

# Exploring Mobility in Rural Areas. A Case Study in the Marche Region's Central Apennine

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**Abstract.** This study investigates the critical role of rural mobility in combating the risk of rural abandonment and facilitating the re-population of the pilot inner area of the Marche Region, Italy, for the Italian National Strategy for Inner Areas (SNAI). The research delves into the primary reasons behind residents' mobility, including daily needs, socializing, work, and leisure, spanning municipalities and nearby urban areas. Using qualitative and quantitative methods alongside tools like QGIS, Komoot, Moovit, TomTom, and Python, the study aims for a thorough analysis and evaluation of current mobility patterns. It seeks to reveal detailed insights into travel behaviors, including off-peak private vehicle usage, peak travel times, and trip lengths, with the goal of highlighting critical conditions and potential opportunities for redevelopment strategies. Ultimately, the study aims to contribute to evaluating the region's transportation infrastructure and identifying areas for improvement. Furthermore, it explores alternatives, such as micromobility options, to effectively substitute short-distance trips, thereby fostering sustainable rural mobility practices that will help re-inhabit the region.

**Keywords:** Rural areas · inner areas · sustainable mobility · Marche region Central Apennine

## 1 Introduction

Mobility in rural areas is a topic that has been left behind in discussion and research as compared to mobility in urban areas. The rural areas have been facing the issue of mobility for decades. The public transport options cannot satisfy the user demands, and the public transport operators themselves are not willing to offer them any transport options due to some reasons. Their scattered and uneven distribution of the population, low population density, low travel distances, and low demand for transport make it very difficult for public transport operators to offer them any public transportation because it's not economical for them. One of the factors that affect the demand for rural areas is the seasonality of the tourists that visit rural areas at specific times of the year, which creates problems and challenges for responding to the needs of the residents with sustainable and efficient public transport as an alternative to private cars. The seasonality

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also affects the actual demand for transportation. According to Robertson, seasonality in the transportation sector has a number of significant and varied effects, some of which include traffic jams on major thoroughfares, infrastructure damage, extreme pollution, energy loss, longer travel times, harm to historical sites, and low-quality services for tourists [1]. Thus, managing seasonal traffic peaks well is crucial to preventing a decline in tourism in these areas and, consequently, preserving the high revenue generated by the tourism industry [2].

Most rural residents need transportation for healthcare purposes, groceries, education, shopping, social life, etc., which remains unmet or the possibility of meeting those needs is limited. Due to limited mobility options, residents in rural areas mostly use their own cars. Residents with reduced mobility are the most affected group. Rural communities in the United Kingdom have become more dependent on privately owned cars as a result of a reduction in investment in public transportation. This has led to an increase in carbon emissions per passenger per kilometer (DfT, 2020), car trips per person (33% more than the national average), and miles traveled per person (66% more than urban cities and towns). While having a look at the Italian data, approximately four fifths of Italians own at least one automobile. Since the economic boom and the introduction of the Fiat 500, cars have been an essential aspect of Italian culture and daily life. As a matter of fact, the majority of Italians commute to work using private vehicles [1]. According to Eurostat data, there are 684 passenger cars per 1000 inhabitants in Italy in 2021 [3].

Regarding the transport policies for rural areas, there has been no specific attention given to rural and mountainous areas in the transport policy so far. Furthermore, the orientation given for EU mobility in the 2011 white paper is specific for urban mobility; there is no specific policy orientation document for rural mobility. Indeed, in the new 2014–2020 programming period, rural mobility does not appear as a priority, neither in the general strategy of EU2020, nor in the rural development policy or the cohesion policy [2]. There is neither a policy for rural mobility at the European level nor any obligation for member states to have such a policy [4]. Currently, the EU is starting a project about sustainable mobility policies in rural areas with the title “A long-term vision for the EU’s rural areas up to 2040.” The objectives of this initiative are: 1) Sustainable multimodal mobility best practices for rural areas will be developed to support rural municipalities in identifying best practices and replicating them in their territory, 2) Rural digital futures will address digital connectivity issues by closing the gap between rural and urban areas, encouraging digital innovation and the use of new technologies, boosting new competencies needed for the digital transformation, and measuring progress towards closing the digital gap [5].

This study aims to delve into the transport infrastructure of the selected Apennine region, evaluating the utilization of various mobility options by residents, and identify gaps for future intervention and improvement. By conducting an in-depth analysis of transportation patterns, infrastructure limitations, and community needs, this research seeks the complexities of rural mobility.

## 2 Literature Exploration

A person's ability to access employment, education, services, society, and all other aspects of their existence is known as their "mobility." Stated differently, one of the most important factors that makes a community function is mobility, particularly in rural areas where a lot of necessities are spread out across a large area. Increasing the availability of environmentally friendly transportation options can also significantly aid in climate change mitigation. Nonetheless, policymakers have given rural mobility far less consideration than urban mobility, and many metropolitan regions suffer from a severe lack of both traditional transportation and the different shared mobility options available. In many rural places, the fact is that there are very few train stations, few buses, and a near entire reliance on cars. People are compelled by this to travel more expensively and to utilize private transportation instead of more environmentally friendly options [6].

The lack of transport infrastructure and mobility options can lead to a high number of residents migrating from rural areas [7]. In order to reduce social exclusion and youth migration from rural areas, better transport options are essential [8–10].

In the modern world, owning a private vehicle is largely necessary for mobility. Social inclusion and employment opportunities are severely limited for anyone without a car, according to Soder and Peer [11]. The flexibility that a car offers is something that neither public transportation nor car sharing can match, according to Berg and Ihlström [12]. Vern and Taegen [13] assert that the dearth of public transportation makes owning a car essential. Despite the fact that owning a car is frequently the only option available to replace public transportation, less well-off rural residents also have trouble using this form of transportation [14]. A person who does not own a car is more likely to experience social exclusion [15]. Lower-class people frequently live in rural areas. They spend a sizable amount of their income on transportation, which creates a financial barrier to mobility. Additionally, low-income households are more likely to live in suburban areas with little access to public transportation [16, 17]. To keep low-income people from being excluded and to increase their mobility, a variety of financial supports are available [18]. People with low incomes seem to find financial incentives especially appealing [19]. It is important to remember, though, that low-income citizens of small towns and rural areas also have fewer needs when it comes to daily travel and commuting to work [20].

Furthermore, senior citizens' concerns are an important topic of mobility research since they are frequently the majority population in rural areas. Elderly people are a group that needs extra care. Older people exhibit low levels of activity and are typically accustomed to the mobility conditions in their community [21]. A study by Varadi [22] claims that elderly people have a variety of needs. Owing to the particular requirements of that specific group of people, there is a lot of interest in unique forms of transportation, particularly on-demand options that can hold multiple passengers at once. The lack of infrastructure and public transportation options that suit the needs of the elderly, especially those with disabilities, is one of the factors contributing to their low mobility. Seniors' use of public transportation is primarily driven by social and health-related factors, such as shopping, medical appointments, and rehabilitation [22]. As per the research conducted by Shergold and Parkhurst [23], the elderly in rural areas had trouble getting to service places such as specialized hospitals or movie theaters. An increased risk

of social exclusion is linked to living in a rural area and becoming older; an increasing number of elderly people also mention the growing inaccessibility of transportation options.

Some researchers suggest alternative solutions for rural areas; demand responsive transport is one of them. In urban and suburban areas, Demand Responsive Transport (DRT) serves as a feeder service for local public transportation (PT), making it a viable alternative to expand the reach of PT [24–26]. When PT is completely absent in rural areas, DRT may be the only option available. In these cases, local governments often subsidize DRT. Alternatively, DRT can be co-located with mass transit stations (either bus or rail hubs) under the "hub and spoke" business model, which increases user visibility of the service [27]. To give rural and semi-rural communities more options and access to more sustainable options through new modes of transportation, higher levels of subsidies are necessary if on-demand mobility services are unable to draw in the necessary amount of demand. Studies conducted on the periphery of rural and urban areas, where there seems to be less demand for travel, have indicated that larger vehicles with eight or ten seats are needed to meet demand [28, 29]. Additionally, DRT services can be more economical than traditional bus routes by reducing CO2 emissions [29, 30]. This is mostly because of the area's features and the demand that already exists [31]. Passengers are likely to be drawn to a DRT that operates in areas of transport poverty where PT services are inadequate and integrates with pre-existing PT services [32, 33].

In addition, there are other ways to travel, like ride-sharing, vanpooling, and hitchhiking, which are examples of alternative mobility options that could establish the necessary connection with other villages and regions [34–36]. Hitchhiking, entails going with someone else on a journey with basic amenities [37]. For their travels, hitchhikers rely on the assistance of others [38]. However, drivers and passengers must consider their privacy and safety when using such shared modes of transportation. Drivers are less likely to share their cars with strangers because of their attachment to them [39]. In addition, passengers worry about crimes like violence and robbery as well as their own safety. Robbery and violent crimes are typically more likely to occur during hitchhiking.

## 3 Methodological Approach

This study is carried out as part of the larger PhD research project "Habitat matters. Managing and reducing the risk of built heritage by promoting the ecological transition, accessibility, and sustainable mobility in rural areas". The methodology for the larger research project encompasses three main steps. Firstly, a background study was conducted to identify reference studies and best practices related to sustainable mobility in rural areas. From these studies, guidelines and valuable insights about rural mobility were extracted, leading to the publication of a conference paper. Secondly, an analysis of the existing transport conditions was carried out at the MIC-HUB Company, utilizing skills and tools acquired during the period in the industry. This article focuses on this part of the research. Lastly, the final phase of the PhD project will involve an overarching analysis of rural areas across the EU, aiming to highlight gaps, criticalities, issues, and opportunities in the transport system and the policies that different European governments are setting in place to solve the issues related to mobility in rural areas.

The methodological approach employed in this study involves a combination of qualitative and quantitative tools. The strategy entails gathering data both on-site and from diverse online and offline sources and tools. Qualitative data collection methods include visiting the case study area, conducting on-site research analyses, and performing photographic surveys during the Rail to Land project site visit [40]. Additional on-site data were collected as part of the Branding 4 Resilience project. [41]. The specific qualitative tools used for the collection and analysis of the data are: the QGIS (QGIS (Quantum Geographic Information System) is a free, open-source software that allows users to create, edit, visualize, analyze, and publish geospatial information), the Komoot app (a mobile app for navigation and route planning which Map your bicycle, walking and running adventures with the GPS tracker), Moovit (a mobility as a service provider and journey planner app which is more than a train and bus time *app*, helpful for public transit navigation, maps, schedules, real-time arrivals and more) and Tom Tom (a leading independent geolocation technology specialist, shaping mobility with highly accurate maps, navigation, real-time traffic info etc.). With the help of QGIS, we analyze the transport infrastructure of the area. The road infrastructure, which is further categorized into different types of roads, i.e., motorways, highways, primary roads, secondary roads, and tertiary roads, the railway infrastructure available in the area, and some abandoned railway lines in the region, might play a vital role in the development of this territory [42]. The Komoot app is used to analyze the bicycle infrastructure in the area. There are several bike ways available in the area, which is presented in a map through QGIS tool in this research. Moovit is another tool that is used to analyze the public transport in the area. The public transport system is not frequent in the area, but we still need to analyze and assess it in detail. Another useful tool is the Tom Tom. The Tom Tom is used to analyze private trips, specifically car trips that were taken by the residents. The car trip data are taken only for the month of October 2022. Unfortunately, we did not get all the data we originally planned for the study, due to its high cost. Indeed, accessing a wider spectrum of data would have meant to purchase specific and detailed datasets from TomTom's database, which was financially unfeasible as it exceeded our budgetary limitations and available resources for the research project. Yet, we acquired data for different specific days in the month of October 2022 and we systematized and categorized them as follows, in order to extrapolate possible useful information from their analysis. The first set corresponds to the first Monday of October (03 Oct), the second set to the middle of the week (12 Oct), the third set to the weekend (15 and 16 Oct), and the fourth set to the end of the month and week (28 Oct). These sets include trips between the Apennines and nearby cities. Additionally, we collect two data sets, one focusing solely on trips within the Apennine region for October 18 and the other for October 22 and 23. Car trips is particularly important in this study, given that private vehicles are the predominant mode of transportation in rural areas.

The data collected from these sources is compared for further analysis. Specifically, TomTom's data provide us some insights into trends regarding the increase or decrease in private trips during the day. Additionally, analyzing the demand for trips during non-operating hours and the length of the trips also shed light on potential opportunities for micromobility solutions.

This research was conducted at MIC HUB Company [43] on mobility in the peripheral and rural areas of the Marche region, which is the pilot inner area of the Marche Region, for the Italian National Strategy for Inner Areas (SNAI). The area is specifically named "Appennino basso Pesarese e Anconetano," which comprises nine municipalities, a total population of 33,146, and a land area of 846.16 sq. km. The demographic variation according to the ISTAT census for 2011–2017 is −5.23%. The inner areas are those areas that are significantly distant from the supply centers of essential services (education, health, and mobility) but rich in important environmental [44] and cultural resources. These areas are usually characterized by low population densities. The average density of the area is 39.17 person/km$^2$, which is much less than the Marche region density of 158.5 person/km$^2$ compared to 200 person/km$^2$ in the entire Italy. The area is far from essential services, i.e., there is no hospital in any of its nine municipalities except for a healthcare center in Cagli. The absence of a railway line makes it more difficult to reach the area and hinder its overall accessibility. There are some existing railway tracks that pass through-the area, i.e., the Fano-Fermignano-Urbino line, the Fabriano-Pergola line, and the Pergola-Fermignano line. These lines are abandoned due to landslides, suffered in World War II and other natural disasters [45]. The Fabriano-Pergola line was opened for tourists in September 2021. Two of the authors themselves traveled with this historic tourist train in June 2022. It was a very nice experience witnessing and experiencing the majestic and phenomenal landscapes of the area, which is not possible with any other mode of transport. Regarding major roads and highways, there is no highway passing through these areas. The nearby airports are Umbria International Airport in Perugia and Ancona International Airport, which are 1 h and 15 min, and 1 h and 30 min, respectively. The distance from Rome is 231 km, 73 km from Ancona, and 48 km from Pesaro. The study was conducted to examine the role of rural mobility, the ways in which people move around in the Apennine region, and how inefficient mobility can contribute to the abandonment and depopulation of these areas. A comprehensive review of the existing literature regarding the context analysis highlighted gaps and areas requiring further investigation. From this literature and from the overall study of the context, several research questions were derived, aiming to address key aspects of the study area's transportation system.

- What are the different options to move around the Apennines mountain area in the inland of Ancona?
- How frequently do residents in the area utilize cars for transportation?

The questions are directly aligned with the broader research objectives of understanding rural mobility patterns and their implications for community development. By examining the available transport infrastructure, modes of transport, and dominant usage patterns, the study seeks to provide insights into current mobility dynamics and inform future interventions aimed at enhancing transportation accessibility and efficiency in the area.

## 4 Research Findings

In the picturesque landscapes of the Apennine Marche region of Italy, the dynamics of mobility take on a unique significance, weaving through the idyllic countryside and quaint villages nestled amidst rolling hills [42]. This research shedding light on the diverse modes of transportation and infrastructure utilized by residents to navigate their surroundings in the Marche Central Apennines. There are different types of infrastructure and modes of mobility that is explored in this study, and the results are presented in this chapter. The research findings will be presented in two parts: the first part will focus on the transport infrastructure, while the second part is about the findings from different modes of mobility in the region.

In the first part, the transport infrastructure of the Marche region, particularly the central Apennines, is examined. Figure 1 illustrates the road and rail network of the Marche region, showcasing various types of roads and railways. The Autostrada Adriatica (Motorway A14) traverses the Marche region, providing a major transportation route. Additionally, other roads such as Strade Statali (State roads SS), Strade Provinciali (Provincial roads SP), and Strade Bianche & Comunale (white and Municipal roads) contribute to the region's road network.

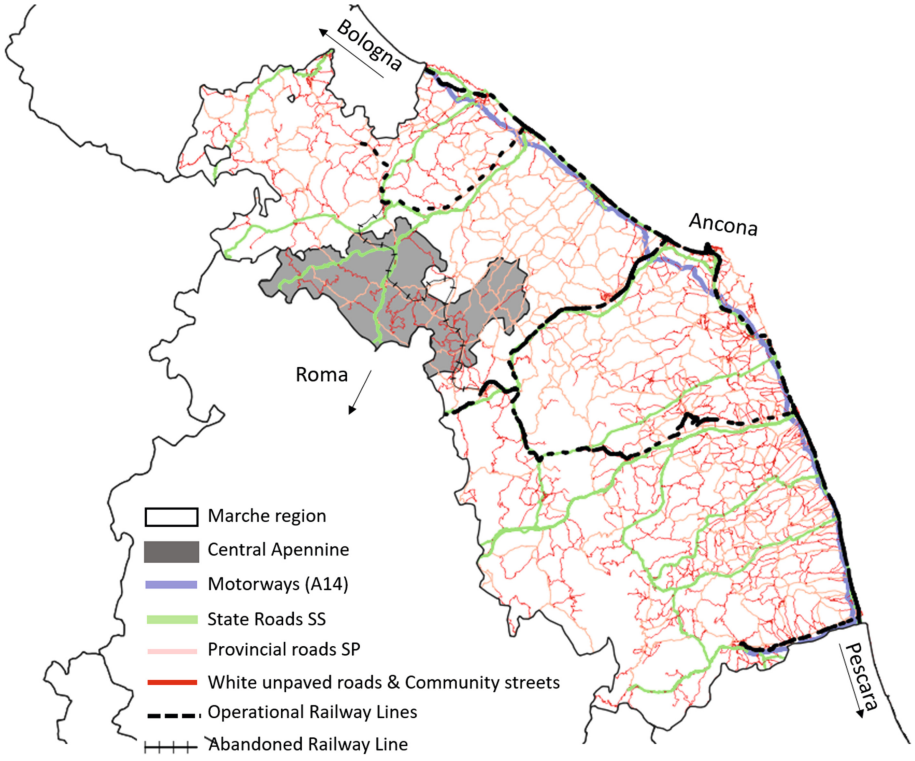


**Fig. 1.** Marche region Road and Rail Infrastructure @ *Junaid M., 2023* (Data source: EU Environment Agency & Humanitarian Open Street Map)

However, it is noteworthy that the Autostrada A14 does not extend into the central Apennines, but it is longitudinal along the coastline. Instead, only SS3 and SS257 pass through this mountainous region, specifically in the municipalities of Cagli, Piobbico, and Apecchio. Other roads, like Strade Bianche and Comunale, also play a role in the local transportation network. In addition to roads, there are also railway lines in the Marche region. The important railway lines include the coastal Milan-Bari line, which connects most of the seaside resorts, and the trans-Italy Ancona-Rome line, which links a few of the larger towns in the central part of the region. However, none of these train lines pass through the Apennine region. In fact, there are some abandoned railway lines in the region.

Other infrastructures include cycling paths, pedestrian routes, and hiking paths, as presented in Fig. 2. The central Apennines of the Marche region boast numerous cycling routes, including the ciclovia alte Marche. This cycling route project is of great interest, connecting nine municipalities in the central Apennines in the provinces of Pesaro, Urbino, and Ancona. It winds through an area rich in natural and cultural attractions, comprising ten sections of the Apennine Cycle that form a ring. While some parts of this project have been realized, others are yet to be completed. Additionally, besides these cycling routes, there are pedestrian paths and hiking trails both in the Marche region and specifically in the central Apennines.

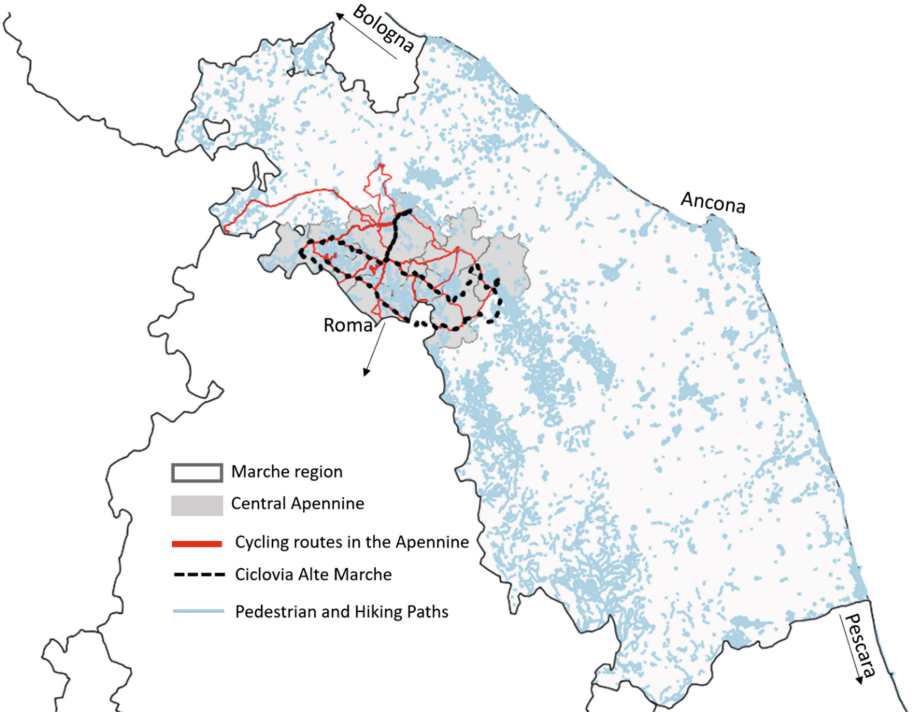


**Fig. 2.** Appennino Basso Pesarese e Anconetano Cycling, Pedestrian and Hiking Paths @Junaid M, 2023 (Data source: Komoot App & Humanitarian Open Street Map)

In the second part of the research, various modes of mobility utilize the aforementioned infrastructure. However, this section will specifically focus on the private trips taken by residents, primarily due to limited mobility options.

In the first section of this part, we analyze the schedule of public services and their frequency in the central Apennine region, along with their connections to nearby cities. Tables 1, 2 and 3 present detailed schedules of these services. Table 1 illustrates connections for travel to nearby cities, Table 2 outlines return connections to the Apennines from nearby cities, and Table 3 displays the schedule and frequency of services within the Apennines.

It is evident from the service schedule that services are non-operational on Sundays, with some also non-operational on both Saturdays and Sundays. Another notable observation is the gap in service frequency, particularly between the hours of 6:00 or 7:00 and 13:00, resulting in approximately a 6–7 h hiatus in service. While it may be assumed that there is limited demand for service during these hours, further investigation will cross-check this assumption by analyzing private car trips during the same time frame.

Furthermore, connections with nearby cities are infrequent, with some cities having only a single departure per day. Similarly, connections within the Apennines are also not very frequent, with gaps of 3–4 h between departures, especially during the morning and evening hours.

**Table 1.** Connections of Apennines with the nearby cities @Junaid M, 2024 (Data Source: Moovit App)

| Line | From | To | Schedule | Frequency |
|---|---|---|---|---|
| VI1 | Pergola | Fabriano | Mon–Sat: 06:00, 06:40, 06:55, 14:05, 15:35 | |
| VI3 | Arcevia terminal | Jesi Bus Station | Mon–Sat: | Only bus at 06:27 |
| BS2 | Arcevia | Senigallia | Mon–Sat: 05:52, 06:52, 13:37, 14:33 | |
| 35 | Pergola | Marotta Mondolfo | All week 05:10–17:35 | Every 60 min |
| 24 | Acqualagna | Fossombrone | Mon–Fri: 07:00, 14:20 | |
| 25V | Acqualagna | Urbino Park St. Lucia | Mon, Tue: 07:10, 07:15 | Every 30 min |
| 23 | Acqualagna, Piobbico, Apecchio | Citta di Castello | Mon–Sat: 06:48, 18:07 | - |

The next part involves analyzing the TomTom data for private car trips made by residents. This analysis encompasses six types of data collected on different days throughout October 2022.

**Table 2.** Connections to move back to Apennines from nearby cities @Junaid M, 2024 (Data Source: Moovit App)

| Connection | From | To | Schedule | Frequency |
|---|---|---|---|---|
| VI1/SFB/22R | Fabriano | Sassoferrato/Pergola/Urbino | Mon–Sat: 07:17, 09:01, 12:41, 13(31, 36, 38) 16: 40, 18:02 | |
| VI3 | Jesi | Arcevia | Mon–Sat: | Only bus at 14:35 |
| BS2 | Senigallia | Arcevia | Mon–Sat: 06:40, 13:45, 19:30 | – |
| BS2 | Marotta Mondolfo | Pergola | All week: 07:05–19:30 | Every 60 min |
| 25S | Fano | Fossombrone | Mon–Sat: | Only bus at 06:30 |
| 25 | Fossombrone | Acqualagna | Mon–Sat: 07:32, 13:13, 13:50, 14:50 | |
| LV | Pesaro | Urbino Park S. Lucia | Tue–Sun: 06:25–20:30 | Every 30 min |
| 20/22R | Urbino Park S. Lucia | Acqualagna | Mon–Fri: 06:00, 14:20, 17:35 | |
| 23 | Citta di Castello | Acqualagna, Piobbico, Apecchio | Mon–Sat: 06:04, 13:04, 13:44, 15:39 | |

The first set of data is from the beginning of the month and week (03-10-2022), followed by the second set from the middle of the month and week (12-10-2022), the third set for weekend data (15/16-10-2022), and the fourth set from the end of the month and week (28-10-2022). These four sets of data include trips taken within the Apennines, as well as trips to nearby cities.

Additionally, our study incorporates two distinct datasets focusing exclusively on trips within the Apennine municipalities. These datasets were collected for the dates of October 18th, 2022, and October 22nd to 23rd, 2022. Furthermore the TomTom data was normalized, knowing that TomTom claims to have data for around 20% of existing vehicles. This means that if TomTom shows that there were 5 trips, we say it was 25 (multiplying all number by 5).

The results derived from the initial dataset are depicted in Figs. 3, 4, and 5, highlighting a predominant occurrence of trips within the cities and intra-city travels. Additionally, a notable number of trips were observed within the Apennines and between cities,

**Table 3.** Connections inside the Apennines @Junaid M, 2024 (Data Source: Moovit App)

| Line | Connection | Schedule |
|---|---|---|
| 20/52/24 | Acqualagna to Cagli | Mon: 06:40, 08:30, 08:48, 09:00, 11:48, 12:48 (12:48–19:45 every 1 h) |
| 21 | Frontone to Serra San't Abbondio | Mon: 06:12, 06:55, 11:43 |
| BS2 | Arcevia to Sassoferrato | Mon: 07:40, 12:45, 13:45, 14:45, 21:00 |
| VI1 | Sassoferrato to Serra San't Abbondio | Mon: 06:15 |
| VI3 | Arcevia to Sassoferrato | Mon: 06:53 & 16:43 |
| 23 | Acqualagna to Piobbico & Apecchio | Mon–Sat: 06:48, 13:48, 14:40, 15:12, 18:07 |

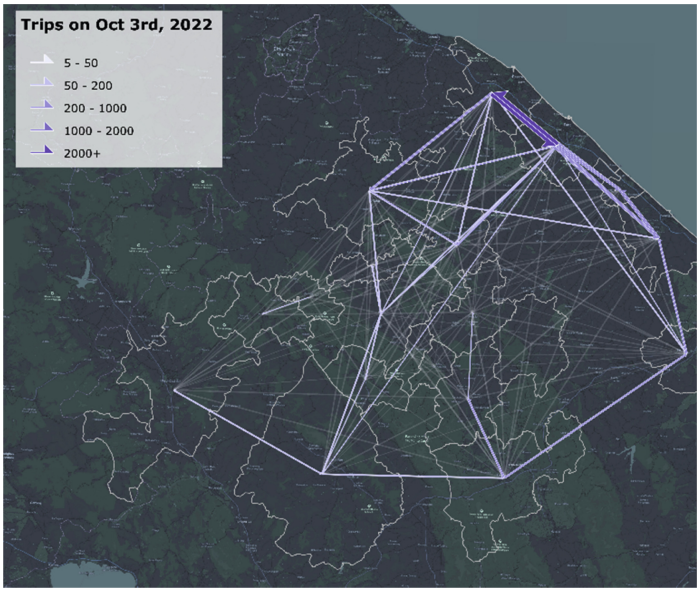


**Fig. 3.** Showing the trips taken on 3rd Oct 2022 in the Apennines and with other cities ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

ranging from 5 to over 200 trips. Further examination of trip lengths and starting hours reveals additional insights. Analysis of trip lengths reveals that approximately 33% of trips are under 10 km in length, with around 46–47% of trips under 20 km. Regarding trip initiation times, peak hours are identified between 7–9:00 a.m., 13–14:00 p.m., and 17–19:00 p.m. However, significant trip volumes persist between these peak hours; for instance, between 9:00 a.m. to 12:00 p.m., approximately 2500 trips were recorded each hour. Notably, despite this substantial activity during off-peak hours, many public bus lines remain non-operational, indicating potential gaps in transportation service coverage during these periods.

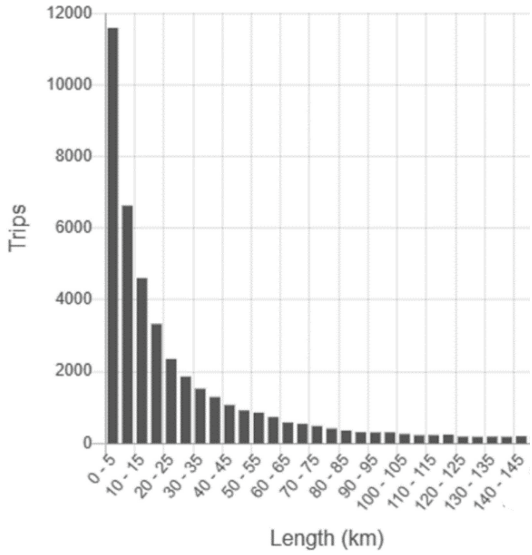


**Fig. 4.** Showing length of these trips on 3rd Oct 2022 ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

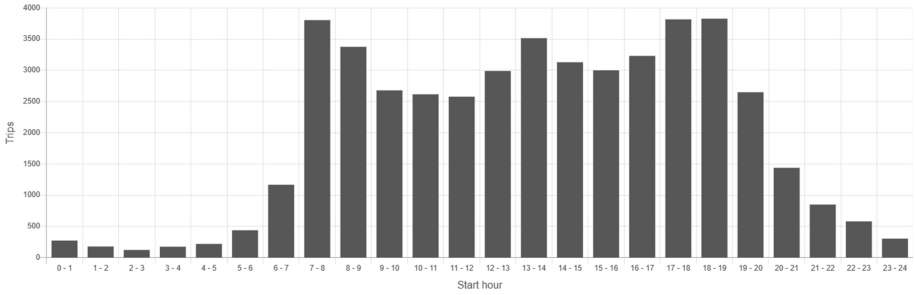


**Fig. 5.** Showing the starting hour of trips on 3rd Oct 2022 in the Apennines and with other cities (Data Source: Tom Tom)

The findings extracted from the second dataset are showcased in Figs. 6, 7, and 8, revealing a similar trip pattern to the preceding dataset. Once again, the majority of trips exhibit lengths under 10 and 20 km. Peak travel hours mirror those identified in the previous dataset.

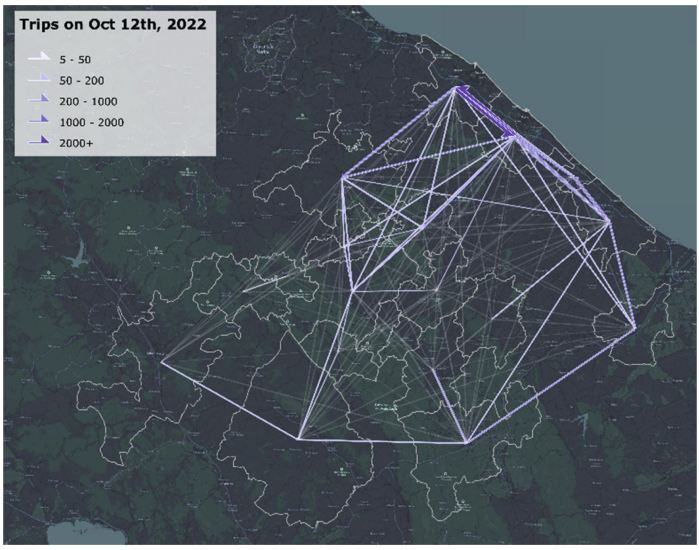


**Fig. 6.** Showing the trips taken on 12th Oct 2022 in the Apennines and with other cities ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

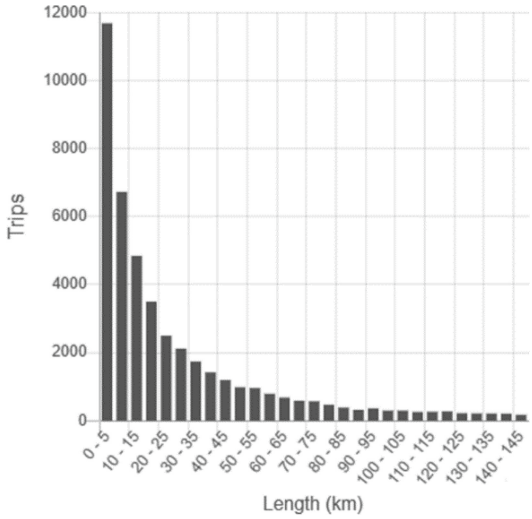


**Fig. 7.** Showing length of these trips on 12th Oct 2022 ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

The third dataset, representing weekend data, is illustrated in Figs. 9, 10, and 11. Notably, the trip pattern lines appear darker, indicating a higher volume of trips during the weekend compared to weekdays. Within the Apennines, the number of trips ranges from 5 to 800 over the two-day period, suggesting potential destinations such as grocery

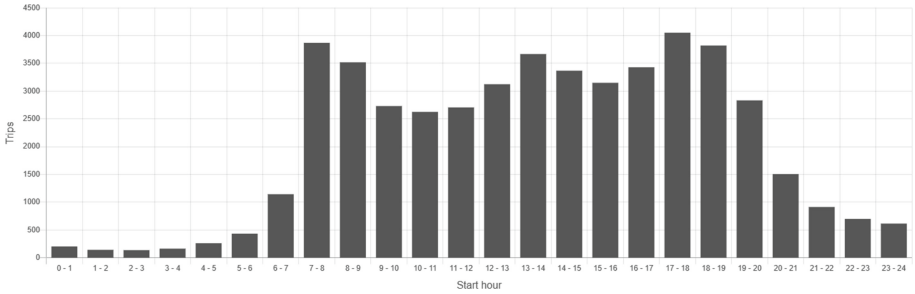


**Fig. 8.** Showing the starting hour of trips on 12th Oct 2022 in the Apennines and with other cities (Data Source: Tom Tom)

stores and social activities. Trip lengths exhibit a similar distribution to previous datasets, with the majority falling within the 0–10 km and 11–20 km ranges.

Interestingly, there is a shift in peak hours during the weekend. Morning peak hours are displaced towards the afternoon, with new peak hours observed between 10:00 and 13:00. Following a slight decrease in trips, another peak is observed from 15:00 until 20:00. This shift in peak hours highlights the altered travel behavior and activity patterns during weekends compared to weekdays.

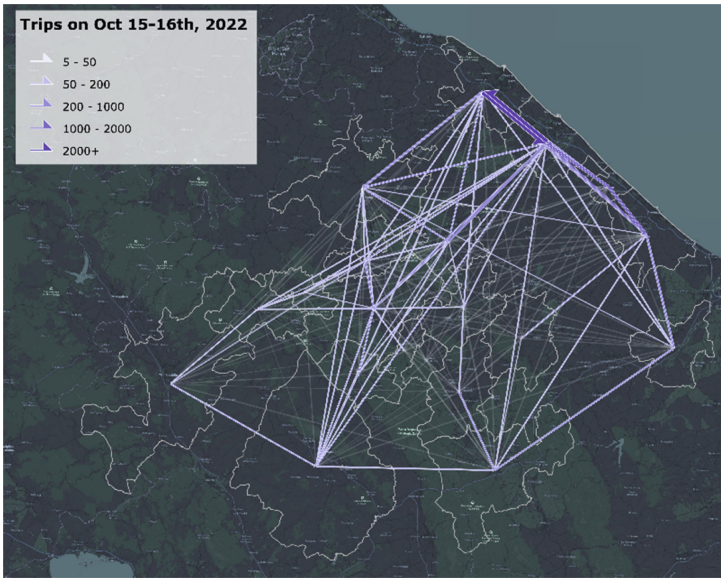


**Fig. 9.** Showing the trips taken on 15th and 16th Oct 2022 in the Apennines and with other cities ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

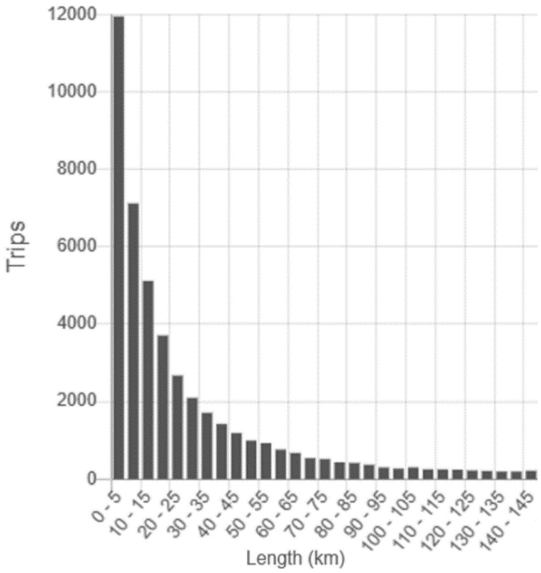


**Fig. 10.** Showing length of these trips on 15th and 16th Oct 2022 ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

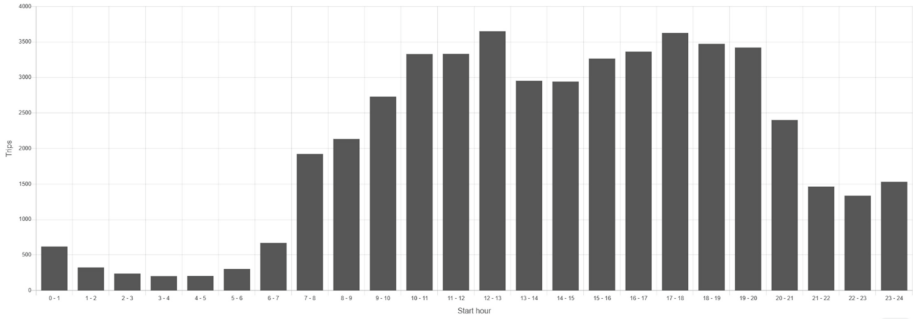


**Fig. 11.** Showing the starting hour of trips on 15th &16th Oct 2022 in the Apennines and with other cities (Data Source: Tom Tom)

The fourth dataset, collected at the end of the month and week, is depicted in Figs. 12, 13, and 14. Interestingly, there is a slightly higher volume of trips compared to the first two datasets. However, upon closer examination, it is evident that there are no significant differences in trip patterns across different times of the month on weekdays and various days of the week.

Overall, the analysis indicates a consistent trend in trip frequency and peak hours across the datasets. Despite a slight increase in the number of trips in this dataset, the peak hours remain unchanged. This suggests a stable mobility pattern irrespective of the specific timing within the month or week, with the exception of weekends, where distinct shifts in peak hours and increment in number of trips were observed.

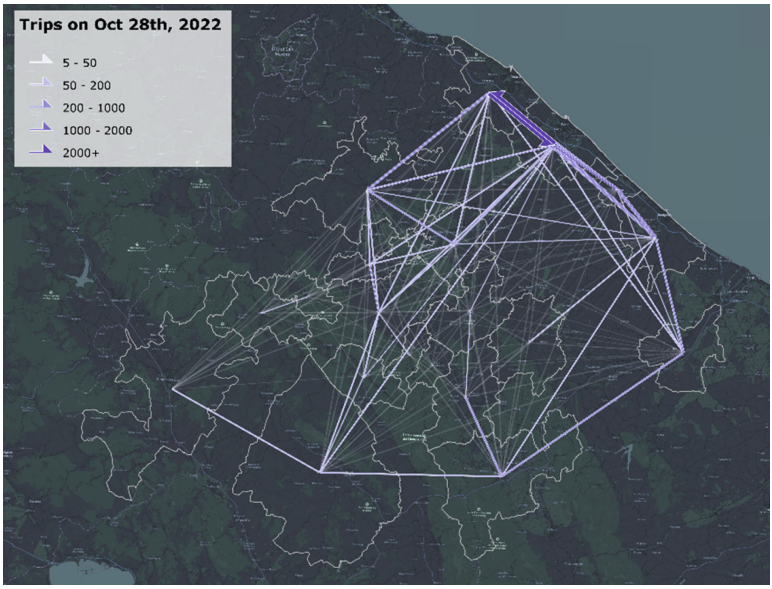


**Fig. 12.** Showing the trips taken on 28th Oct 2022 in the Apennines and with other cities ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

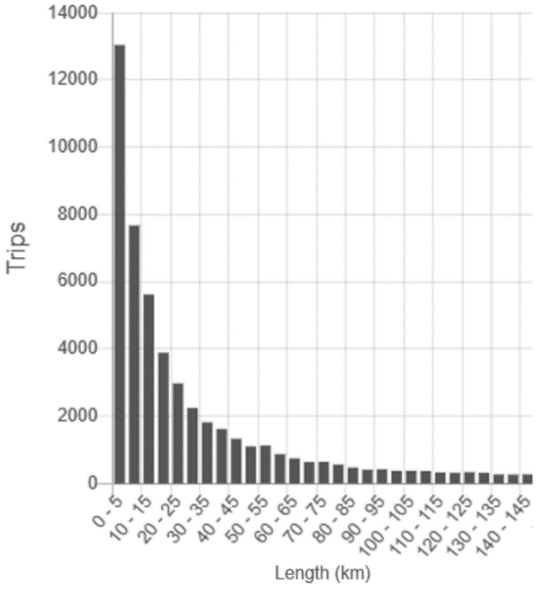


**Fig. 13.** Showing length of these trips on 28th Oct 2022 ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

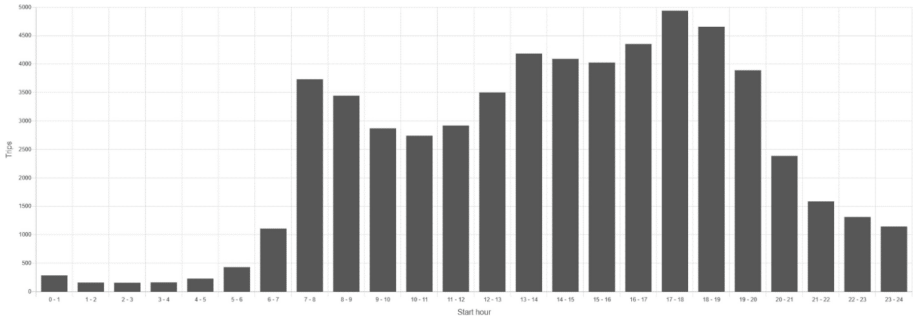


**Fig. 14.** Showing the starting hour of trips on 28th Oct 2022 in the Apennines and with other cities (Data Source: Tom Tom)

The fifth dataset exclusively comprises trips taken within the Apennines municipalities, depicted in Figs. 15, 16, and 17. Results indicate a considerable number of trips, exceeding 50 trips in a single day across various areas. Trip lengths align with previous data, predominantly falling under 10 km and extending to 20 or 25 km. Peak hours exhibit similar trends, with a slight alteration in the afternoon hours, including the addition of 12:00 PM as part of the peak period.

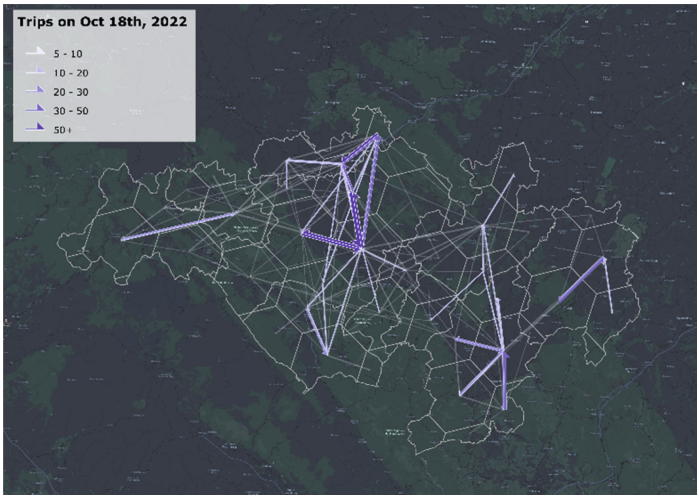


**Fig. 15.** Showing the trips taken on 18th Oct 2022 inside the Apennines ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

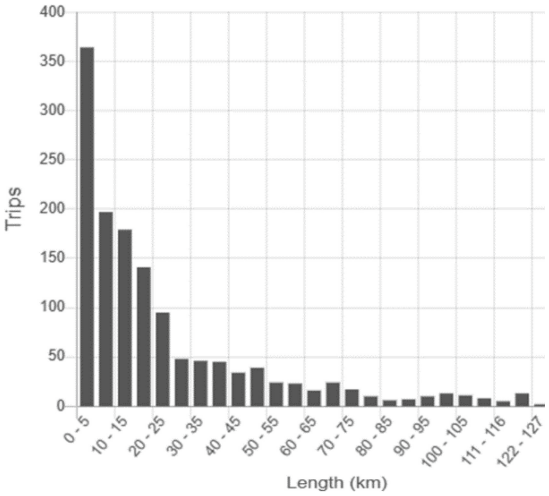


**Fig. 16.** Showing length of these trips on 18th Oct 2022 ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom)

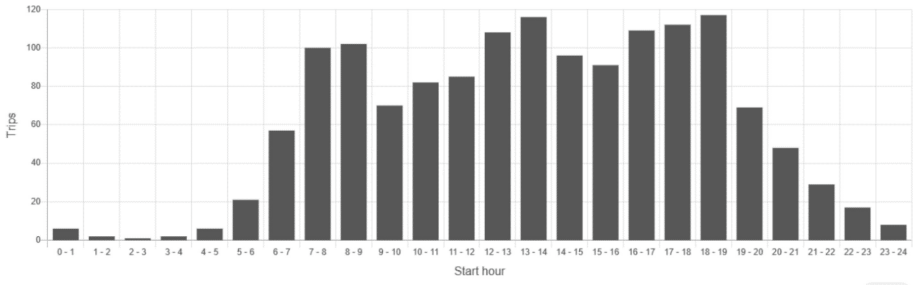


**Fig. 17.** Showing the starting hour of trips on 18th Oct 2022 inside the Apennines (Data Source: Tom Tom)

The last dataset examines weekend trips within the Apennines, showing varying trip volumes across different areas, with consistent trip lengths predominantly categorized as short. Unlike previous datasets, peak hours are observed at 12:00 p.m. and between 15:00 and 18:00. Despite public bus lines not operating, significant resident movement, mainly facilitated by private cars, is evident. This highlights the potential for reducing private car usage by offering alternative transportation means during non-operating hours, leading to a substantial decrease in private car trips and promoting sustainable mobility practices within the Apennines municipalities (Figs. 18, 19 and 20).

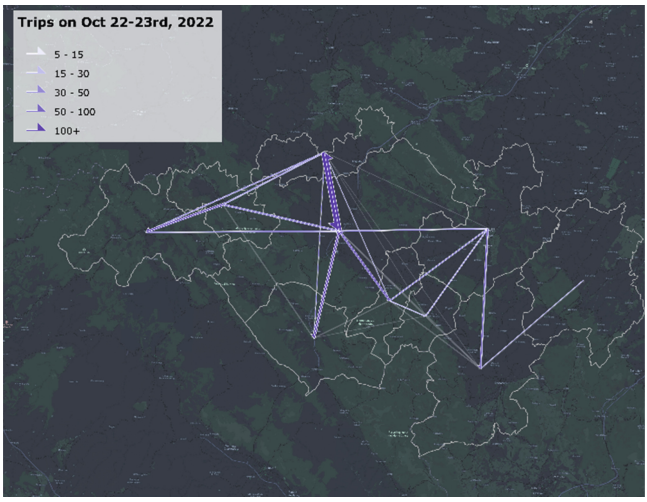


**Fig. 18.** Showing the trips taken on 22nd and 23rd Oct 2022 (weekend) Inside the Apennines ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom).

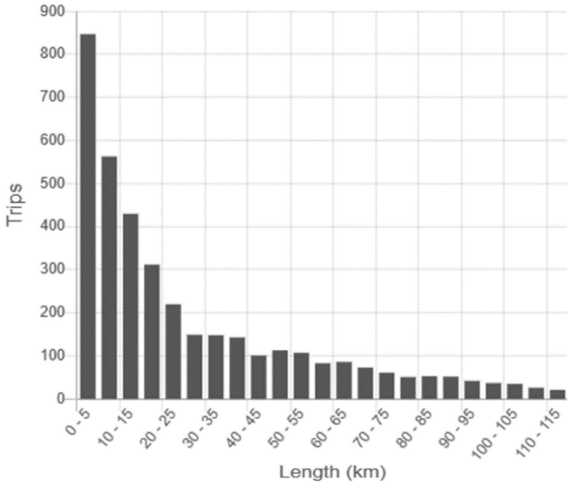


**Fig. 19.** Showing length of these trips on 22nd and 23rd Oct 2022 (weekend) ©Elaboration by Gorokhov D, 2024 (Data Source: Tom Tom).

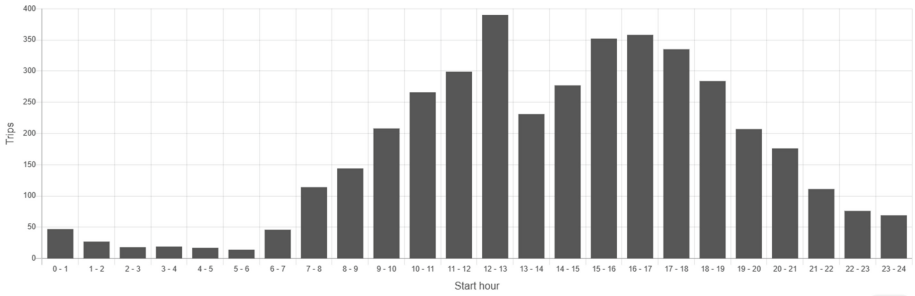


**Fig. 20.** Showing the starting hour of trips on 22nd and 23rd Oct 2022 (Weekend) inside the Apennines (Data Source: Tom Tom)

## 5 Discussion and Conclusion

The research on rural mobility in the Central Apennine of the Marche Region aim to discuss the crucial role of transportation infrastructure in preventing rural abandonment and promoting sustainable mobility practices. The study delves into the residents' mobility, emphasizing the challenges faced due to limited public transport options, particularly in rural and mountainous areas. One of the central focal points of our investigation is the examination of the transportation infrastructure network crossing the Apennine region. From the well-traveled Strada Statale (state roads) to the more localized Strade Provinciali (provincial roads) and the smaller Strada Comunali (municipal roads), the territorial analysis has shown qualities, potentials as well as criticalities in the connectivity and accessibility of the area. Despite the abundance of bicycle routes, hiking trails, and pedestrian paths, the absence of public transport, such as the railway, is a fact that is made even more evident by the territorial footprints of the rail remnants of the abandoned historical line. Within this intricate web of infrastructure lies a mosaic of mobility behaviors, each with its own nuances and challenges. While cyclists and pedestrians navigate the winding paths of the Apennines, public bus lines and private cars emerge as the lifelines connecting remote villages to urban centers. However, our focus narrows to dissecting the dynamics of public bus lines and private car usage, recognizing their pivotal roles in shaping the area's mobility landscape. The analysis of bus line schedules reveals temporal gaps, particularly during non-operating hours sandwiched between morning and afternoon peak periods. This temporal asymmetry underscores the need for a nuanced understanding of mobility demand throughout the day, prompting us to delve deeper into private car trip data sourced from TomTom. The aim of analyzing the TomTom data is to examine car trip data at various times of the year, particularly during public holidays and summer vacations, in order to uncover trends in private car usage. Tourist activity in these areas may influence fluctuations and trends in private car trips. Unfortunately, obtaining the necessary data proved to be too expensive. Such specific and detailed data from TomTom likely required purchasing access to their database, which is beyond our research project's budget constraints and resources. In the future, the required analysis might become feasible if specific funded projects will provide the necessary financial support. These projects will enable the gathering of the necessary resources and capabilities required to conduct comprehensive analysis of TomTom data

at various times of the year. As a result, researchers will be able to delve deeper into understanding car travel patterns and behaviors, particularly during critical times such as public holidays and summer vacations.

For this study, as mentioned, we focused only on data from October 2022, which is freely accessible. Our aim with this data is to uncover the complexities of car travel patterns, particularly during crucial non-operating hours of public transport, which could reveal hidden insights into residents' mobility preferences and behaviors. Beyond the confines of daily routines, our study aspires in the future to capture the essence of seasonal fluctuations in travel patterns. By performing an analysis spanning through different seasons, including the bustling tourist season, we aim to glean insights into how external factors, such as tourism flows, influence residents' travel choices and mobility planners' decisions. Regrettably, the unavailability of specific TomTom data hindered our ability to delve into these seasonal nuances, leaving an open way for future exploration. Nevertheless, the findings gathered from our analysis cast a revealing light on the pervasive reliance of the area's population on private vehicles for a myriad of purposes, ranging from essential errands to social engagements, work commitments, and leisure pursuits. This reliance underscores the pressing need for innovative, sustainable alternatives that not only mitigate the environmental effects of transport in the area, but more generally foster a greener, more inclusive mobility landscape for the residents of the Apennine region.

### 5.1 Mobility Pattern and Challenges

The analysis reveals an interesting trend: a significant portion of trips within the region span distances of less than 10 km. This finding hints at a promising opportunity for embracing micromobility solutions tailored to efficiently cater to these short-distance journeys. Whether it's zipping through narrow village streets or navigating scenic pathways, micromobility options like electric scooters, bicycles, or even innovative shared mobility schemes could offer convenient and eco-friendly alternatives for residents and visitors alike. Moreover, the prevalence of private trips during the non-operating hours of public bus lines highlights a critical gap in the current transportation ecosystem. During these periods, when traditional public transit services are limited or unavailable, the need for alternative modes of transport becomes glaringly apparent. This is where the concept of transport-on-demand comes to light. With its flexibility and responsiveness to individual travel needs, transport-on-demand emerges as a compelling solution to supplement existing public transportation services and bridge the gaps in service coverage. By leveraging modern technologies such as ride-hailing apps or community-based shuttle services, transport-on-demand can offer residents the convenience of tailored mobility solutions precisely when and where they need them. This not only enhances accessibility for underserved communities but also promotes a more integrated and resilient transportation network for the entire region [24, 25].

### 5.2 Implications for Rural Mobility Policies

The TomTom data is limited to only one month due to the limited scope discussed above in this article. However, even from this restricted data, when studying the challenges and

opportunities in the region, we can still assume this conclusion that there is an urgent need for tailored policies and interventions to address the unique mobility challenges faced by rural communities. While current EU mobility strategies predominantly focus on urban areas, there is a glaring absence of specific policies catering to the needs of rural and mountainous regions. Initiatives such as the "A Long-Term Vision for the EU's Rural Areas up to 2040" project represent a step towards rectifying this gap by promoting sustainable multimodal mobility practices and bridging the digital divide between rural and urban areas.

Furthermore, our research advocates for a holistic approach to rural mobility that goes beyond infrastructure development to encompass digital connectivity enhancement and the promotion of alternative transportation modes. By diversifying mobility solutions and addressing the multifaceted needs of rural communities, policymakers can foster inclusive and sustainable mobility practices that contribute to economic growth and social cohesion in rural areas.

### 5.3 Limitations and Future Recommendations

The study relies on existing data sources and methodologies for analyzing mobility patterns, which may have inherent limitations such as data accuracy, completeness, and reliability, as well as constraints in availability. Additionally, the study's findings are based on data collected within a specific timeframe, and mobility patterns and infrastructure may evolve over time, potentially leading to an incomplete depiction of long-term trends or changes in mobility behavior beyond the study period.

Looking ahead, it is imperative to continue exploring innovative mobility solutions tailored to the specific needs and challenges of rural communities. Initiatives such as transport-on-demand services and the integration of micromobility options hold promise in enhancing accessibility and reducing dependence on private vehicles, particularly during non-operating hours of public transit.

Furthermore, ongoing collaboration between policymakers, researchers, and local stakeholders is crucial to ensuring the effective implementation of rural mobility policies and interventions. By fostering a participatory approach and leveraging insights from interdisciplinary research, stakeholders can work together to design and implement sustainable mobility solutions that address the diverse needs of rural communities and contribute to the long-term prosperity of rural areas.

In conclusion, our study serves as a foundational step towards understanding and addressing the complex dynamics of rural mobility in the Marche Region's Central Apennine. By shedding light on existing challenges and opportunities, it provides a roadmap for future research aimed at fostering sustainable and inclusive mobility practices in rural areas. Through collaborative efforts and innovative solutions, we can pave the way towards a more accessible, resilient, and vibrant rural landscape.

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