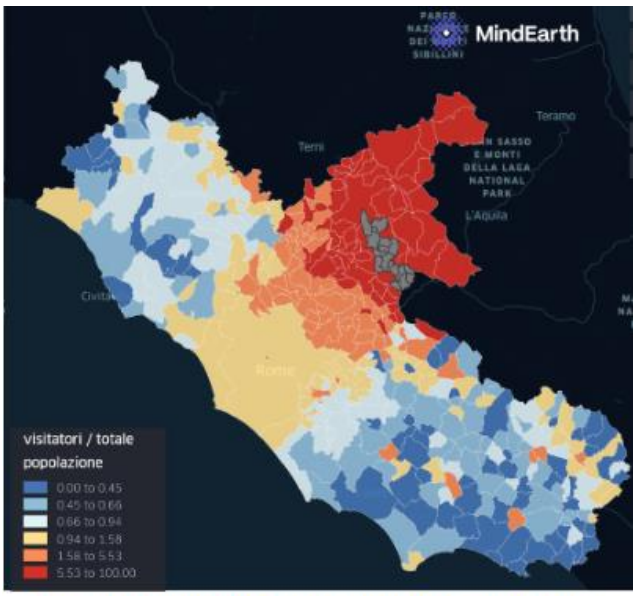
One of the most influential factors in determining where visitors to the Turano Valley come from is its proximity. People are more likely to visit destinations that are easier and faster to reach. The large share of visitors from **Rome** and **Rieti** reflects this concept. Residents of these areas have access to direct road connections to the Turano Valley, which makes travel convenient and efficient. For smaller municipalities in the Lazio Region, the connection to the valley depends on the quality of road access and the travel distance required. Municipalities that are closer to the valley contribute higher shares of visitors, while more distant areas contribute fewer visitors due to the higher travel time and cost.

Accessibility is another key driver of visitor origins. The quality and availability of road connections play a significant role in facilitating visitor movement. **Direct road connections** between the Turano Valley and major population centers like **Rome and Rieti** create easy travel routes, encouraging visits for leisure activities. The quality of transport routes also impacts smaller municipalities. Even if a municipality is geographically close to the valley, it may not contribute many visitors if road access is poor or indirect. This is why some municipalities that are physically close to the valley appear to send fewer visitors than more distant but better-connected areas.

One of the most distinctive insights from the analysis is the concept of **relative engagement**. By looking at visitation rates relative to each municipality's population, it becomes clear that smaller municipalities near the Turano Valley exhibit high engagement with the valley. While these municipalities may not send large numbers of visitors in absolute terms, their visitation rates relative to population size are significant. This perspective highlights the role of the Turano Valley as a **local leisure space** for surrounding communities, not just as a tourist destination for urban visitors. The valley acts as part of the **extended living environment** for these communities, offering a natural area for recreation, social gatherings, and family outings.



Municipality of origin of visitors travelling to Turano Valley relative to total visitors of the Turano Valley



Municipality of origin of visitors travelling to Turano Valley relative to the population of the municipality of origin

3.5. Special Events: How Do Seasonal Trends, Weekends, and Special Events Influence the Number of People in the Area?

Recurring trends, such as **seasonal tourism peaks,** and special events, such as **festivals** and **fairs**, play a major role in driving visitor numbers to destinations, as they attract large crowds and cause sudden spikes in movement. These patterns have a direct impact on **tourism flows, local congestion, and service demand**. Understanding these patterns is essential for local authorities to anticipate and manage fluctuations in the number of visitors and **plan for crowd control** and **traffic management.**

The analysis highlights how the number of people visiting the Turano Valley fluctuates significantly depending on **seasonal trends, weekends, and special events**. The analysis reveals that the most pronounced increases in visitor numbers occur during **summer (June to August)** and the **Christmas holiday season (late December to early January)**. These periods experience sustained high visitation, driven by family vacations, public holidays, and leisure tourism.

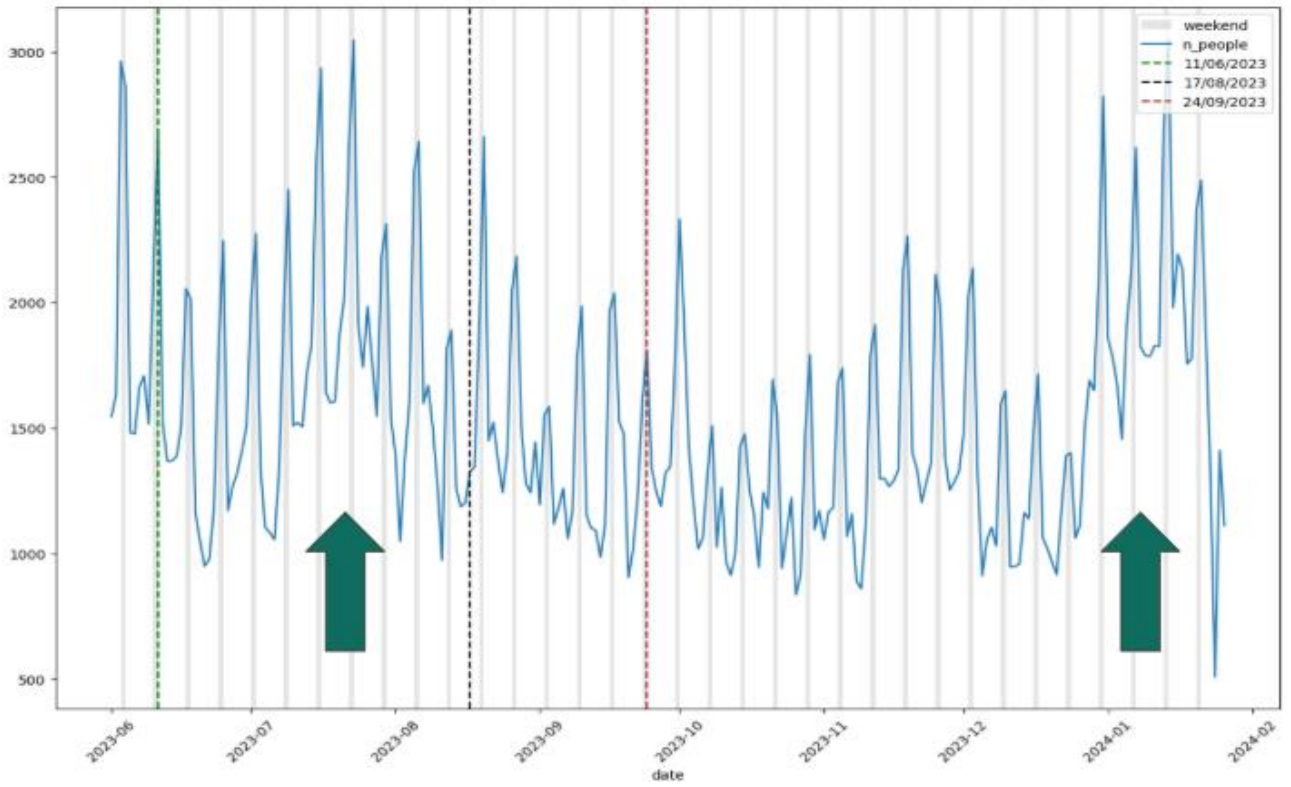
In addition to seasonal trends, clear spikes in visitor numbers are observed every **weekend**, especially on Saturdays and Sundays. The concentration of visitors during weekends is linked to short leisure trips made by residents of **Rome and other urban centers,** reflecting a pattern of weekend getaways, as well as returning part-time residents, as seen before, with peaks often starting on **Friday afternoon and lasting until Sunday evening.**

The role of **special events** in shaping visitor numbers was also analyzed. Three specific events were examined:

- **Turano DiVino** on **June 11, 2023** (Castel di Tora)
- **Mangiando Sotto le Stelle** on **August 17, 2023** (Castel di Tora)
- **Sagra degli Strigliozzi** on **September 24, 2023** (Castel di Tora)

Contrary to expectations, these events did not generate significant spikes in visitation beyond typical weekend fluctuations. While some increases in visitor numbers were observed, they remained comparable to normal weekend visitation. The **Turano DiVino** event on **June 11, 2023**, showed some additional activity, but it fell within the range of typical **weekday-to-weekend fluctuations**. This finding suggests that the natural draw of weekend tourism may be more influential than individual event promotions.

Despite this, the analysis of special events still provides insights into how to **distribute visitor flows more evenly**, for example by scheduling more frequent events during off-peak times to balance tourism demand. Local governments can also use this data to prepare for event-driven traffic surges by implementing **temporary traffic control measures**, increasing **parking availability**, and enhancing **public transport services** on key event days.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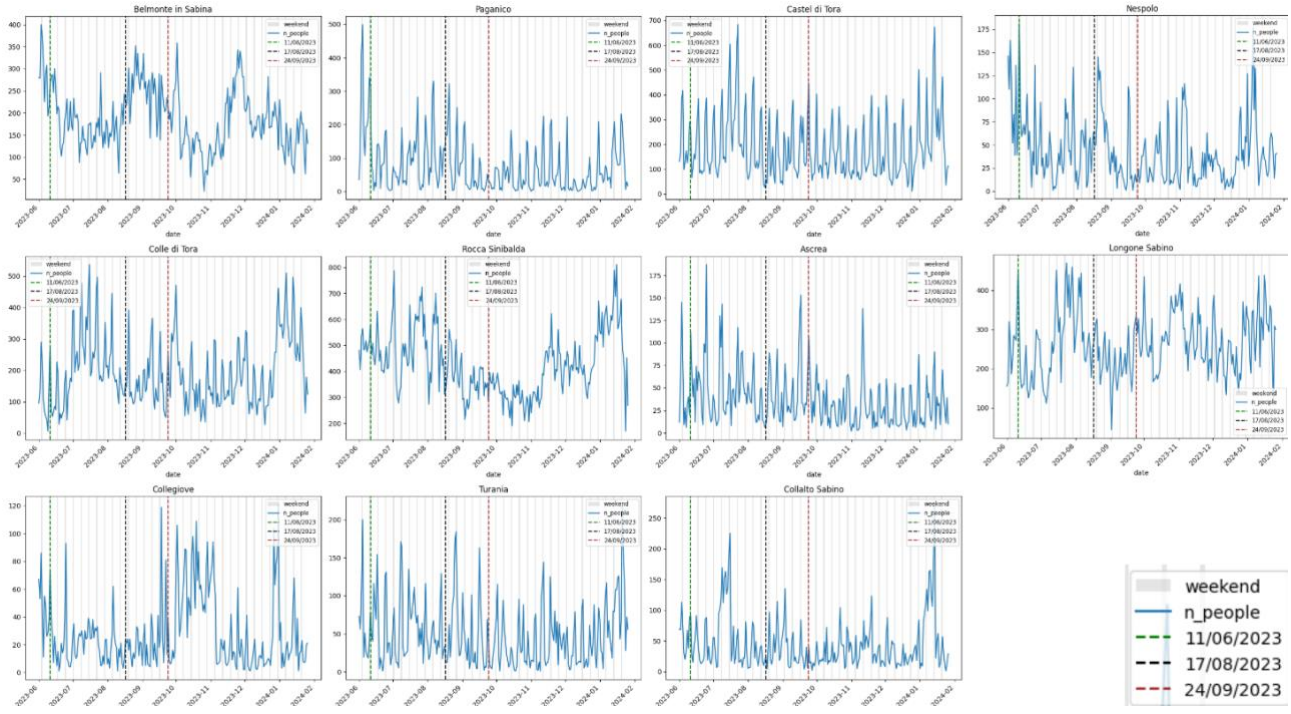
Belmonte in Sabina
Paganico
Castel di Tora
Nespolo
Colle di Tora
Rocca Sinibalda
Ascrea
Longone Sabino
Collegiove
Turania
Collalto Sabino
weekend
n_people
11/06/2023
17/08/2023
24/09/2023

4. Next Steps

Based on the analysis of human mobility in the Turano Valley, a set of **next steps and strategic recommendations** has been identified. These actions aim to improve **tourism management, infrastructure planning, local economic development, and visitor experience**. By addressing the insights gained from data on tourist behavior, resident movement, and event-driven traffic, local authorities, tourism operators, and stakeholders can make informed decisions that benefit both **visitors and local communities**.

1. **Improve Visitor Management and Traffic Flow During Peak Periods:** The analysis revealed that visitor peaks are driven by **seasonal trends, weekend effects, and the presence of special events**. These peaks result in **congestion, parking demand, and crowding**. Possible actions include:
    - Introduce temporary traffic flow measures during peak weekends, holidays, and special events. These could include **one-way traffic routes, dedicated event parking zones, and temporary speed limits**.
    - Set up a **digital visitor dashboard** to provide real-time information on crowding, parking availability, and weather conditions. This would help tourists plan their visits and avoid overcrowded areas.
    - Actively promote visits during weekdays and off-peak seasons (e.g., spring and autumn) by organizing events and launching **off-peak tourism campaigns**. This strategy would help distribute visitor flows throughout the year and reduce weekend congestion.
2. **Diversify Tourism Offerings to Encourage Longer Stays:** The analysis identified distinct categories of visitors based on their length of stay: **day-trippers, weekend tourists, and multi-day visitors**. While many visitors only stay for a day or two, encouraging longer stays could result in higher **local economic benefits**. This could be achieved by diversifying the types of activities, accommodations, and events offered. **Key actions include:**
    - Create and market **thematic travel packages** (e.g., hiking tours, cultural trails, and wellness retreats) that require tourists to stay for multiple nights. By encouraging longer stays, local businesses (hotels, restaurants, and shops) will benefit from increased visitor spending.
    - Support the development of **new accommodation facilities**, such as small hotels, agritourism stays, and vacation rentals. Local authorities could offer **incentives to private investors** to increase the availability of tourist lodging in municipalities that currently rely on day-trip tourism.
    - Given the appeal of nature tourism, local stakeholders could introduce new recreational activities like **guided hiking tours, cycling routes, and adventure sports** to attract tourists looking for immersive experiences.
3. **Leverage Semi-Resident Presence for Economic Development** The analysis revealed that people with second homes in the valley or people that live in working hubs during the week and come back home during the weekend play a role in shaping local tourism flows. While they behave like tourists, their connection to the valley is deeper, and they provide a **stable source of income** for local businesses. Engaging this group could strengthen the local economy while fostering a stronger sense of community. Possible actions in this sense include:
    - Develop a platform to facilitate **short-term rentals** for second-home owners. This would increase available accommodation for tourists while allowing owners to generate income from their properties.

- Develop **"Return Home" weekend events or festivals** specifically targeting semi-residents. These events could encourage semi-residents to engage in community life, spend more time in the valley, and contribute to local economic activity.
- Encourage semi-residents to participate in **local decision-making** and community planning activities. Their dual status as "visitors" and "residents" makes them valuable stakeholders in shaping the future of tourism and development in the valley.

4. **Optimize the Impact of Special Events on Visitor Flows:** The analysis of special events, such as **Turano DiVino, Mangiando Sotto le Stelle, and Sagra degli Strigliozzi**, showed that while these events attract visitors, they do not generate significant surges beyond normal weekend traffic. To increase the impact of events on visitor numbers, event planning and promotion must be **better aligned with visitor motivations and local tourism flows**. In particular:
   - Schedule major events during **shoulder seasons (spring and autumn)** to attract visitors during periods of lower demand. This approach could help balance tourism flows, reduce peak season congestion, and extend the tourism season.
   - Use digital marketing campaigns to attract a wider audience, particularly from **Rome, Rieti and other urban centers**. Campaigns could highlight the unique experiences offered at local events, such as culinary experiences, traditional festivals, and cultural exhibitions.
   - Involve local restaurants, agritourism operators, and small businesses in event planning to create **event-linked packages and exclusive offers** for event attendees. This would strengthen the local economy while enhancing the visitor experience.
5. **Enhance Local Mobility and Commuting Options:** The analysis revealed that **many residents commute to urban centers** for work, particularly to **Rome and Rieti**, while others engage in local work within the valley. While it was reported via interviews with residents that most people rely on private vehicles and public transport is not sufficiently efficient to be considered as a viable alternative option, ensuring **sustainable transport options** and addressing commuting challenges could improve residents' quality of life while supporting tourism-related movement. Notably:
   - Advocate for improved **regional bus routes and public transport connections** from the Turano Valley to major employment hubs. Better connectivity would reduce travel times, support commuter movement, and create new tourism opportunities.
   - Introduce **eco-friendly mobility options**, such as e-bike rentals, electric shuttles, and walking tours. These initiatives could reduce congestion and support **sustainable tourism goals**.
   - Develop **seasonal parking management systems** in municipalities like Castel di Tora, where demand for parking is highest. Options could include temporary parking lots, shuttle services, or dynamic pricing for parking fees during peak periods.

5. Privacy and Ethical Considerations

The analysis presented in this report relies on data collected from GPS-enabled smartphones. While the use of smartphone data offers significant benefits in terms of spatial accuracy, temporal granularity, and the ability to track human movement continuously, it also raises important ethical and privacy considerations. Ensuring the responsible use of personal location data is paramount, especially when dealing with sensitive information about people's movements. This section outlines the key aspects of data collection, anonymization, aggregation, and compliance with privacy regulations.

5.1. Data Collection Process

The data used in this analysis was sourced from smartphone applications that rely on location-based services. These applications, which may include navigation tools, weather apps, ride-hailing apps, and social media platforms, require users to grant permission for location tracking. Once permission is granted, the app continuously collects GPS data in real time as users move from one location to another. This data is transmitted to a secure server where it is processed and aggregated to ensure privacy.

The key information captured during data collection includes:

- **Location coordinates** (latitude and longitude) with high spatial accuracy (1 to 20 meters)
- **Timestamps** indicating when the movement occurred
- **Movement trajectory** showing the path of users as they travel
- **Device ID** (anonymized) to distinguish one user’s journey from another

While this raw data provides a granular, real-time view of human mobility, it also introduces risks related to privacy and data protection. Without proper safeguards, the continuous collection of location data could potentially be used to track individual users, revealing where they live, work, or visit frequently. To mitigate these risks, ethical protocols are followed to protect user privacy, as outlined below.

5.2. Anonymization of Data

A key pillar of ethical data collection is **anonymization**, which ensures that the identities of individual users cannot be traced from the data. The process of anonymization involves removing or masking any identifiers that could link a data point to a specific person. In this analysis, several steps were taken to achieve anonymization:

1. **Removal of personal identifiers**: Direct personal information such as name, phone number, or email address is not collected at any stage.
2. **Anonymized device IDs**: The unique device IDs used to track movements are scrambled, hashed, or replaced with random identifiers that cannot be traced back to the user's device.
3. **Location smoothing and blurring**: In certain cases, exact coordinates may be generalized or "blurred" to reduce precision, especially in sensitive areas like residential neighborhoods, hospitals, or places of worship.
4. **Limited data retention**: Data is not stored indefinitely. After the analysis is complete, raw data may be deleted to further protect user privacy.

These measures ensure that while researchers have access to useful information on population-level movement patterns, it is impossible to track, identify, or re-link the data back to any specific individual. Even if an unauthorized party were to access the dataset, the lack of identifiable information would prevent them from determining who the data belongs to.

5.3. Aggregation of Results

Beyond anonymization, **data aggregation** is another essential safeguard for privacy. Aggregation involves combining the movement data of multiple users into larger, collective units, such as summary statistics, counts, or density maps. Instead of tracking individual journeys, the data is grouped to show general patterns, like the total number of people visiting a tourist destination or the density of movement within a specific area. The aggregation process works as follows:

- **Spatial aggregation**: Instead of displaying precise user coordinates, the data is grouped **into** larger spatial units (such as 100m x 100m grids) or into polygons corresponding to administrative regions (like municipalities or neighborhoods).
- **Temporal aggregation**: Movement data is combined across time intervals (e.g., hourly, daily, or weekly) to provide insights into patterns over time, such as peak travel hours or weekend tourism surges.
- **Data filtering**: Only movements above a certain volume threshold are reported. For example, if only one person visits a location, that data point may be suppressed to avoid the possibility of re-identification.

Aggregation allows for the analysis of large-scale patterns while eliminating the need to track individual user movements. For instance, instead of focusing on "User A went from Point X to Point Y at 10:30 AM," aggregation reveals trends like "200 people traveled from X to Y on Monday morning." This ensures that privacy is maintained while still providing valuable insights for policymakers and planners.

5.4. Compliance with Data Privacy Regulations

The collection and analysis of smartphone mobility data are subject to strict legal and regulatory frameworks. One of the most prominent and influential regulations is the **General Data Protection Regulation (GDPR)**, which governs data privacy and protection for all citizens of the European Union (EU). Since this analysis was conducted in the context of the Turano Valley, located in Italy, compliance with GDPR was a legal requirement.

The **General Data Protection Regulation (GDPR)** mandates that personal data be collected, processed, and stored with specific safeguards to protect the privacy of individuals. It defines personal data as any information that could directly or indirectly identify a person, such as names, phone numbers, and precise geolocation data. For mobility data to comply with GDPR, the following key principles must be observed:

1. **Lawful processing**: Data collection must be justified by a lawful basis, such as the user's explicit consent or a legitimate interest in improving public services or research.
2. **Data minimization**: Only the minimum data necessary for analysis should be collected. For mobility studies, this means collecting only the latitude, longitude, timestamp, and anonymized device ID, while excluding unnecessary details.
3. **Transparency and user consent**: Users must be informed when their data is being collected, and they should be able to opt out of tracking. Many apps provide this option through their privacy settings.
4. **Right to erasure ("Right to be forgotten")**: Users can request that their data be deleted from the system, ensuring that no information linked to their movements remains in the dataset.

5. **Data security and protection**: Mobility data is encrypted and stored on secure servers to prevent unauthorized access. Strong cybersecurity measures ensure that data breaches are avoided.

5.5. Ethical Considerations in Mobility Analysis

Beyond legal compliance, ethical considerations play a critical role in ensuring responsible use of mobility data. Ethics go beyond the letter of the law and address broader questions of fairness, accountability, and transparency. Several ethical principles guided the design and execution of this analysis.

1. **Avoidance of bias and discrimination**: Data collection should not lead to biased outcomes or discrimination against certain groups. For example, movement patterns in low-income neighborhoods should not be used as a basis for increased surveillance or policing.
2. **Transparency and accountability**: Stakeholders (like governments and local authorities) must be transparent about how data is used. Users should be aware that mobility data is being analyzed and for what purpose. In the Turano Valley study, the primary objective was to support tourism development, local economic growth, and transport planning, with no commercial interest in tracking individual users.
3. **Privacy by design**: Ethical data use is achieved by designing systems with privacy in mind from the outset. Privacy-enhancing technologies (like encryption, anonymization, and aggregation) were embedded in the analysis process.
4. **Data stewardship and oversight**: Organizations handling large-scale mobility data have an obligation to establish oversight processes, ensuring that data is used responsibly. This may include internal audits, third-party assessments, or consultation with data protection authorities.