ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

DEPARTMENT OF ECONOMICS

MSc in TOURISM ECONOMICS AND MANAGEMENT

PUBLIC TRANSPORT FOR TOURISTS: AN EVALUATION FRAMEWORK FROM THE MULTIMODALITY VIEWPOINT

Dissertation in

SUSTAINABLE DESTINATION DEVELOPMENT

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Graduation Session / October 2025

Academic Year 2024-2025

To the me who chose this path, and to the me who will keep charting my way.

Acknowledgments

This Master's degree has been one of the most meaningful periods of my professional and academic life, made possible by the help of many people.

Above all, I am deeply grateful for my family, who have always been there for me and supported me through my decisions.

I am equally indebted to the professors at Università di Bologna and Wageningen University for their knowledge and passion. The many inspiring discussions we had gave me the courage to take on this work.

My heartfelt gratitude goes to Professor Lorenzo Masiero, who welcomed my ideas while challenging me with the hard questions. His expertise and advice were instrumental in applying theoretical concepts to a working model.

To my friends in TEaM and Rimini, you have been the best family I could ask for during my first chapter in Europe.

I am also thankful to my supportive and caring colleagues at ACJ. Being part of the team from halfway across the world would have been impossible without you.

Finally, to all my friends, wherever you are, thank you for being my constants in a life of change.

Abstract

This thesis proposes a framework for the evaluation of tourist accessibility at a destination, focusing on infrastructure of the public transportation system under the lens of multimodality. There are many studies on multimodality and tourist transportation, but few has looked at these in combination. Furthermore, by investigating Rimini, a coastal destination looking to better integrate the various modes of public transit, the study also examines the effectiveness of the framework, and aims to deliver recommendations to municipal policymakers.

By incorporating data from GTFS-based online routing platform (Google Transit) and micromobility service (Lime), the study constructed an accessibility index, and other indicative metrics to assess major transport routes used by tourists in the peak season. Supplemented by micromobility potential time savings if integrated into the system, individual trips were analysed and generalised to identify pain points in the system. The result reveals that Rimini visitors benefit from well-planned links when getting to Rimini, but suffer inconveniences when visiting different, especially peripheral, attractions. The main weaknesses are lack of coordination between modes, and underdevelopment of transport infrastructure in the northern areas. Moreover, current micromobility tend to serve well-connected areas, and need to expand to help improve low-connectivity districts. Suggested enhancements include improved scheduling and stop location, tourist-geared transport supplement, and targeted infrastructure improvement.

The evaluation model shows potential in assessing the transport system of the destination as a whole. However, limitations including limited temporal scope, reliance on commercial engine, lack of detailed data, should be addressed in future research.

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List of Abbreviations

Abbreviation	Definition
API:	Application Programming Interface
GIS:	Geographic Information System
GTFS:	General Transit Feed Specification
IQR:	Interquartile Range
LCC:	Low-cost Airline
MaaS:	Mobility as a Service
MCA:	Multi-criteria Analysis
OD:	Origin-Destination
OSM:	OpenStreetMap
POI:	Point of Interest
PT:	Public Transit

Chapter 1

Introduction

Rimini is among Italy's most visited coastal destinations, receiving over 3.5 million tourists in 2023 (ISTAT, 2025a). In recent years, municipal authorities have undertaken significant interventions to expand public transit, most notably the Metromare line connecting Rimini with Riccione and micromobility solutions (bike and scooter sharing), to mitigate personal vehicle use among tourists, especially during peak summer months. Despite these achievements, the shift from private vehicles to integrated multimodal options have much to improve. Seasonal surges in visitor arrivals continue to overwhelm parking spaces (AltaRimini Editorial, 2025) and intensify traffic on the main roads, worsening residents' quality of life and impeding the city's ambition to reposition from mass tourism toward a sustainable and diversified tourism industry.

Despite the wealth of study of public and/or urban transit, and their usage by tourists, there are few comprehensive, destination-specific framework that evaluates door-to-door accessibility by public transit. Existing studies in transportation and tourism emphasise the importance of reliability and convenience in public transit choice, but few have integrated real-time schedule data with micromobility data, especially in a popular Italian destination that does not have advanced PT system. Without quantitative evidence on how multimodal combinations (train + bus + e-scooter) perform in terms of travel time, connectivity, and vehicle availability, policy makers lack the empirical basis to optimise resource allocation and effectively promote sustainable mobility to visitors.

This thesis therefore develops a data-driven multimodal evaluation framework tailored to Rimini's specific transport and tourism environment. By combining the Google Transit API (for train, bus and trolleybus schedules) with Lime micromobility data (rental scooter and e-bike coverage), it produces accessibility metrics for routes from arrival gateways (airports and bus/train stations) to major accommodation hubs, as well as from these hubs to key points of interest (culture sites, theme parks, wellness facilities…). The framework's outputs: a set of travel time matrices, connectivity scores, and multimodal integration evaluation - are designed to inform municipal decision makers on where targeted investments and service adjustments can most effectively encourage tourists to choose multimodal public transit over private vehicles.

1.1 Rimini Tourism and Transportation

1.1.1 Rimini Tourism Overview

Rimini is located on the Italian Adriatic coast. It is one of the main cities in the Emilia-Romagna region, approximately 120 kilometres from the regional capital Bologna. As one of Italy's oldest and most prominent seaside destinations, its 15-kilometre stretch of beaches has attracted visitors since the late 19th century. In the 1950s, it saw an explosive hotel growth and nightlife, beachfront discotheque and Fellini's cinematic portrayals, cementing its "sun-sand-party" reputation (Battilani & Fauri, 2009). In the 1970s–80s, Rimini relied on seasonal mass tourism, with up to 82% of annual arrivals concentrated in June–September (Figini & Vici, 2012), leading to overcrowding and monotonous accommodation buildings. Early diversification efforts began in the early 1990s, focusing on cultural events. Substantive rebranding accelerated after competition from emerging Adriatic destinations such as Croatia's Dalmatian Coast. The 2010-published "Strategic Plan for Rimini and its territories" [1] and subsequent urban directives (2015 & 2019) spurred conference facilities, festivals, wellness initiatives, and boutique hotel development, repositioning Rimini beyond mere beach tourism.

In 2023, Rimini recorded over 14.68 million overnight stays. Domestic tourists comprised roughly 78% of arrivals, while the remaining 22% were international visitors (ISTAT, 2025a). In terms of economic benefits, the transportation, accommodation, and food service sectors accounted for nearly 27% of Rimini's GDP (ISTAT, 2025b) in 2022. The Romagna Commercial Chamber (2025) placed trade and tourism employment at approximately 25.6% of the city's workforce in the 2024 Economic Report. However, over-reliance on beach tourism led to pronounced seasonality; the same report indicated that the four months of June to September accounted for 76% of the annual tourist night count of 2024, and only 37.5% of accommodation facilities open year-round that year.

In recent years, the municipal authorities continued to push for diversification by developing cultural attractions, and promoting the city as a destination for conferences, sports events, and wellness retreats. These efforts aim to extend the season and keep a constant flow of incoming visitors throughout the year outside of the summer. Consequently, it is important that the city understands how tourists get to these attractions and event venues, to adjust the transportation options and support a wider visitation pattern.

1.1.2 Current Transport System

Rail service is the main public means to access the city. Rimini Station is a key node on Italy's Adriatic corridor, with frequent regional, intercity and high-speed trains between Bologna, Milan, and Ancona, Bari. Trains or high-way buses also connects the city to the main regional airport in Bologna. Local Federico Fellini International Airport, or the nearby Forlì, serve international and domestic routes, albeit mainly in the summer with much less frequent flights in other seasons. There are also a range of high-way bus lines, most notably by FlixBus, joining Rimini with other major Italian cities and nearby countries.

Upon arriving at the destination, core public transportation are operated by Start Romagna with a bus network focusing on coastal routes (Rimini Tourism, 2024). The Metromare, a dedicated bus rapid transit line, runs between Rimini and nearby Riccione along key coastal stops[2]. While coverage is reasonable along the coast, movement among peripheral residential zones, inland attractions, and nature areas remains fragmented. For tourists, navigation is also hindered by language barrier and confusion in obtaining tickets for different modes.

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[1] https://www.riminiventure.it/storia-2007-2023/

[2] https://www.startromagna.it/servizi/metromare/

Rimini has invested much in recent years to promote sustainable mobility. Besides the fully electric Metromare, the Parco del Mare coastal redevelopment project has enabled pedestrian and cycling paths (Corticelli et al., 2022), while micromobility services (mainly Lime) offer e-scooter and e-bike rental alternative, though the coverage is also focused on the coastal areas.

Rimini's strategic plans such as the Sustainable Urban Mobility Plan (PUMS, Conti et al., 2016) and 2023 Strategic Plan (Ridolfi, 2023) advocate a shift toward integrated, multimodal transport. Yet, gaps in inter-modal coordination, limited promotion, and lack of information concentration negatively affect usability especially for tourists. These issues underline the need for a structured framework to evaluate how effectively the transport system supports tourist movement to and around the city.

1.1.3 Importance of Multimodal Access for Tourists

For visitors, especially those who don't speak Italian and are unfamiliar with the local transit network, the ease of usage is essential to provide a smooth public transport experience. As Rimini push to diversify the tourism activities, visitors come for not only beach leisure but also cultural events, sport activities, and business conferences. Many of these venues are dispersed, some far from the coastal line. As a result, relying on a single mode of transport, whether train, bus or micromobility, is often inconvenient and inadequate for their needs.

Not only ensuring much wider coverage than any single mode, multimodal integration, by combining train, bus, and scooter services, also greatly improves flexibility and convenience, especially as door-to-door access is highly valued by travellers (Bergantino et al., 2023). However, separated ticket systems, lack of concentrated information, and limited digital solution remain large barriers. These issues reduce the attractiveness of the whole system and push visitors towards car dependency.

From a policy standpoint, encouraging multimodal access aligns with Rimini's broader goals to promote sustainable tourism, reduce car use, and encourage visit to lesser known neighbourhoods. However, there has not been a comprehensive study that assesses how effectively tourists can access these destinations by public transit (without a private vehicle). Addressing this gap is therefore essential to achieving both transport and tourism policy objectives.

1.2 Problem Statement & Research Questions

At present, there is no integrated framework that quantifies door-to-door accessibility for tourists across Rimini's network of train stations, airport gateway, public buses, and shared mobility services. Existing tools are either limited to commuter contexts or fail to reflect the specific journey patterns and constraints of temporary visitors. For city planners, this absence of evaluative capacity makes it difficult to prioritise improvements or assess the effectiveness of recent transport investments. For tourists, it contributes to continued reliance on cars, missed opportunities for sustainable travel, and inconsistent access to cultural or recreational points of interest.

Developing a method to assess tourist accessibility in Rimini is therefore important both for urban mobility planning and for improving the visitor experience. A robust evaluation would help planners identify weak links, improve transport coordination, and promote the modal shift away from private vehicles. More broadly, it would contribute to a growing body of work on mobility systems tailored to the needs of short-term urban users.

This thesis addresses the following primary research question:

> *How can we build an evaluation framework to quantify tourist accessibility in Rimini from the multimodal transport viewpoint.*

To operationalise this question, the study will examine the following sub-questions:

1. Which multimodal routes offer the most efficient access from Rimini's main gateways (e.g. railway station, airport) to key accommodation zones?
2. How can publicly available transit and micromobility data be used to model complete door-to-door journeys for tourists?
3. Where do multimodal transport options underperform in terms of travel time, transfers, or waiting times?
4. How do accessibility patterns vary across the network, and what insights can be drawn to support local transport planning?

To answer above questions, below objectives are laid out:

1. Develop quantitative indicators for multimodal trips (e.g., total trip time, number of transfers, frequency, micromobility availability) that represent tourist door-to-door travel experience within Rimini's transit network.
2. Compile a set of workable multimodal data by combining transit schedules (train, bus, trolleybus) with Lime micromobility availability.
3. Compute comprehensive origin-destination performance matrices between (1) gateways to accommodation hubs, (2) those hubs to key attractions. Evaluate these performance elements, including inter-mode transfer, walking time and coordination of schedules, to determine how effectively these separate means of transport operate as a unified network.
4. Identify segments or transfer nodes where trips exhibit inconvenience, longer-than-ideal travel times or availability gaps. Rank these shortcomings to help prioritise infrastructure investment or service adjustments.
5. Produce visualisations (graphs, maps, and diagrams) that highlight strengths and weaknesses of current multimodal options. Formulate actionable recommendations to help Rimini planners in enhancing visitor mobility.

This thesis is organised into six chapters, the first being introduction which outlines Rimini tourism transformation, the growing need for sustainable mobility, and the gap in multimodal accessibility assessments. It defines the research problem, objectives, and central questions. The second chapter reviews studies on transport and tourism, with a focus on multimodal access, and door-to-door travel concept and evaluations. It identifies methodological and contextual gaps that the study aims to address. The third chapter proposes the method of research. It covers development of the evaluation framework, describes the data sources, and indicators used to evaluate multimodal performance. It also details the analysis procedures. The fourth chapter summarises the results, including the accessibility scores, travel time matrices, and trip performance comparisons across selected routes. The discussion chapter interprets the findings in light of Rimini's tourism and transport goals. It reflects on patterns of accessibility in Rimini PT system, followed by suggestions for municipal planners and tourism authorities. The discussion also considers methodological implications, limitations and direction for future studies. Finally, the thesis concludes with reflections on the applicability of the proposed evaluation framework and offers perspectives on the regional transport system for tourists.

Chapter 2

Literature Review

2.1 Transportation and Tourism

Transport and tourism are fundamentally interdependent, where means of transportation serve as both constraints and enablers of tourist experiences. An example was the rise of low-cost airlines (LCCs) in Europe during the mid-1990s, which revolutionised the intra-continent travel landscape. The next revolution, multimodal transportation, is seeing initial success in metropolis such as London, Hong Kong, and Singapore (Dawda et al., 2019). While inadequate infrastructure limits tourists' ability to enjoy destinations without a car, well-designed multimodal systems can expand travel options and enhance the overall tourism experience (Hall & and Ram, 2019). This relationship becomes particularly complex in tourism-dependent cities, where transport systems must simultaneously serve resident populations and temporary visitors.

2.1.1 Tourist Mobility Patterns

Tourist mobility patterns exhibit several fundamental differences from that of the citizens, which means PT system design and evaluation for each population have significantly separated considerations. Masiero & Zoltan (2013) demonstrate that tourists face a different decision-making process when deciding on destinations and transport modes, as their familiarity with the destination is a significant determinant, and activities motivation and participation encourage varied travel patterns. Kuhnimhof et al. (2006) explored the knowledge dimension in-depth, indicating the unfamiliarity makes travellers more dependent on intuitive network design, clear signage, and accessible information systems.

Moreover, according to Bursa et al. (2022), tourists mobility decisions also depends on factors such as weather conditions, group composition, and the nature of their activities. Recreation and sightseeing interests would necessitate flexibility and coverage of multiple detours.

The temporal dimension of tourist travel create additional complexity. In the same 2022 study, Bursa et al. found that unlike residents who mainly travel on routine schedules, tourists operate within compressed time frames where transport decisions carry higher stakes: a missed connection or inefficient route can cut into a limited holiday duration. The study concluded that due to this time budget, tourists value service quality and reliability over low cost. This is understandable because while citizens are often highly price-sensitive due to regular and relatively consistent use, tourists generally demonstrate lower price elasticity. Furthermore, transport costs usually represent a small portion of the trip expenditure, thus tourists are willing to pay a premium for convenience, reliability, and comfort during their journeys. This was also noted by Transport for London (2013), that tourists utilised every transport mode more extensively than local users.

Finally, in terms of group composition, member makeup and size play a big role in shaping mode choice. Based on Domènech et al. (2023) findings, larger groups may prioritise private vehicles to simplify coordination and save costs, whereas smaller groups or solo travellers would be more willing to experiment with public transport or micromobility options, even if they are unfamiliar.

2.1.2 Transportation Impacting Accessibility and Tourist Satisfaction

Transport infrastructure not only determines where tourists can go, but also dictates how they experience the destination once they arrive. Hall & and Ram (2019) found that considering time constraints, tourists prefer to explore new places by mobility modes that maximise sightseeing and activity opportunities. And public transit needs to satisfy their expectations in terms of speed, connectivity, comfort and convenience to become their choice instead of private car.

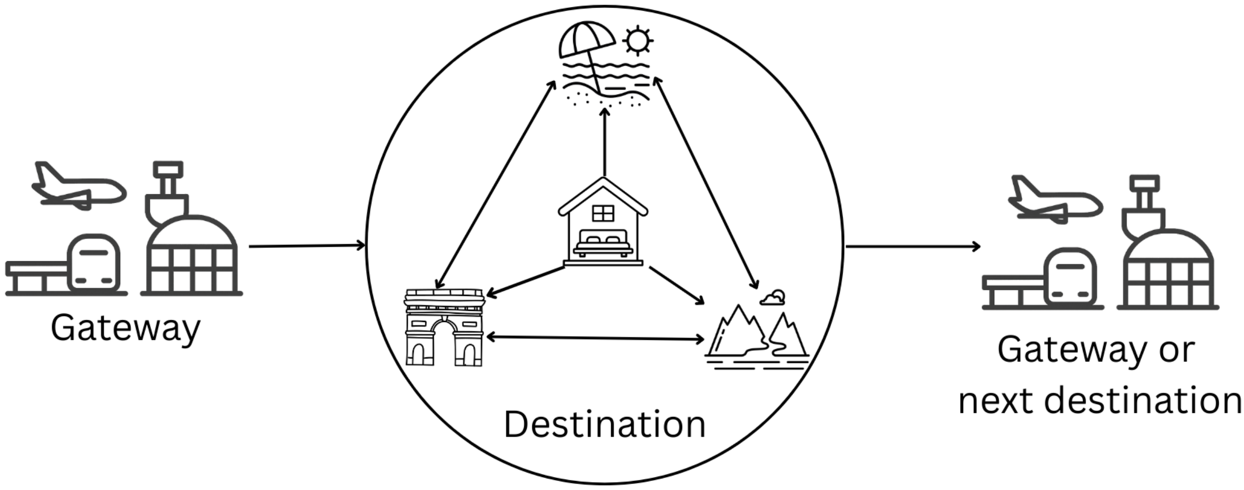

Figure 1: Tourists transportation usage cycle

Tourist dispersal (the distribution of visitors across different areas and attractions) is fundamentally shaped by transport accessibility. Masiero & Hrankai (2022) concluded that besides the attractiveness of the attraction itself, how effective and reliable the tourists can get there is key to boosting visitation, especially to peripheral areas. In this sense, accessibility influences whether tourists concentrate in central areas or venture to less visited attractions. This distribution impacts both tourist satisfaction and destination management. Good transportation network can facilitate more balanced visitor flows, while insufficient connectivity would exacerbate overcrowding in popular areas, heightening stress and dissatisfaction.

In a follow-up study, Masiero et al. (2023) also explored how public transport contributes to drawing tourists to remote points of interests. As have seen before, time is of utmost value to visitors. Here, a decrease in minibus travel time of 20% led to an increase in the transport mode shares. Convenience also encourages adoption, as direct transport access showed substantial boost in visitation of attractions. Moreover, information availability inside vehicles and at stops help to alleviate the unfamiliarity and build confidence in the system, thus supporting tourists' visit intention to these less visited sites.

As seen in these studies, the factors affecting user satisfaction becomes much more complex in the context of multimodal transport due to involvement of multiple means and respective linkages. Tourists must navigate between different modes, each with different usage method, ticketing/ information systems, and service standards. The seamless integration of these modes significantly influences the tourists' ability to access destinations efficiently, and is key to encourage off-the-beaten-track exploration. As Masiero et al. commented, a capable public transport system would deliver travellers faster and provide effective information at both ends and in between modes, ideally even better with direct connections from accommodation to attractions.

2.2 Multimodal Accessibility and Evaluation Methods

2.2.1 What is Accessibility?

While we may see them appear interchangeably, accessibility, mobility and, to a lesser extent, connectivity are distinct concepts.

Accessibility measure how easy tourists can travel between the origin and destination. Litman (2023) emphasised that 'access is the ultimate goal of most transportation'. This dimension covers network coverage, quality of connection and walking… Connectivity is also a contributing factor to accessibility, indicating the level of integration of different public transportation systems (Preston, 2012). The components of connectivity are transfer service facilities, quality, and penalty. They are further defined by Cheng & Chen (2015) to include 'transfer accommodations, passenger transfer information, services' integration, station staff, as well as any negative perceptions in the ease of transfer'. On the other hand, Litman refers mobility to the movement itself, quantifying qualities such as speed, reliability, comfort, and crowding levels.

For our evaluation, this distinction is particularly important. High mobility shown in fast travel time and frequent service has an important impact on usage decision. However, for a multimodal network to function at a high level, accessibility and connectivity become critical, because they determine user perception and satisfaction for the whole trip, regardless of any single mode's mobility condition. The need for door-to-door access also highlight the role of walking elements, which makes up the start and end of the travel chain, and help link different mode if necessary (though ideally guests should not need to walk during transfer).

Lastly, it is necessary to recognise the gap between objective accessibility (measured times), which can be improved by network design and infrastructure, and perceived accessibility (effort required), which can be improved by better info-system and network-wide integrated user interface. Therefore, accessibility should be understood as a multidimensional construct, and a robust assessment of the transport network must account for both objective and subjective factors. Barbosa et al. (2017) propose a model that defines accessibility across three primary domains: physical (transport infrastructure, distance), temporal (frequency, travel duration), and perceptual (comfort, reliability, safety). This is further developed by Diana (2012), introducing the idea of satisfaction-based accessibility. Rather than treating accessibility as a function of measurable inputs alone, her approach incorporates user evaluations of trip quality. This is particularly useful in tourism contexts, where expectations and unfamiliarity often lead tourists to perceive the trip more negatively than quantified characteristics.

2.2.2 Accessibility Evaluation and Indicators

Quantifying accessibility for tourists requires indicators that reflect both the functional performance of the transport network and its utility for this user group. To address this complexity, researchers have turned to multi-criteria analysis (MCA) and hybrid evaluation techniques that incorporate both quantitative and qualitative variables. One of the leading theoretical frameworks was developed by Krygsman et al. (2004). This work conceptualises the journey as a chain of transport modes, which can be quantified with an interconnectivity ratio. This study focuses on access and egress travel time, and concludes that interconnectivity properties of different multimodal trips are influenced by socio-demographic, transport, and land-use factors.

Barbosa et al. (2017) proposed another comprehensive framework with a seven-stage multi-criteria assessment process at the core. Starting with the construction of the user journey map to reproduce the door-to-door travel experience, it clusters affecting items, assigns weights and creates the evaluation scales. These feed into an assessment equation which captures the complete visitor experience. The framework reveals criteria that might be overlooked, such as the stress of navigating unfamiliar connection, the value of clear signage, and the cumulative effect of multiple small inconveniences across a multimodal trip.

The perceptual element of accessibility also receive a lot of attention. The study by Diana (2012) uses ordered satisfaction scores to represent user perceptions, suggesting that an attractive system depends not only on its raw performance but also how users experience those values. Furthermore, stated preference experiments are often used to derive factors impacting users willingness to engage with public transport. A targeted study of the transfer stage (Garcia-Martinez et al., 2018) reveal that even when total travel time is acceptable, poor transfer conditions significantly reduce the overall perceived accessibility. Masiero & Hrankai (2022) apply a discrete choice experiment, which combines varying level of different attributes of the transport system to model tourists' perceived accessibility to peripheral attractions. The study confirms the importance of information presentation (maps, pavement markings, in-vehicle monitors) in tourists' adoption of public transport.

These studies provide a solid foundation on how to design a multi-criteria study that combines system performance and user experience to evaluate accessibility effectively. In terms of specific indicators, many share a similar set of measures. On subjective dimension, we can classify them into performance and connectivity. Performance indices are travel time, walking distance, network coverage, frequency and reliability (Barbosa et al., 2017; Birr et al., 2014). Connectivity is reflected in waiting, number of transfers, intersection coverage, route overlap (Garcia-Martinez et al., 2018; Hadas, 2013). Perceived aspects are evaluated through comfort, security, cleanliness (Barbosa et al., 2017; Göransson & Andersson, 2023) and integration of information and usage (Diana, 2012; Masiero et al., 2023)

Additionally, subset of studies such as Karner (2018) focuses on service equity, resulting in the choice of indicators that represent demographic (worker and job characteristics, aggregated employment opportunity) and travel time (including simulated walking time) variables.

2.2.3 Data Sources, Tools, and Practical Challenges

For objective performance-related metrics, evaluation models typically requires reliable data sources and then try to integrate them. In recent years, General Transit Feed Specification (GTFS) datasets, and digital routing platforms that aggregate them, have become one of the go-to tools for transport analysis. However, their application in tourism contexts requires specific parameter choice and compromise to overcome obstacle in terms of data resolution, behavioural assumptions, and network variability.

Hadas (2013) incorporated GTFS with spatial representation of the transport network to model the public transport network. The GIS-based approach allowed adjustment of the model scale (from street- to city-level) and network characteristics (frequency, stop placement) to determine design effectiveness that would minimise transfer impact. This method is utilised in multiple papers, including another (Karner, 2018) which was discussed earlier. This study in Phoenix (US) used GTFS feed of the urban metro line and street network from OpenStreetMap to model accessibility indicators and assess access equity among different neighbourhoods.

Typically, these feeds contain information on stop locations, service schedules, and routes, which can be parsed to calculate frequency, waiting time, and spatial coverage. However, one major weakness when applying this to multimodal network is that it requires GTFS feeds from all modes in the locality, some of which may not be publicly available, especially from smaller operators. To tackle this issue, Haitao et al. (2019) proposed a slightly different angle involving Google Directions API, which aggregates GTFS from multiple operators and calculate door-to-door public transit routes between a set of origin and destination. Several benefits are outlined, including reduced need for data collection, lower local computing resource, and duplicable results.

Limitations do exist, from potential changes in the Google engine to inability to cater route for different travel purposes and socio-economics traits. However, it concluded that ‘API probing’ serves as an efficient way to evaluate accessibility, though open-source services would function better than proprietary ones such as Google.

There are other considerations with scheduled data usage. Hadas notes that accurate modelling would benefit from the addition of real-time information, which may be unavailable or unreliable in many systems. Moreover, this approach strictly measures performance and connectivity indicators. To obtain data on perceptual attributes (service quality, information availability and system-wide integration), other data collections must be complemented, via infrastructure assessment, survey, or other qualitative methods.

Overall, these studies demonstrate that accessibility modelling is sophisticated and data-demanding process. It is complicated further in tourism context with the introduction of unfamiliarity and irregular travel patterns. For a city like Rimini with a less developed transit database, the challenge lies in making use of the limited available data to develop a framework that is data-informed and behaviourally realistic. This study aims to propose a simplified evaluation framework based on Google API feed that is adapted specifically to model the visitors’ experience navigating the city’s multimodal transport network.

2.3 Transport for Tourists: Applied Studies

Interdisciplinary research integrating transportation and tourism has seen a rise in popularity in the past two decades, but more profoundly as sustainability became an urgent agenda in every industry. Studies of existing multimodal transport implementation, either targeting tourists, or conducted in tourism-dependent locations, provide valuable insights into the challenges of improving accessibility and suggests interesting angles for the evaluation framework.

2.3.1 Transport Network and Design in Tourism Cities

Traditionally, many works have zoomed into identifying why tourists choose specific means of transportation. Masiero & Zoltan (2013) explored the links between tourist profiles, number of visit areas and transportation decision in the Canton of Ticino, Switzerland. The study, using discrete choice experiment, found a linkage between tourists’ movement patterns and their choice of transportation mode. Importantly, the major elements influencing transportation decision all pushed tourists to use public transit. Furthermore, the study highlights the importance of connecting attractions and offering public transport promotions, since these improvements encourage domestic tourists to explore multiple regions and incentivise international visitors to peruse the public transport network. Another study by Domènech et al. (2023) also delved into the mode choice determinants. Researching visitors to Barcelona, a major European tourist destination, their work confirms that several factors influences this decision, including traveller profile, pace of visit (pull factors) and supply of each mode (push factor). It emphasises that a metropolis with large proportion of tourists like Barcelona would benefit from integrating this population into its mobility and infrastructure planning.

On the system side, there are also works that attempt to analyse accessibility in infrastructure. A highly relevant case to this study, Bergantino et al. (2023) compares accessibility performance of buses, trains and cars from regional gateways to coastal destinations in the Apulia region. The findings suggest that buses are more efficient than trains, while both underperform regarding travel time relative to private vehicles. The study pioneers an approach for tourist-aimed transport network evaluation in a coastal area, serving as methodological precedence for this thesis. Also focusing on tourists in Apulia, a recent addition to this subsection comes from Morgese (2024), who proposes an accessibility indicator for multimodality that integrates bikes and public transport. The resulting metrics identify areas that are more friendly to the implementation of bike-PT combination, and recommend adjustment to the existing bike lane network and shared bike infrastructure to improve accessibility.

2.3.2 Micromobility in Tourism Cities

Besides the insurgence of cycling, the rapid growth of shared micromobility services has expanded options for tourism transport modes. In terms of multimodality, they promise solution to first-and-last-mile issues, but integration into existing PT systems has proven uncertain, while assessment of their combined effectiveness is still not a prominent topic in the literature.

Recent research has begun to look at how tourists interact with these services. Surveying travellers in three major tourism cities (Barcelona, Berlin, Rome), Jażdżewska-Gutta et al. (2023) question micromobility's potential as first/last mile mode in a multimodal public transit journey. They concluded that while there is a feasibility, tourists show low potential as a majority would adopt shared bike and scooter during travel only if having previous experience at home (whether for work or recreation). While for potential users, ease of usage is not as an important factor compared to availability and coverage, this familiarity condition shows the need for specific strategies to push this mode to visitors and encourage integrated use.

While not specifically geared towards tourism, D'andreagiovanni et al. (2022) examine the regulations and spatial dimensions of mobility sharing in Rome, a major tourist hub. The paper combined the analysis of service coverage of various operators, and national and municipal-level regulations. It exposes the need for open data on service area of the services, including operating, parking, and prohibited zones. The result also highlights the concentration of services in central historical districts, noting the equity need of service expansion to cover peripheral neighbourhoods.

2.3.3 Identified Gaps in Tourism Accessibility Literature

Despite growing recognition of tourism transport as a distinctive subdomain, several analytical and methodological gaps remain in the literature. In particular, only a small number of research look to evaluate "hard" accessibility (or the infrastructure and physical connection), that satisfy tourists movement patterns. Since this has been demonstrated to differ from residents', combined with the fact that in tourism cities, the system must serve both populations, this segment warrants a detailed examination.

Moreover, many studies have pointed out the importance of familiarity in tourists' mode choice. However, existing system-side evaluations face difficulty quantifying this trait, and to a larger extent, develop metrics to account for tourist-specific constraints such as limited local knowledge, time budget, and unfamiliarity with local networks. Moreover, while micromobility became much more prevalent on the streets in the past years, and has high potential to strengthen the multimodal network, the lack of literature highlights the need for more attention on this specific linkage. Researching micromobility and tourism accessibility under a unified framework will significantly benefit our knowledge and provide insights into how to utilise this innovation.

Methodology-wise, there exists a similar need to involve multiple data sources in a single analysis. As far as this review has looked, no study combines digital routing platform like Google Directions API with micromobility data to evaluate accessibility of tourists, who have specific travel patterns. The direct use of Google API might yield insightful result, because it simulates tourists' increasingly reliance on digital platforms for navigation at the destinations. The combination with micromobility may review factors that would improve accessibility for the system.

2.3.4 Rimini as a Case Study

Rimini is a compelling case for tourism accessibility analysis due to its tourism-focus economy, traditional transport network, and the policy emphasis on multimodal integration. Developed as a summer destination, Rimini has long suffered from heavy seasonality and car dependence. Figini & Vici (2012) discusses targets to attract visitors in the off- and mid-seasons. Besides the improvement in product offerings and targeted marketing strategy, enhanced public transport is also mentioned as a means to extend visitation beyond traditional peaks. However, in that period, transport infrastructure, together with developing cultural tourism, had been seen as a long-term investment.

In recent years, culture has become a main product segment as the city pursue further markets such as conference, sports, and wellness. The public transit network also went through major changes. The Rimini Sustainable Urban Mobility Plan (PUMS 2016) identifies the province's transport challenges, many of which directly concerns tourists' accessibility and served as the foundation for many investment projects in infrastructure. In PUMS and later strategic plans, the city explicit identifies optimisation and integration of public transport systems as a core objective, alongside development of intelligent transport network and info-mobility services. These efforts resulted in several notable improvements, including the Metromare rapid transit and the Parco del Mare urban redevelopment, both described previously.

The city's recent transformations offer an interesting case for analysis. Corticelli et al. (2023) look specifically at the canal port area, but transportation is only a small portion in the analysis of the urban regeneration progress. Saying that, the authors mentioned the focus on soft mobility which fosters space for walking, cycling and socialising. Pazzini et al. (2021) surveyed visitors at gateways to propose improvement in connection between inland and coastal areas. The study highlights demand for an integrated bus-train ticket within the region, and identify tourists' high willingness to pay for such integrated solutions.

Finally, Rimini is well covered in the Google Transit engine, with the majority of train and bus lines having up-to-date schedules and, for major lines, even real-time vehicle location and traffic constraint update. This, combined with the city's well established tourism landscape and the existence of Lime micromobility service, present an ideal opportunity to explore the infrastructure dimension of tourist accessibility. The sufficiently complex transit network, and large number of attractions (in varying distances) serves as a strong foundation to formulate a data-driven research framework, while the relatively small destination size may make it easier to apply findings to policy or management recommendations.

Chapter 3

Methodology

3.1 Overview of Approach

This section aims to lay out a data-driven method to evaluate tourist accessibility of Rimini's multimodal public transport system. The framework integrates trip data from the Google Directions API with spatial representation of Lime micromobility zone, and calculates a series of indicators to assess door-to-door performance across various origin–destination (OD) pairs. While the method is not derived from an existing model, its indicator structure is derived after considering the tourist journey with Barbosa et al. (2017) 7-stage transport service assessment, and draws inspiration from the interconnectivity ratio concept outlined by Krygsman et al. (2004).

The key methodological choices are:

- Schedule-based evaluation of public transport journeys using Google API itineraries. The API data covers most major public transport modes, including regional and high-speed trains, highway buses, local buses (Start Romagna), and the Metromare trolleybus line.
- Due to the nature of tourist-centred scope, the chosen types of OD pairs are gateways to accommodations and accommodations to points of interest.
- Focus on multimodal integration by viewing walking, public transport and micromobility as a unified system.
- Private vehicles, including taxis, car rentals, and car sharing, are excluded.

The workflow: There are four main stages to the research, each will be explained in-depth in the sections later.

1. Data acquisition: Identify the routes by building the list of gateways, accommodations and attractions. Then use Google Directions API to simulate public transport trips for selected OD pairs. Alongside this, prepare Lime's service zone data for integration into the analysis.
2. Data cleaning of API trips: Remove duplicates and transform raw API output into structured data set. From the raw output, individual steps for each trip is also extracted to perform trip-level step analysis.
3. Indicator construction: Calculate trip-level metrics (travel time, walking time, transfer wait time, transfers, etc.). These metrics are aggregated into route-level for a presentation of each OD pair performance. From this, we can develop a composite accessibility index using weighted components and apply to route level.
4. Analysis and evaluation: Several analyses are performed, such as the use of transit modes and multimodal integration on route level, between weekend and weekday. Moreover, after integrating Lime service zone, it is possible to simulate potential micromobility

enhancement if replace long walking legs. A dissection of sample trips can help identify pain points in the multimodal system, and generalise into weakness profile for those routes.

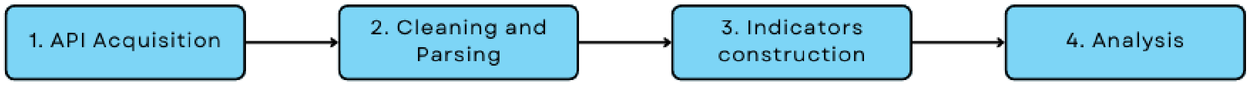

Figure 2: Data Workflow

The use of secondary instead of primary data

The data query from Google API constitutes secondary data. Looking from the tourist point of view, who is unfamiliar with Rimini's transport operators, it is likely that their first choice to look up when and how to reach a point is by route-planning platforms such as Google or Moovit. Therefore, unlike traditional GTFS-based studies, this approach reflects real planning logic and represent more closely the public transport trip that would be experienced by non-local users. Google Directions API aggregates timetables and traffic constraints from multiple operators, calculates transfers and walking segments, making it particularly well-suited for multimodal analysis.

3.2 Study Area and Scope

3.2.1 Spatial Coverage

The study focuses on the municipality of Rimini and the adjacent city of Riccione, a major summer destination on the Italian Adriatic coast. These are treated as a unified tourism destination due to their proximity and shared infrastructure. Moreover, both destinations have an intertwined development history and are usually considered together as one large destination. Travel routes are modelled between each gateway and clusters of hotels, and between hotel clusters and individual POIs.

Three categories of locations are included, whose selection will be discussed in details in data acquisition:

- Gateways are defined as the major access points into the region: Rimini Train Station, Rimini Flixbus Station, and the nearest airports—Bologna, Rimini, and Forlì.
- Accommodations as seven zones: Torre Pedrera, Rivazzura, Viserba, San Giuliano Mare, San Giovanni, Rivabella, Riccione (Alba).
- Points of interest considered in the analysis span both coastal and inland areas, including sightseeing, cultural, recreational sites. They comprise of 10 spots: Rimini Historic Center, OltreMare, Rimini Port, Rimini Parco del Mare, Mirabilandia, Shopping Center le Befane, Italy in Miniature, Misano World Circuit, Rimini Fiera, San Leo.

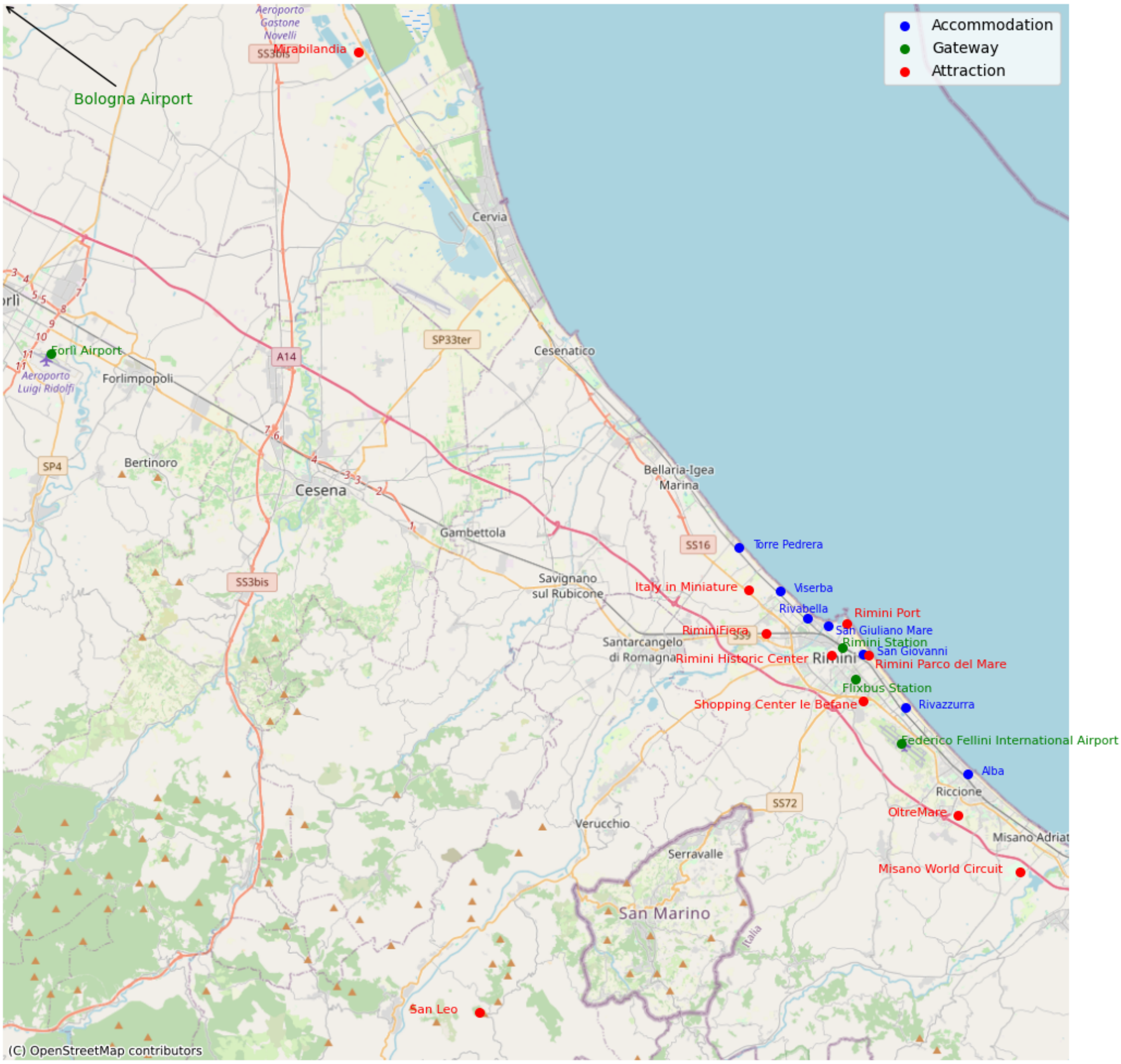

Figure 3: Origins and destinations map

3.2.2 Temporal Scope

Transit journeys are examined for two specific days in June, one weekday and one weekend day to capture variety in schedules and connection. The weekend is June 20, aligned with La Notte Rosa - the major event marking the start of holiday season.

While we can try to increase sample variety by considering other dates in shoulder and off seasons, the scale of this study is limited and do not allow for such data range. Moreover, the accuracy of Google API (the underlying engine of Google Maps) decrease the further away from the query date.

3.3 Data Sources and Acquisition

3.3.1 Google Directions API

This is the core of this study framework. Public transport itineraries were obtained via the API, using the `mode=transit` and `alternative=True` to get as many trips per query as possible. We queried all origin-destination pairs, 35 for gateway to accommodations and 70 for accommodations to attractions. Example of an API URL:

```
https://maps.googleapis.com/maps/api/directions/json?origin=Via Annibale Fada, 
47923 Rimini 
RN&destination=44.0063295726817,12.653564890726816&mode=transit&departure_time=
1750867800&key={key}&alternatives=true
```

For each OD pair, departure times were set hourly from 00:00 to 23:59, for both the chosen weekday and weekend. This produced a rich set of route samples, capturing a snapshot of one full day of public transit trips with all variations across the day. Each query returns up to six itineraries, showing the options that would appear on Google Maps at the specified departure time. These vary in mode combinations, number of transfers, or walking distances.

There are several limitations to this approach. The API may not present all possible trip options: it returns only those deemed optimal by Google's internal algorithm. This means we have to rely on Google's blackbox, and cannot rigorously justify the combinations. Some valid but less convenient routes which locals can take may be excluded, reducing the completeness of the dataset. Besides not justifiable, the routing logic is also not customisable.

However, it mirrors what a tourist would receive and follow when searching on the apps. Since the majority of tourists lack the knowledge of the local transit system and rely on platforms such as Google Maps for transit direction, this method has practical relevance to our case, despite analytical opacity.

Since the result are more accurate the closer the specified date is, all queries were executed within two weeks of the selected travel dates in June to ensure most accurate and complete transit route data.

3.3.2 Accommodation and Attraction Choice

To find out the most representative locations that represent Rimini and Riccione (from here on referred to together as Rimini) lodgings, a complete list of accommodation is extracted from OpenStreetMap. OSM is freely available and is regularly maintained by the community. Moreover, it offers a consistent data source across regions, and is quite strong in Europe. While it may not be as complete as proprietary data from Google or Booking.com, it returns 744 properties, which is sufficient number to serve our purpose of picking out the representative.

Seven accommodation clusters were identified using DBSCAN spatial clustering, with parameters tuned via k-distance analysis (`eps = 0.1` and `min_samples = 10`). The approach ensures inclusion of major lodging zones along both northern and southern coastal segments. Manual examination also showed that major hotel concentrations had been covered. Then, the centroid of each cluster was extracted to serve as the origin or destination point in routing queries.

There are several implications of this clustering method, the most obvious being areas with low-density or niche properties like castle stays would be omitted by the cluster parameter. Moreover, the generalisation of a zone with diverse locations into a single centroid means within-zone accessibility cannot be considered. However, with eps representing the distance between points in the cluster at 100m, this is good enough for this system-level study.

Attraction representatives were selected from a process integrating multiple sources. First, entries from TripAdvisor's "Things to Do in Rimini" were recorded. The first 5 pages provided 150 venues that are highly ranked and frequented by the site users. The site's ranking is based on visitor reviews, ensuring the top entries have high perceived importance and touristic value. This list is then complemented by venues from VisitRimini, the city's official tourism site. This created a dual narrative, combining attractions that are popular with visitors, and those that the city wants to promote.

Since the project scale cannot work with hundreds of attractions, a weighted scoring method was applied. Google Maps' rating and review count for all entries were used to ensure fairness between the 2 lists. To prioritise relevance to tourists and to our research objectives, entries appearing on both platforms were fully retained, accompanied by the top 15 that only appeared in each of single-source list (TripAdvisor or VisitRimini). Beaches were excluded on the assumption that visitors would walk to the closest one from their accommodation.

With the list of potential candidates, clustering was performed to group geographically close attractions to avoid having multiple nearby attractions saturating the transit analysis. These cluster centroids and the other stand-alone attractions at the top of the weighted score ranking formed the attraction list for the accommodations to point of interests routes.

Table 1: Top 10 points of interest in Rimini

Name	**Weighted score**
Rimini Historic Center	6.3 (cluster)
OltreMare	6.4 (cluster)
Rimini Port	6.0 (cluster)
Rimini Parco del Mare	5.0 (cluster)
Mirabilandia	6.9
Shopping Center Le Befane	6.7
Italy in Miniature	6.7
Misano World Circuit	6.7
Rimini Fiera	6.4
San Leo	6.3

While convenient, there are limitations to using online ranking and review counts. Firstly, these do not reflect actual visitation, and introduce a demographic skew depending on the platforms' user population. Moreover, TripAdvisor and Google data was added manually which may contain mistakes. Lastly, subjective decisions (such as removing beaches or admitting all clusters without checking weighted scores) were necessary to simplify the research but may lead to under-representation of certain visitor interests. However, as our goal is to identify sites that are popular with tourists in general, this method is sufficient albeit imperfect.

3.3.3 Micromobility Service Zones

Due to time limit and lack of data access, this study do not use real micromobility trip data. Instead, the aim is to simulate micromobility usage for legs that are within the zone of these services. Here Lime is used as the main scooter-sharing operator in Rimini.

A polygon representing Lime service zone was redrawn manually from the visual boundaries shown in the mobile app. Later during simulation, the walking segments were assessed for micromobility eligibility based on whether both start and end coordinates fall within this polygon.

Figure 4: Lime service zone geofence

A weakness of this approach is the accuracy of the redrawn polygon. This is minimised by double checking and comparing border street names between the app and redrawn version. Another is that many assumptions need to be asserted pre-simulation: uniform availability, vehicle density, static battery levels and lax parking regulations, which are dynamic and always changing in real life.

Furthermore, It also assumes that a trip is eligible only when both ends of a walking segment fall inside the zone, ignoring cases where a scooter could replace part of the walk. However, to our objective of exploring the potential of micromobility as a part of the multimodal system, it is not necessary to be precise in the usage patterns and data.

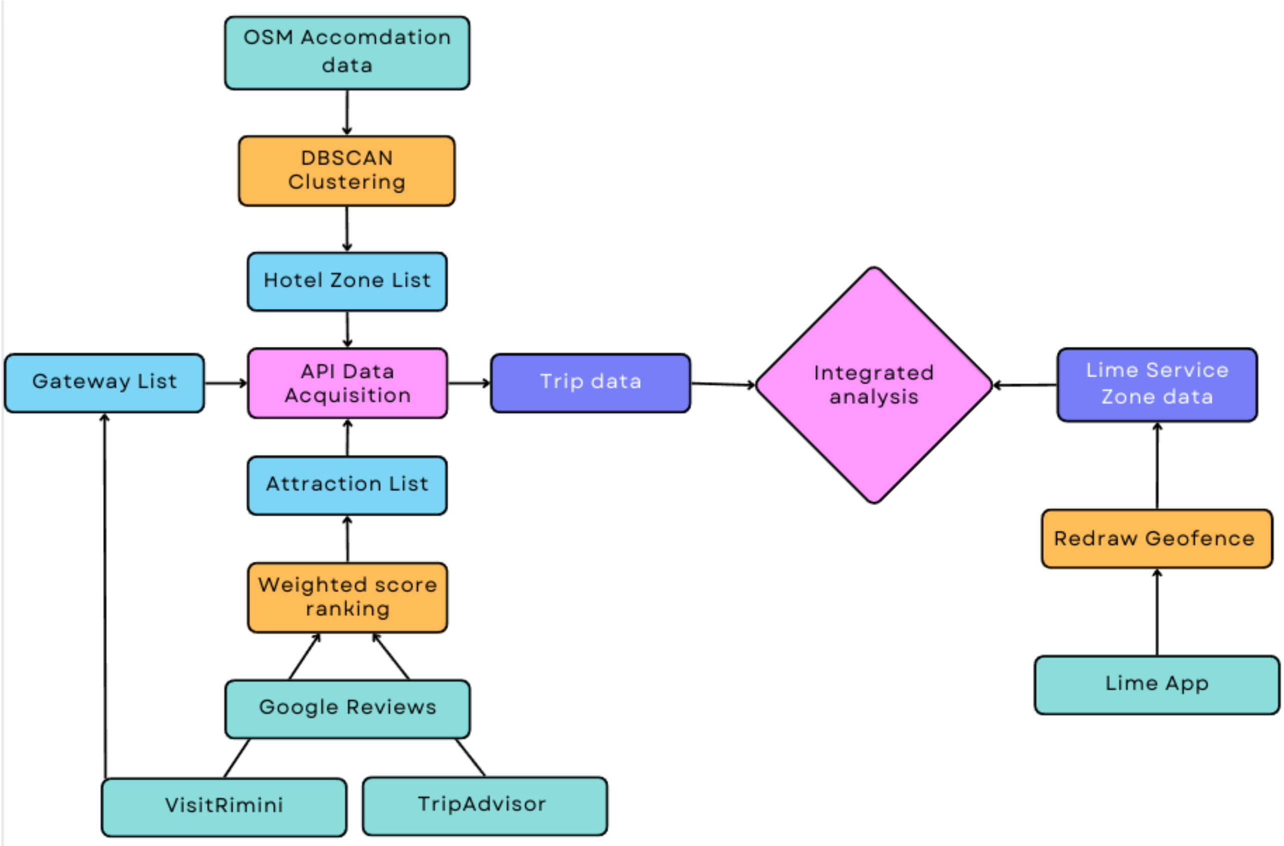

Figure 5: Data processing workflow

3.4 Data Cleaning and Processing

3.4.1 Deduplication and Trip Indexing

The initial route query outputs included multiple overlapping trips for each OD pair. This is because Google API returns 6 routes per query whose departure time are closest to query time. If there are less than 6 trips departing in that specific hour, those starting later would also be included, coinciding partly with the query results from later hours. Duplicates were identified grouped based on identical `start_time`, `end_time`, `start_point`, `end_point`, and route structure (`route_steps_details`). Among these, the one with the earliest query time was retained.

Each trip was then assigned a unique `trip_idx` to facilitate downstream processing and analysis.

3.4.2 Step Expansion and Timestamp Parsing

Besides the overall time data, an important part of the raw data was the `route_steps_details` field (a JSON list), which contains the anatomy (timings and type of each mode used) of the trip. To facilitate the use of this in later stages, it was exploded into a step-level dataset with each trip record representing by a sequence of travel legs. Step order within a trip was preserved using `step_index`.

This step-level data contains coordinates (start and end latitude-longitude); mode (either WALKING, TRANSIT); duration; departure and arrival timestamps (only available for transit). All time-related fields were parsed into standard datetime format. Duration fields were standardised in seconds.

3.4.3 Metric Construction

From the cleaned route data, three primary components of trip time were calculated:

- In-vehicle time represents total duration of all transit steps.
- Walking time sums that of all walking steps.
- Transfer wait time needed to be calculated as it was not explicitly in the data. We identify it as the idle time between two transit legs. There are 3 cases:
    1. If the whole trip consists of 1 transit leg, there are no wait time.
    2. When 2 transit steps happen consecutively, the wait time is the gap between them.
    3. When 2 transit steps have a walking step in between, the wait time is the gap between them subtracted with walking time.
        - To preserve logic of real life transfer, if the result is negative (walking time > time between vehicles, wait time is set to 0).

The final trip duration was computed as the sum of all three components.

3.4.4 Ensure Trips Validity

Overnight trips: For accommodation to attraction trips, those with overnight transfers were excluded, since it is highly unlikely tourists choose to visit a point of interest with overnight public transportation. These are flagged if two consecutive transit legs departed on different calendar days AND had a gap exceeding one hour.

However, this logic does not apply to trips from gateway to accommodation, since it is feasible that visitors arrive late in the day and get to Rimini after midnight. For this type of trips, overnight sequences were retained, and a random manual inspection confirmed their validity as long-distance arrivals.

At the end of the process, 2 datasets were generated for each OD type for weekend and weekday:

- `valid_df` with cleaned and filtered trip-level data.
- `df_steps` containing exploded step-level data.

Example of route dataset:

	trip_idx	start_point	end_point	num_transfers	travel_modes_sequence	route_steps_details	...	end_time_dt	query_departure_time_dt	invehicle_time_s	total_walking_time_s	transfer_wait_s	total_duration_s
0	0	Piazzale Cesare Battisti	Viale Gaspare Gozzi	0	WALKING	[{'mode': 'WALKING', 'duration_text': '22 mins...	...	2025-06-20 00:22:21+00:00	2025-06-19 23:10:00+00:00	0	1341	0.0	1341.0
1	1	Piazzale Cesare Battisti	Viale Livenza	0	WALKING, TRANSIT, WALKING	[{'mode': 'WALKING', 'duration_text': '3 mins'...	...	2025-06-20 16:57:00+00:00	2025-06-20 14:10:00+00:00	540	395	0.0	935.0
2	2	Piazzale Cesare Battisti	Via Umberto Di Miniello	0	WALKING, TRANSIT, WALKING	[{'mode': 'WALKING', 'duration_text': '3 mins'...	...	2025-06-20 16:53:00+00:00	2025-06-20 14:10:00+00:00	300	547	0.0	847.0
3	3	Piazzale Cesare Battisti	Viale Gaspare Gozzi	0	WALKING, TRANSIT, WALKING	[{'mode': 'WALKING', 'duration_text': '4 mins'...	...	2025-06-20 16:55:55+00:00	2025-06-20 14:10:00+00:00	595	393	0.0	988.0
4	4	Piazzale Cesare Battisti	Viale Zandonai	0	WALKING, TRANSIT, WALKING	[{'mode': 'WALKING', 'duration_text': '2 mins'...	...	2025-06-20 17:05:00+00:00	2025-06-20 14:10:00+00:00	1200	345	0.0	1545.0

Figure 6: Example of route dataset -gateway to accommodation on weekend

3.5 Route-Level Summary

Cleaned trip-level data were aggregated to generate route-level summary indicators. These summary metrics provide the basis for later construction of the accessibility index and pattern comparison. This task is used for all datasets (gateway/attraction on weekday/weekend).

Trips were grouped by `origin` and `destination` to produce one row of summary data per OD pair per day. For each group, the following were computed:

- A. Duration and times: - `avg_duration_m`: mean total travel time - `avg_invehicle_m`: mean duration spent in a public transportation - `avg_walk_m`: mean walking time - `avg_transfer_wait_m`: mean wait time between transit legs
- B. Mode and transfer: - `avg_num_transfers`: average number of transfers for a trip on that route - `direct_routes_pct`: percentage of trips with only one transit leg - `avg_walk_pct`: average share of walking time in total trip duration
- C. Route time and Frequency indicators - `earliest_service` / `latest_service`: first and last recorded departure times - `service_span_hours`: show operation hours of the multimodal trip - `frequency_routes_per_hour`: average number of routes per hour during operation duration - `frequency_routes_per_day`: total number of valid itineraries per OD pair per day
- D. Threshold-based indicators - `routes_within_30min`, `routes_within_60min`, `routes_within_120min`, `routes_within_180min`: number of trips in a route that takes a certain amount of time.
  - Corresponding percentage values (`pct_within_30min`, etc.) - The threshold system (30, 60, 120, and 180 minutes) was inspired by Bergantino et al. (2023).
- E. Walking Acceptability - `excessive_walk_pct`: percentage of trips with at least 1 walk leg exceeding walking threshold. - `viable_routes_pct`: percentage of trips in which all legs within the walking threshold. - Walking threshold is set as 5 minutes per session (leg). This is a conservative value, based on the findings of O'Sullivan & Morrall (1996) (average walking distance to station placed at 329-649m) and Monzon & di Ciomo (2016) (Barcelona tourists are disatisfied with transfer walking distances longer than 400m).

Besides providing descriptive statistics support visual analyses, this route-level summary served as the basis for constructing the accessibility index, and filtering for "bad trips" and pain point generalisation.

	origin	destination	total_trips	avg_duration_m	stddev_duration_m	avg_invehicle_m	avg_walk_m	...	pct_within_60min	routes_within_120min	pct_within_120min	routes_within_180min	pct_within_180min	query_date	origin_destination
0	Alba	Italy in Miniature	83	80.40	21.79	42.89	22.80	...	9.6	81	97.6	82	98.8	2025-06-20	Alba_to_Italy in Miniature
1	Alba	Mirabilandia	69	139.94	29.46	84.80	17.52	...	0.0	14	20.3	61	88.4	2025-06-20	Alba_to_Mirabilandia
2	Alba	Misano World Circuit	59	59.79	10.91	11.90	42.50	...	76.3	59	100.0	59	100.0	2025-06-20	Alba_to_Misano World Circuit
3	Alba	OltreMare	108	31.75	7.58	4.90	26.84	...	100.0	108	100.0	108	100.0	2025-06-20	Alba_to_OltreMare
4	Alba	Rimini Historic Center	117	43.73	6.18	24.29	15.71	...	99.1	117	100.0	117	100.0	2025-06-20	Alba_to_Rimini Historic Center

Figure 7: Example of summary dataset - accommodation to attraction on weekend

3.6 Accessibility Index

To provide a better tool for evaluating and comparing public transport performance across OD pairs, this study conceptualises and examines the model for a composite accessibility index. The index integrates key travel components, and apply a weighted penalty to each.

3.6.1 Design

The model conceptualise the four components of a PT journey as "burdens" that affects the utility of a specific trip for tourists. Each component has different significance, and with appropriate treatment, can be combined into a single comparative score. The score is expected to represent more accurately the overall performance of a trip, and would be useful to rank OD pairs based on overall accessibility; compare weekday vs weekend scenarios; identify accommodation zones with consistently poor or strong connectivity to both gateways and attractions. However, the index reflects relative performance, not should not be interpreted as a benchmark of the system quality.

The accessibility index is computed as:

$$\text{Index} = (1 \times \text{avg\_invehicle\_m}) + (2 \times \text{avg\_walk\_m}) + (3 \times \text{avg\_transfer\_wait\_m}) + (15 \times \text{avg\_num\_transfers})$$

In which the components and assigned weight are:

- `avg_invehicle_m`: average total time spent on transit mode of a route. This is the base component (weight = 1), as commonly used in utility-based models (e.g. Krygsman et al., 2004; Tahmasbi & Haghshenas, 2019).
- `avg_walk_m`: average total walking time (including first/last miles and mode transfer). This is weighted double to reflect physical effort and tourist discomfort (Tahmasbi & Haghshenas, 2019).
- `avg_transfer_wait_m`: average total wait time while transferring. This is a more heavy burden on travellers (weight = 3) due to the inconvenience of uncertain, passive time (Garcia-Martinez et al., 2018).
- `avg_num_transfers`: average number of transfer per trip. It is penalised at 15 minutes per occurrence, drawing on research such as Garcia-Martinez et al. (2018) and Krygsman et al. (2004) which estimated transfer penalties between 7 and 18 minutes.

The accessibility index represents perceived travel cost in equivalent minutes of total effort.

To assess the robustness of the formula and verify the weights, a sensitivity analysis is performed using One-at-a-Time method. We tested (recomputed) the index through 3 scenarios. In each of which, only one weight is adjusted, with index change, ranking change and percentage of routes affected by either change being analysed. The scenarios were:

1. Walk-up: increased the walking time weight from 2 to 3
2. Wait-down: reduced the waiting time weight from 3 to 1
3. Transfers-down: reduced the transfer penalty from 15 to 10

The result revealed that while the accessibility index is numerically sensitive to changes in certain weights—particularly walking time and waiting time, the relative rankings of OD pairs remain highly stable across all scenarios. Spearman correlation values exceeded 0.99 in every case, indicating that the rank order of accessibility outcomes is largely unaffected by small adjustments to component weights. Given that the index is primarily used for comparative assessment, this stability suggests that the chosen weight structure is sufficiently robust for the intended research purposes.

3.6.2 Analysis

The index was computed for all four existing OD-level datasets. The analyses covered variability across gateways and attractions (using box plots); spatial accessibility patterns between origins and destinations (O-D matrix); ranking of best, worst OD pairs; and accessibility shifts between weekday and weekend (with bar chart).

Moreover, as both OD types has a common dimension in the accommodation zones, it was possible to construct an opportunity matrix that can classify each accommodation zone into one of four quadrants. This enables zone-specific weakness identification, and helps prioritise routes or zones for further attention.

- Good gateway / Good attraction
- Poor gateway / Good attraction
- Good gateway / Poor attraction
- Poor gateway / Poor attraction
- Medians index values were used as thresholds to separate quadrants.

3.7 Micromobility Usage Simulation

As micromobility has become an important travel mode in many cities, it is necessary to treat shared bikes and scooters as an integral player that can enhance public transit travel, especially by solving the first/last mile issue. In Rimini, Lime scooters are a frequent sight in central and tourist-concentrated areas. This study aims to quantify the potential role of micromobility in improving accessibility for walking segments in public transport trips. The simulation models potential time savings using scooter substitution and visualises its effect at trip, OD-pair, and zone levels. It enables assessment of whether replacing eligible walking segments with micromobility (e.g. scooters) could meaningfully reduce travel time and contribute to enhancing tourists' accessibility while using multimodal public transport trips.

The result is expected to identify which OD types or zones benefit most from scooter availability; Whether micromobility can support accessibility-poor areas; and where to encourage Lime's service expansion to yield network-level gains.

3.7.1 Simulation Model

With the step-level data and Lime service zone geometry, each walking segments with both ends within the zone is treated as eligible for substitution.

To avoid unrealistic substitutions, very short segments were then excluded. Many studies indicated users are unlikely to substitute walking legs below a certain length due to perceived inconvenience and little time gain. This study used 150m, which is a conservative value based on Q. Liu et al. (2023) 's suggestion of 150m, and 200-300m by Moinse & L'Hostis (2024).

For eligible walking steps, e-scooter travel time was estimated using a distance-speed model adjusted for urban travel characteristics. The model consists of:

- Travel time: Travel time was calculated using the straight line (Haversine) distance between the start and endpoint, adjusted by a path factor of 1.3 to approximate real-world street navigation. An average speed of 12 km/h was used, which is a conservative estimates based on recent literature (average time ranging from 8km/h (Zhao et al., 2022) to 15-16km/h (L. Liu & Miller, 2022; Mitropoulos et al., 2023).

- Unlock and lock time: A fixed value of 90 seconds was added to each scooter trip to account for the time it takes to unlock the vehicle before the ride, and relocking it after use.

- Scooter time equation:

$$T_{scooter} = \frac{d_{Haversine} \times Path\,Factor}{Average\,Speed} + Lock/Unlock\,Time$$

3.7.2 Trip- and Route-level Enhancement

For each trip, several statistics were calculated to estimate the effect of substitution. The first value we care about is total walking time replaced and total time saved as the difference between replaced walking and simulated scooter time. These directly represent the potential of micromobility when integrated into the multimodal trip.

Other metrics that could provide insights included the number of steps eligible and used are also recorded, since a step is only considered replaced if it zone and distance requirements are met, and the simulated scooter time was faster than walking. These will be useful in in-depth analysing of where exactly in a trip micromobility is currently effective. With the simulated scooter time, the "enhanced" trip duration can also be derived. Furthermore, share of eligible steps; and share of eligible steps where scooters were actually used would highlight the coverage of the Lime service along certain PT journeys, and inform service expansion decision.

Similar to previous route-level summary, trips were grouped by origin and destination to perform aggregation on micromobility data. The output indicators cover average time saved in minutes; average walking steps, eligible steps, and used steps; Ratios between eligible-total steps, and used-eligible steps. While trip-level numbers can provide a glimpse, this aggregation establishes a high level view to support pattern identification and strength-weakness analysis.

To confirm the validity of the eligibility filtering, a mapping of substituted segments were plotted against the service zone and confirmed visually that they were within the boundaries. Moreover, distribution of time saved also ensured no extremities or unrealistic scooter time were produced.

3.7.3 Analysis

1. Opportunity Patterns

By examining origin–destination pairs, the analysis highlights accommodation zones and attractions that benefit most from micromobility substitution. Routes with a high proportion of eligible walking and significant time savings suggest strong potential for micromobility integration. Conversely, OD pairs with low eligibility ratio and/or low benefit may indicate either spatial disadvantage or operational inefficiencies. These patterns can serve to inform service expansion or integration enhancement.

2. Correlation with Accessibility Index

To explore broader network implications, the route-level time saving data were overlaid with the accessibility index. The goal is to assess whether micromobility can help alleviate accessibility weaknesses on poorly connected routes. In particular, the analysis tests the hypothesis that routes with lower accessibility may stand to gain more from micromobility integration.

3.7.4 Limitations of the Model

While seemingly positive, it is necessary to note that the proposed model is based entirely on simulation and simplifying assumptions, which limit its applicability to real-life enhancement. Key assumptions include perfect scooter availability (thus zero walking time to reach nearest vehicle), always sufficient battery levels. Furthermore, the analysis relies on parameter-based simulation rather than observed user behaviour or real trip data, and while the parameters were based on previous studies, it cannot represent Rimini-specific use cases.

Operational constraints such as parking regulations, weather conditions, and spontaneous demand fluctuations are not accounted for. As a result, the findings represent the potential benefits of micromobility under ideal conditions, rather than actual outcomes if substituted.

Finally, the study did not consider substituting short transit legs, primarily due to time and workload constraints. As walking is generally perceived as more burdensome, focusing on replacing these segments aligns with the objective of reducing walking effort and enhancing the overall multimodal system.

3.8 Bad Trip Analysis and Pain Point Identification

While the OD pair level indicators can capture broad patterns of the system's performance, they do not reveal exactly where an issue may occur, on what leg, and how frequent that issue is on a route. Moreover, depending on the proportion of favourable and non-favourable trips within the route, the aggregated numbers may mask structurally problematic cases. Therefore, this next analysis stage will target individual noteworthy trips and perform diagnosis. Ideally, it would allow us to see inefficiencies in the sample trips, which lead to identify critical pain points on specific routes, and with a generalisation check, reveal if the trip has a recurring patterns for such issues that can be targeted with systematic fixes.

3.8.1 OD Pair and Trip Selection

Due to time constraint, this step is performed on one dataset, namely the accommodation to attraction OD pairs on weekend. This is chosen as it is the scenario in which public transportation is most useful to tourists.

The three categories of OD pairs envisioned for this analysis were:

1. Worst case in general: the route with highest average index.
2. Operationally difficult: Mid-index OD pairs with high `avg_walk_pct` and high `avg_num_transfers`.
3. Moreover, San Leo was added as the only nature destination in our POI list. As Rimini try to diversify its tourism offerings, it is necessary to see how easy it is to get to non-beach nature attractions.

After having filtered the appropriate routes, the worst trip (highest index) and the average trip (median index) are taken for the individual analysis.

3.8.2 Trip-Level Visual Diagnostics

A collection of metrics is gathered from prepared datasets to perform the analysis:

Table 2: Trip level travel metrics of multimodal public transit journeys.

Metric	Description	Reason for Inclusion
`total_duration_s`	Total travel time of the trip	Reference to assess proportion of components
`invehicle_time_s`	Time spent inside public transport vehicles	Indicates core efficiency of the transit leg
`total_walking_time_s`	Total walking time across all segments	High walking time may indicate bad connectivity
`transfer_wait_s`	Total time waiting between transit legs (excluding walking)	Long wait represents inefficiency and is the main contributor to perceived frustration
`num_transfers`	Number of transfers required in the trip	Simpler trips preferred; each transfer increases complexity/friction
`walk_pct`	Walking time as a % of total duration	Relative burden of walking on user
`wait_pct`	Waiting time as a % of total duration	Helps detect whether schedule coordination is a problem
`invehicle_pct`	Vehicle time as % of total duration	High value expected in efficient routes
`wait_per_transfer`	Average wait time per transfer	Measures quality of connection timing
`longest_walk_s`	Longest individual walking segment	Indicate where in the trip walking burden is concentrated
`first_mile_walk_s`	Duration of the first walking segment	Highlights first-mile access issues (e.g. isolated origin point)
`last_mile_walk_s`	Duration of the last walking segment	Final walk often has biggest impact on user experience
`time_saved_s`	Total walking time saved by scooter	Quantifies enhancement potential with microbility
`num_eligible_steps`	Number of walking segments eligible for scooter use	Indicates micromobility's coverage in the journey
`eligible_step_roles`	Categorical label(s): first/last/intermediate eligible step	Helps classify whether micromobility helps access, egress, or mid-trip

For ease of analysis, a dashboard is constructed for each trip including several visualisations: Time-dimension (distribution of total time across walking, in-vehicle, and waiting); Trip anatomy (chronological sequence of steps and durations); Transfer dissection (transfer time with separated wait and walking durations). These tools enable scrutiny of the journey complexity, multimodal integration, and time distribution inefficiencies.

3.8.3 OD-Level Pain Summary and Classification

To characterise inefficiencies, a set of binary denominator was defined and flagged in each trip. These flags were:

1. Transfer-related:
    - Many transfers (=2)
    - Too many transfers (>2)
    - High wait time (each wait step > 8 minutes). Perceived acceptable wait time depends on several factors (knowledge of next transit, time of day, availability of wait infrastructure, weather conditions - Arhin et al. (2019)). This is a conservative number, considering Arhin's 5-15 minutes range; in another study, Ceder et al. (2013) estimates expected wait to be 8-10 minutes; and Ruiz et al. (2024) concluded that first drop in satisfaction happens at 5 minutes and then further at 10 minutes.
2. Walking-related:
    - High first mile walk (first walk step > 5 minutes)
    - High last mile walk (last walk step > 5 minutes)
    - High transfer walk (each walking steps not first or last > 5 minutes)

These were computed for each trip in each OD pair, then aggregated (percentage) to route level. This generated a multi-dimensional weakness profile for each route.

3.8.4 Micromobility Step-Level Enhancement for Bad Trips

For each individual trip analysed, walking segments were calculated using the micromobility simulation logic in previous section. The enhanced walking durations were visualised alongside the original steps to highlight where and how micromobility reduces friction.

This step supports policy-oriented recommendations by highlighting trips where scooters offer meaningful gain, identifying where service coverage is needed, and demonstrate specific pain types mitigated (e.g. first/last mile).

3.9 Integration

Besides the individual analysis, there are strong links between between components. The joint use of the accessibility index and micromobility simulation would reveal where service enhancements can benefit low-access routes. The index can combine with route-level pain flags to differentiate issue types between routes with similar index, opening path to appropriate and isolated interventions. Finally, micromobility data and pain flags encourage expansion of shared micromobility services that integrate into the multimodal public transport system to enhance its utility as a whole for travellers.

Chapter 4

Result

4.1 System-Wide Patterns

4.1.1 Statistics of Travel Time Components

1. **Average total trip duration overview**

Total duration of trips is the first indicator and one of the most important value for tourists, since it influence all other travel arrangements. Among the routes between gateways to attractions, due to the significant difference in distance, generally further gateways take longer time, in order of Bologna Airport, Forlì Airport, Rimini Airport, Flixbus station and Rimini Station. Moreover, the average travel time on the same route remains relatively stable between the weekday and weekend. On the other hand, among routes to attractions, long distance doesn't necessary mean long travel time, and some routes take much longer on the weekday than weekend. For example, the average trip from Viserba to Mirabilandia takes longer than from Alba (Riccione) on weekday but shorter on weekend.

2. **Distribution of travel times grouped by origin and destination**

Travel time distribution from gateway:

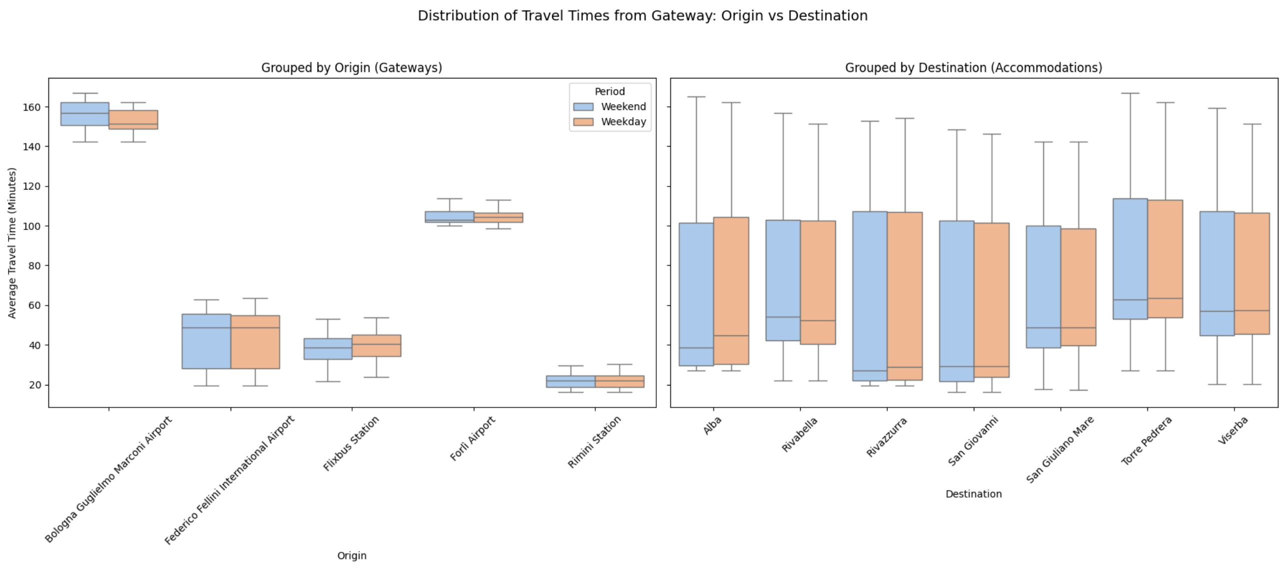

Figure 8: Travel time distribution - gateways to accommodations

The distribution of travel times from gateways to accommodation zones reveals two key traits. When grouped by gateway, most routes exhibit consistent travel times with narrow range and thin IQR. This suggests that well planned transit lines are in place and operated consistently, with low variability in a day and between weekend-weekday. However, wider range and IQR of Rimini Airport implies that travelling from here to different hotel zones have more varied irregular durations. Also, long trips are more prevalent from this airport, due to the mean being closer to the top.

When grouped by accommodation, there are much higher variability from gateways to an accommodation zone with large IQRs, we expect that the physical distance play a big role, with 3 close gateways and 2 longer ones (Bologna and Forlì airports). On a positive note, their generally low placement and low mean value signify that the majority of trips are relatively fast.

Travel time distribution to attractions

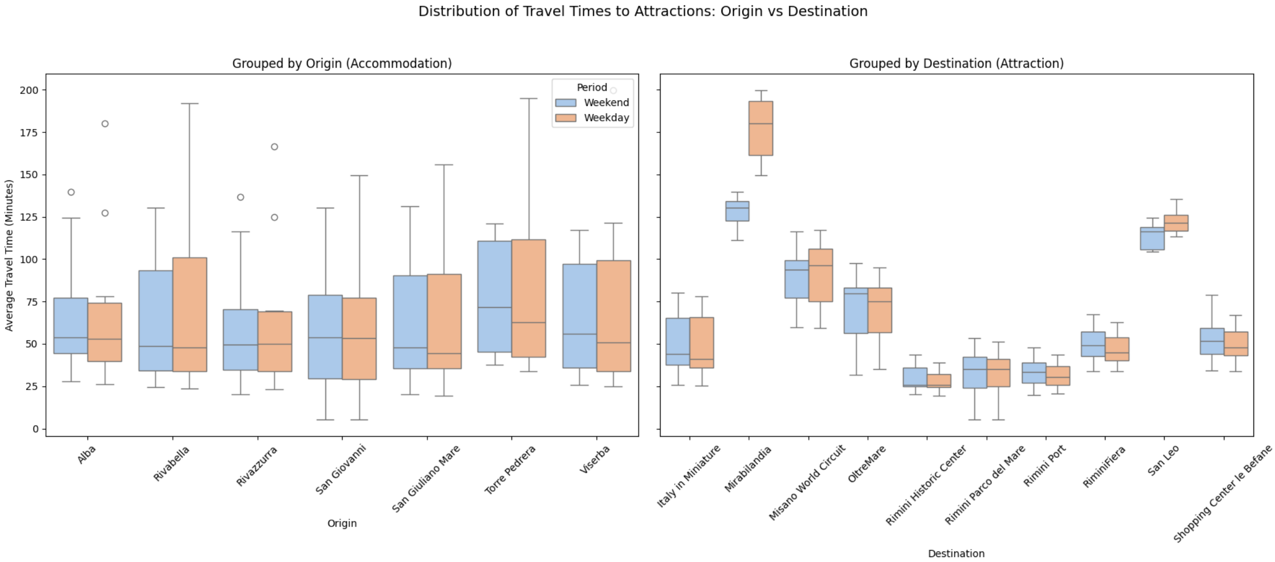

Figure 9: Travel time distribution - accommodation to attractions

Average travel time from one accommodation to all attractions are quite similar, and remains stable between weekend or weekday. This pattern reflects the concentrated nature of Rimini's accommodation along the coastal area, sharing access to major transport nodes. Conversely, travel time from different accommodations to an attraction varies, especially for faraway spots like Mirabilandia and San Leo, and there's higher variation between weekend and weekday. This implies Rimini transport system prioritises connectivity from accommodation areas to common major nodes, but struggles with coverage to peripheral attractions, particularly under weekday schedules.

3. **Share of 3 components: walking, waiting, and in-vehicle time in an average trip.**

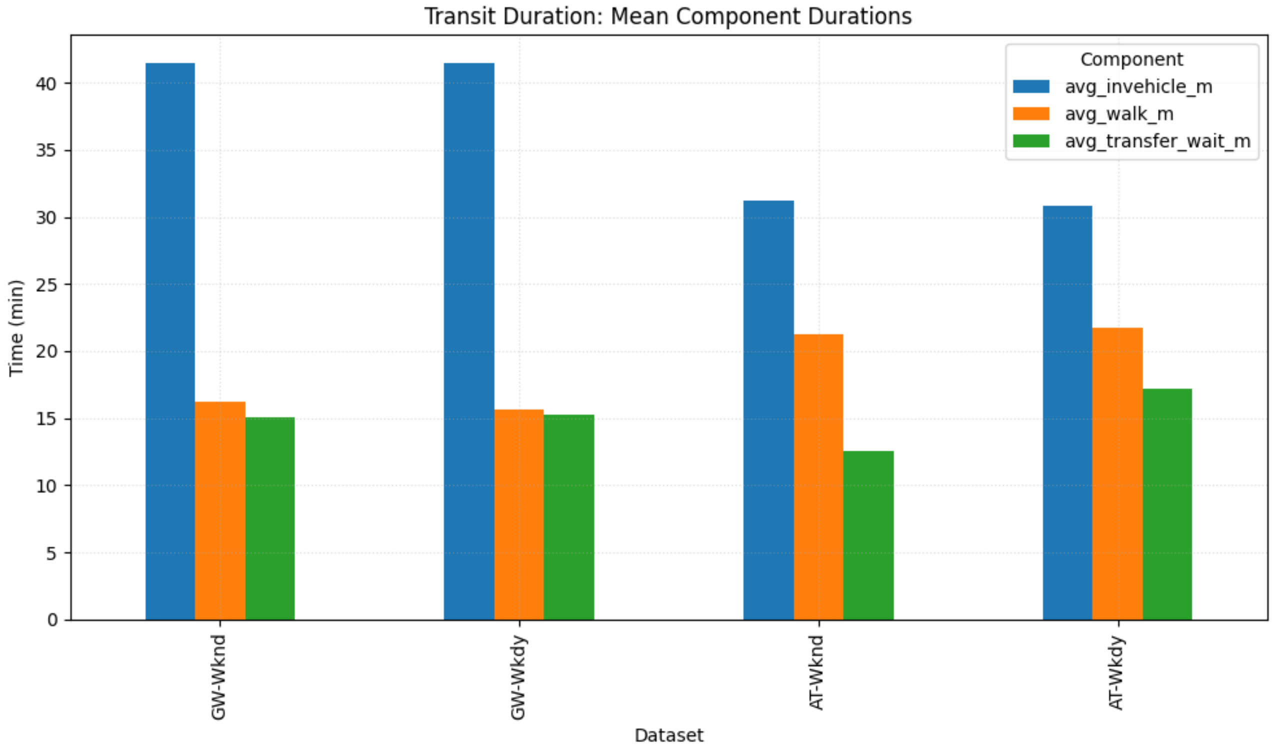

Figure 10: Travel time composition

For all routes, in-vehicle time accounts for the majority of trip, which is to be expected. However, the proportion is much higher for gateway due to the longer physical distance in general. Moreover, wait time and walking time is approximately the same for these trips. This emphasises that gateways' transportation are well organised, and while average wait time is still high they are consistent and reliable.

Travellers going to an attraction, while spending less time on the vehicle, need to walk a longer on average. There are rooms for improvement in terms of stop placement to reduce this trait. Wait time between transport mode on weekday for this type is also the highest, implying inefficient schedule coordination between lines.

4.1.2 Temporal Reliability and Service Availability

1. **Service Span & Coverage**:

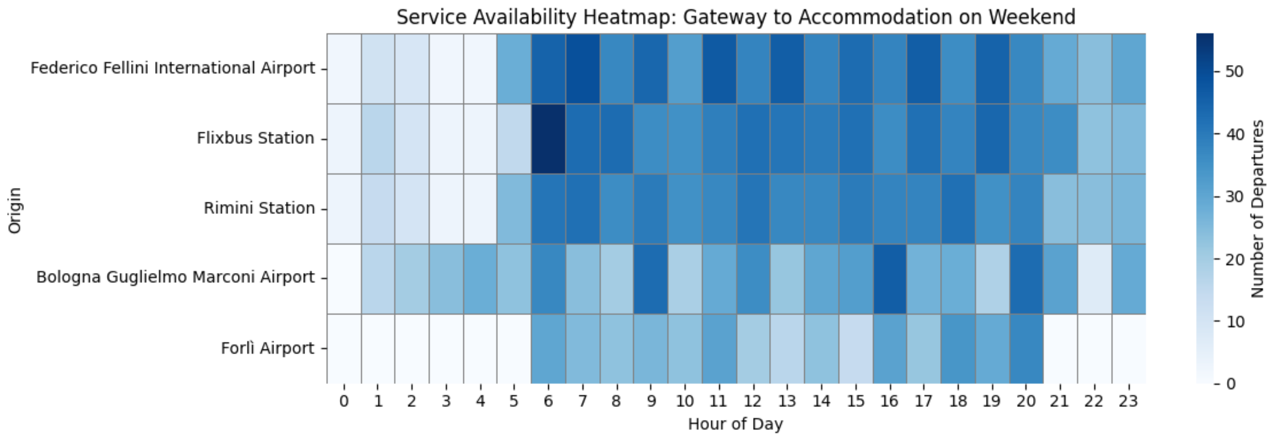

Figure 11a: Service Frequency - gateways to accommodations

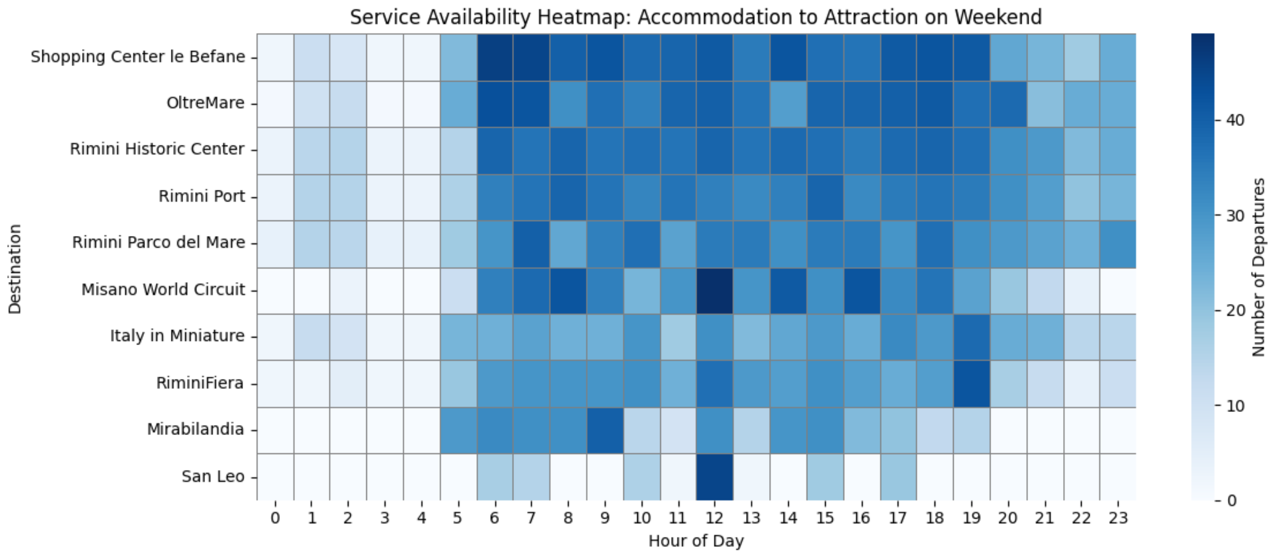

Figure 11b: Service frequency - accommodations to attractions

Forli Airport has the shortest service duration, assumed to be due to limited operation of the airport. Other gateways have a good coverage (from 5-6 AM to 1-2 AM next day). Attractions: San Leo, Misano and Mirabilandia have short service span, usually ending quite early. San Leo and Mirabilandia also have quite spaced out frequency. Visually, the San Leo route has 5 clusters of departure daily on the weekend, which implies that the main transit mode departs 5 times a day.

An OD-pair matrix with binary flags for service availability in early (03:00 to 06:00) and late (21:00 to 03:00 next day) windows confirms above findings. We can identify that routes from Forli airport doesn't have early nor late service. Visitors visiting Mirabilandia can go early but not late, and one cannot depart either early or late to San Leo (except from Riccione with early service).

2. **Frequency Summary:**

Table 3: Rimini Public transportation frequency summary

Gateway Weekend	**service_hours**	**total_trips**	**avg_per_service_hour**	**avg_per_hour**
mean	21.66	99.06	4.54	3.77
min	15.00	49.00	3.27	1.8
max	24.00	125.00	5.27	4.88

Gateway Weekday	**service_hours**	**total_trips**	**avg_per_service_hour**	**avg_per_hour**
mean	21.0	95.77	4.53	3.42
min	15.0	49.00	3.00	0.86
max	24.0	125.00	5.43	4.75

Attraction Weekend	**service_hours**	**total_trips**	**avg_per_service_hour**	**avg_per_hour**
mean	19.74	84.07	4.24	3.14
min	6.00	19.00	1.00	0.63
max	24.00	123.00	5.69	4.78

Attraction Weekday	**service_hours**	**total_trips**	**avg_per_service_hour**	**avg_per_hour**
mean	18.79	80.36	4.26	2.92
min	9.00	24.00	1.00	0.89
max	24.00	118.00	5.95	4.39

All type of travels on both weekend and weekday have similar frequency, with no routes have less than 1 trip per hour during service hours. However, it is necessary to be careful that this is an average over the total operation window, which can be as short as 6 hours. As we see with San Leo routes above, operation may not be continuous but with gaps in between. The hourly frequency over the whole day can be as low as 0.63, but the mean between 2.92 and 3.77 is adequate.

Other than San Leo and Mirabilandia, the spread of trips over hours of the day is also relatively balanced, but there's a lean towards more trips in the early morning than in the evening. This is usual behaviour for public transit system.

4.2 Accessibility Index

While time and frequency statistics on their own offer insight into certain aspects of the transit route, they do not fully reflect the quality of travel experienced by tourists. High service frequency does not guarantee efficiency, and short trips can still be unacceptable if they involve excessive walking, waiting, or too many transfers. This section analyses the accessibility index to gain a combined evaluation of the routes’ performance, and attempt to compose a holistic image of Rimini’s multimodal transportation system.

The index was conceptualised to represent different burdens on the journey, thus the higher value indicates more burden, whether from in-vehicle, walking, waiting time or number of transfers.

4.2.1 Route Level Summary

Gateway index mean remains similar across weekend and weekday. This supports our assumption previously that gateway to accommodation routes are generally well planned, with set transfers that change very slightly across scenarios. But now it is also visible that mean and max values of gateway routes are slightly higher than attraction mean on weekend but lower than attraction on weekday. It may reflect shorter distances or better connectivity to reach attractions, but not so much on weekdays. Moreover, spread of attraction routes between weekend and weekday are relatively similar from min to 75% percentile, but weekday has significantly higher standard deviation and maximum values, potentially signifying bad-performing outliers.

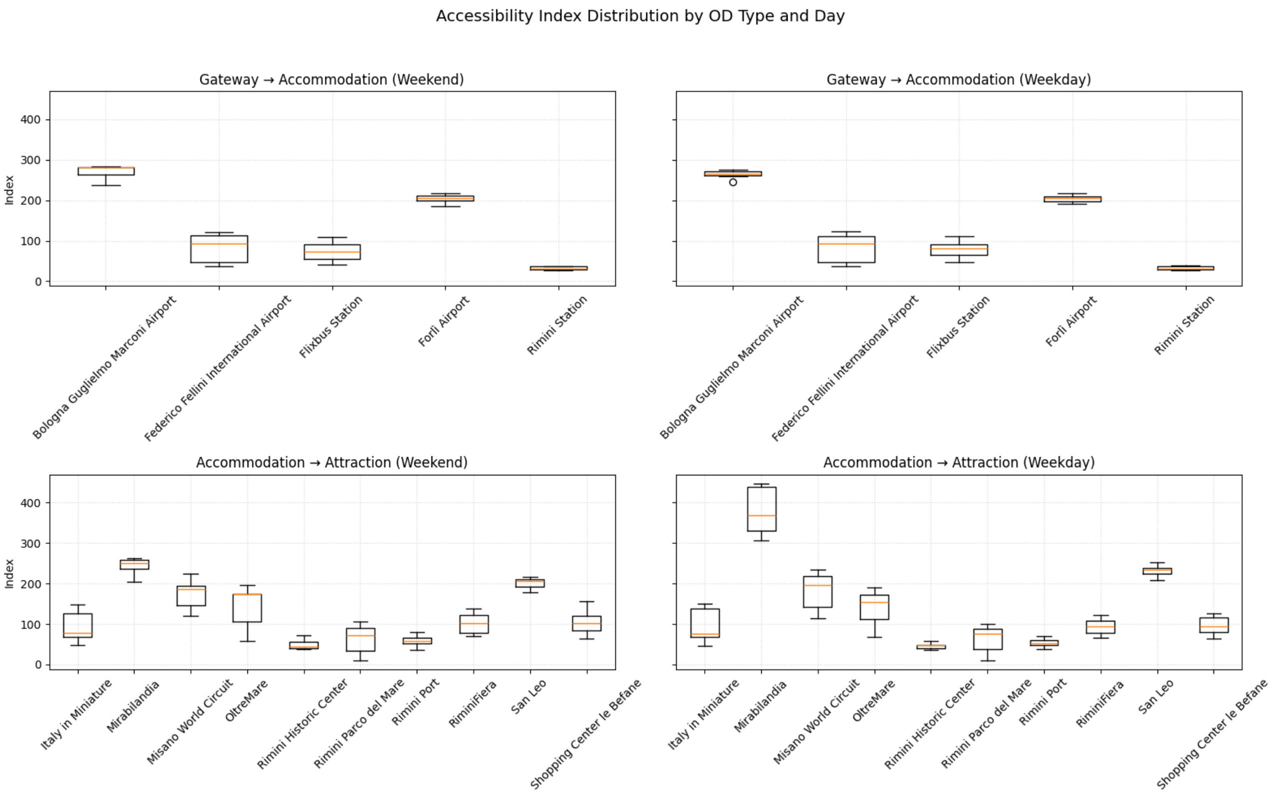

Figure 12: Accessibility Index statistics

Accessibility index distribution by OD pair and date shows that some gateways and attractions have stable indices: Rimini station, Forlì airport, Rimini historic centre and port, and Bologna airport. This could indicate the connectivity for these are planned well and has few variety (the same set of bus/train combinations).

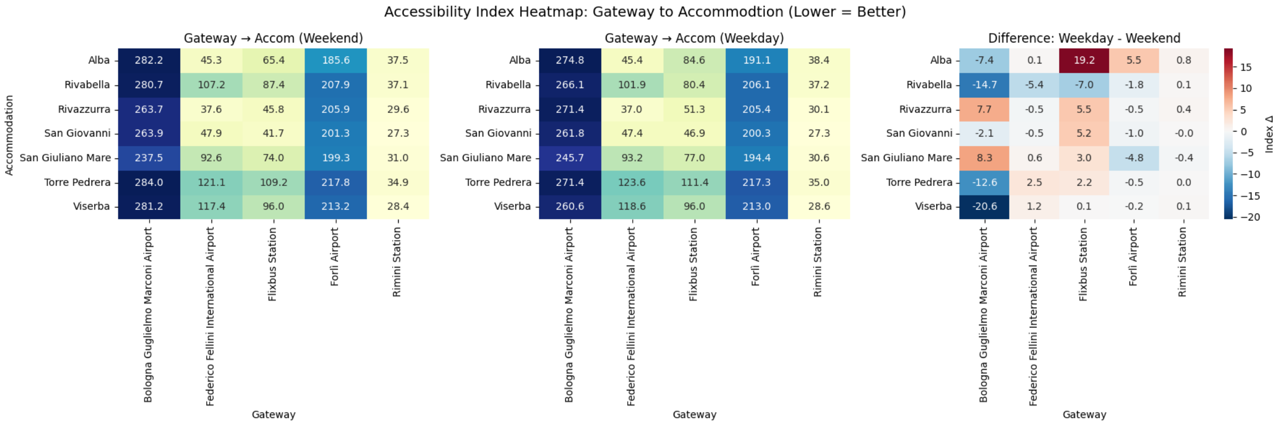

Figure 13a: Accessibility Index - gateway-accommodation matrix

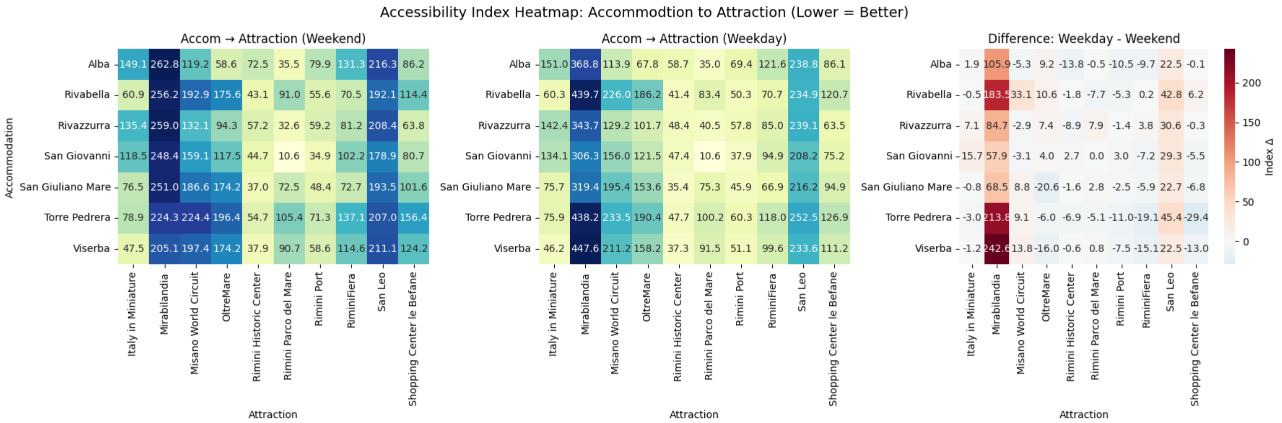

Figure 13b: Accessibility Index - Accommodation-attraction matrix

The origin-destination matrix provides a clear visualisation of the accessibility structure by OD pair. The index shows strong correlation with physical distance. For example, among the gateways, Bologna airport exhibits the highest (worst) scores, followed by Forli Airport, and Rimini Station is the best (lowest). Evidently, in-vehicle time remains the core deciding factor even after applying weights on the other trip components. In terms of attraction, Mirabilandia, Misano and San Leo are among the worst scoring, with Parco del Mare and Rimini port on the opposite side. Notably, despite both being relatively central, the historic centre demonstrated more stable scores across hotel zones than Parco del Mare.

Temporal variations reveal relatively stable performance for most routes between gateways across weekdays and weekends. However, routes from Bologna Airport, surprisingly, often perform better on weekdays. In contrast, the Flixbus station to Riccione route performs significantly worse during weekdays. Among attractions, getting to Mirabilandia is consistently less convenient on weekday from all accommodation areas, a pattern mirrored by San Leo, albeit to a lesser extent. Rimini Fiera, while often holding consumer-focus events on weekend, is harder to reach from Torre Pedrera and Viserba in this period, possibly reflecting the hub-and-spoke nature of the transit network, which arranges many routes through the Rimini station area.

4.2.2 Opportunity Matrix

As the study covers two separate OD sets that share the same accommodation zones, this enables a combined overview of public transport accessibility for each zone. This provides a comprehensive measure of utility a tourist can expect when staying in a specific zone, from getting to the place, and doing trips from it.

By plotting the accessibility index for attraction routes and gateway routes together, we can classify the accommodation zones based on their combined performance on these two dimensions. As shown in figure below, the quadrants are divided based on median values of the two types.

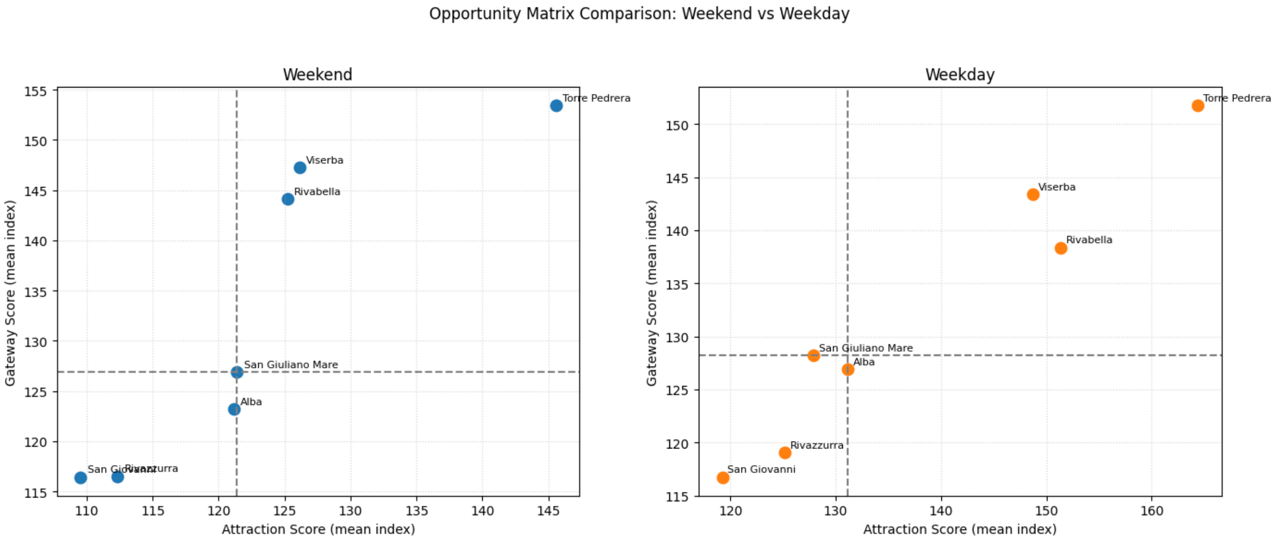

Figure 14: Accommodation zones opportunity matrix

San Giovanni and Rivazzurra are consistently efficient in getting to and travelling around, with low score on both dimensions. This reflects the central location and good connectivity of these zones. Alba (Riccione) and San Giuliano al Mare show median performance on both regards. The former is consistently better in gateway access, and San Giuliano score lower (better) in attraction access on weekend, but the same on week day.

The worst performing accommodation zone is Torre Pedrera, which has the highest average scores for both gateway and attraction routes. The other two also in the bad gateway - bad attraction quadrant are Viserba and Rivabella. All three zones are located on the north side of Rimini city centre. This may indicate the thin public transport coverage on this side. Although Rivazzurra and Alba are similar in distance from the centre to Torre Pedrera and Viserba, their much better performance reflects higher public transport efficiency. Specifically, the investment in Metromare has significantly improved access to the accommodation areas along its stops.

Finally, no accommodation zone shifts quadrant between weekday and weekend, indicating a stable accessibility pattern across different time scenarios.

4.3 Micromobility Potential and Time Savings

For the in-depth analyses, due to time limit, the study will be conducted on one sample data set, which is the Accommodation-Attraction OD pairs on weekend. This choice follows the research objective of evaluating accessibility for tourists. Tourist activity peaks on weekends, with a higher concentration of recreational trips to attractions, making this period most relevant for evaluating the potential impact of scooter substitution.

When identifying walking segments within Lime's service zone, the analysis found that approximately 69.8% of all walking steps were eligible for scooter substitution. Of these, 74% were actually considered "used" to calculate the "enhanced" scenario. As discussed in the Methodology chapter, eligible distances shorter than 150m were excluded, and only segments where the substitution resulted in meaningful time savings (positive value) were considered "used". The average time saved per substituted step is 3.8 minutes, representing 84% of the average for a walking segment time (4.5 minutes). This indicates a significant utility improvement for users.

Importantly, 95.8% of multimodal trips included at least one such beneficial step. However, while positive, it is to be expected since all of our accommodation areas are within Lime service zone. Even so, these findings suggest a non-trivial overlap between public transport use and micromobility availability, highlighting the feasibility of integrating this into the multimodal system.

4.3.1 Trip-Level Impact

For each trip, the total walking time and overall duration were recalculated under the enhanced scenario. This revealed that an average of 9.2 minutes are saved for enhanced trips. On average, this corresponds to a 48.3% reduction in walking duration, reaching up to 74.6% for the most improved trip. Furthermore, the top 25% of trips saw reductions exceeding 18 minutes, especially where multiple walk segments were replaced. These changes are significant, particularly for tourists facing heat, carrying luggage, or in time pressure.

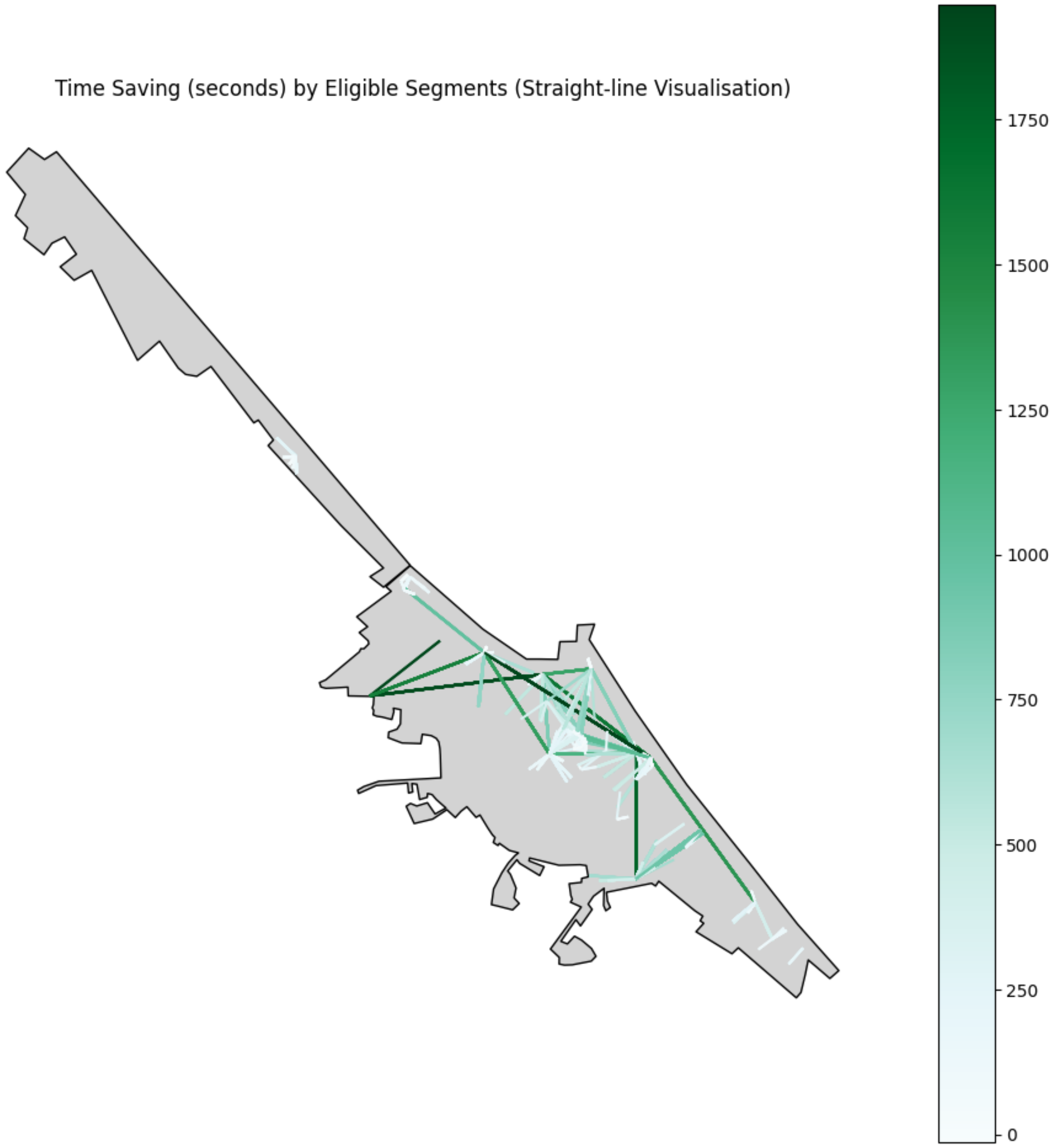

Figure 15: Walking time saved per leg

4.3.2 Strategic Patterns: Who Benefits Most?

Looking at the average time saved by each attraction route, some points of interest located far away, such as Misano Circuit or Italia in Miniature, benefit substantially from using scooter. However, others at similar or longer distances, like Mirabilandia and San Leo, do not show comparable gains. This difference can largely be explained by the coverage of the Lime service zone along these routes, particularly the availability of scooters for last-mile segments near the attractions. Routes with more walking segments within scooter coverage enable greater time savings.

We can also identify the accommodation zones with high time saving to multiple attractions, such as Rivabella and San Giuliano Mare. This shows that micromobility serves well to bridge the hotels to their first transportation node.

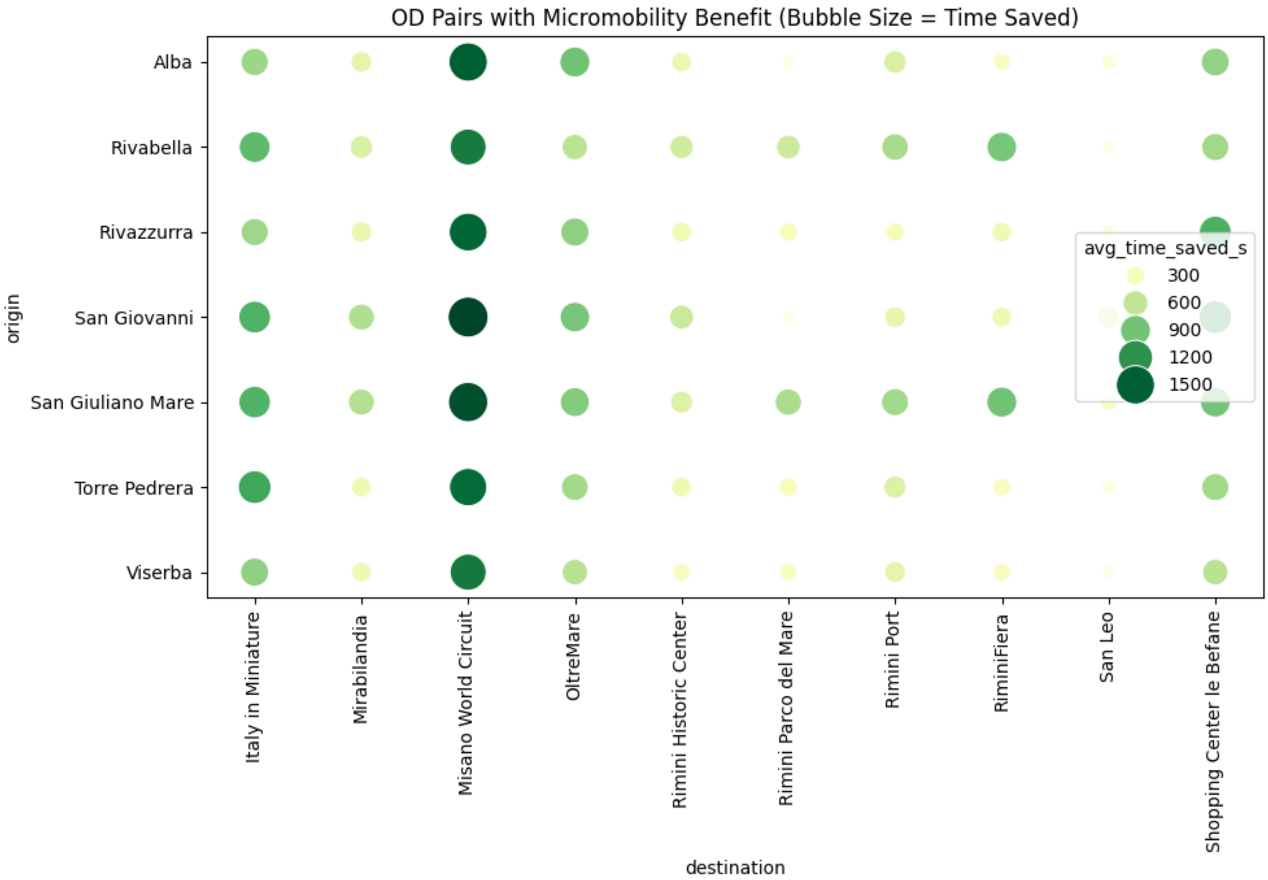

Figure 16: Origin-destination matrix of micromobility benefit

To test whether micromobility delivers the greatest improvement where it is most needed, we examined the relationship between each OD pair's accessibility index and the average time saved through scooter substitution.

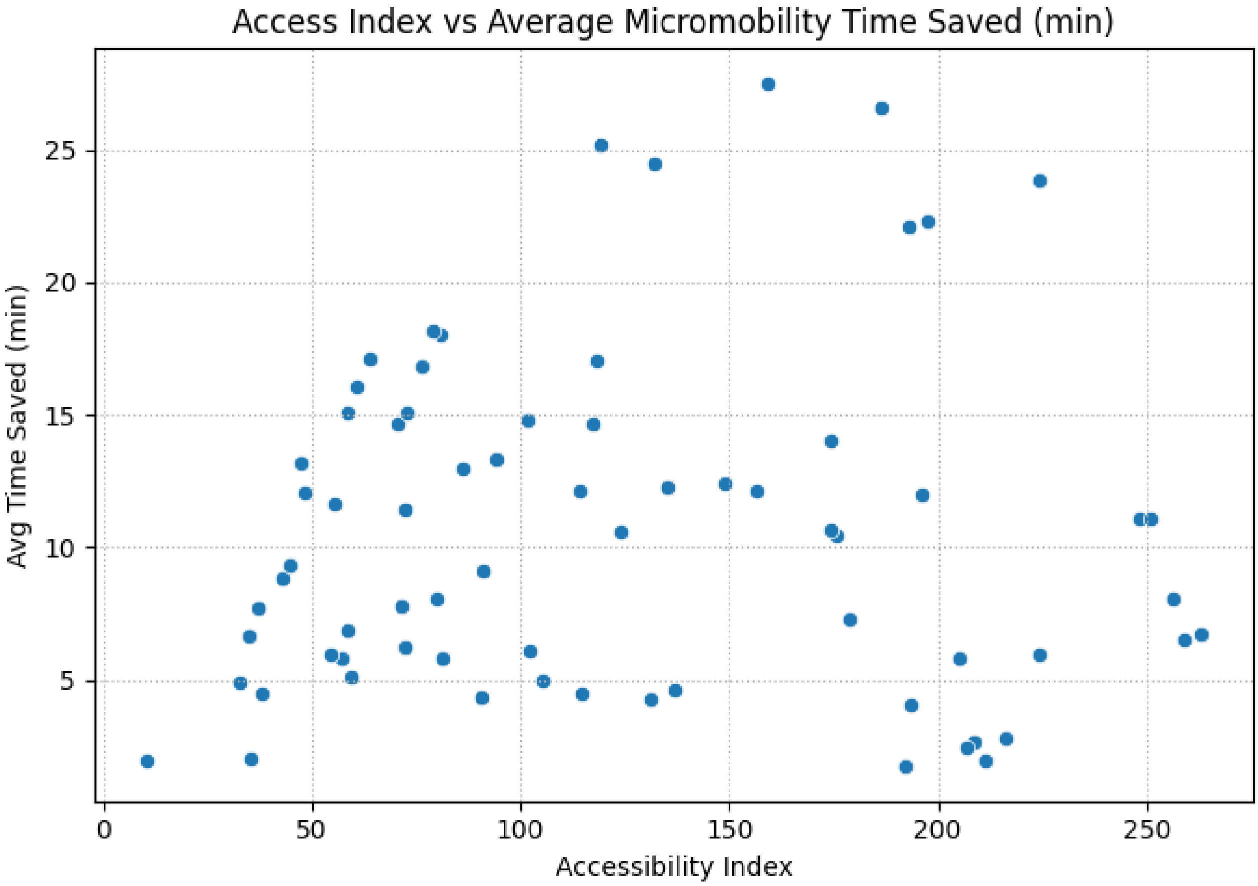

Figure 17: Correlation between micromobility benefits and accessibility index

Unfortunately, this analysis did not find a meaningful relationship. The median time saved show a positive but minuscule correlation with the index (0.1). Median time saved represents the benefit for a typical trip more fairly and reflects what many tourists can expect. This mean high index (struggling) trips are not necessarily benefiting more from the substitution. Furthermore, the percentage of trips with benefit (time saved exceeding 20% of walking time) negatively correlates with the index. This suggests that OD pairs with an already good score have more walking segments eligible for scooter use than struggling routes. This is logical, since "good" trips tend to be physically closer to coast and accommodation areas, which means a greater part of them lies within the Lime service zone.

We also separated the top 25% of the index and compare those with the rest (75%). As with the correlation, we can see that trips with better index (below 75 percentile) enjoy more time saving than the top 25% percentile. Moreover, less of the struggling trips are eligible to be enhanced by scooter rental. This confirms that the lime service zone is only serving the central areas.

Table 4: Micromobility benefits received among routes - Comparison between 25th percentile and the rest of the index

is_struggling (top 25%)	**mean of median time saved (minute)**	**mean of percentage of trips with benefit**
False	10.63	91.99%
True	9.94	76.93%

This suggests micromobility is not reaching its full potential. Micromobility complements good access rather than compensating for poor access. The Lime coverage is concentrated around coastal and central areas, which coincides with OD pairs that already have good public transport performance. As a result, struggling OD pairs (typically longer or more inland) are less likely to fall within the zone, limiting their ability to benefit.

It is also important to keep in mind that the accessibility index reflects more than just micromobility, it also accounts for other burdens, such as waiting times and transfers. As a result, routes with high walking shares but otherwise good accessibility might benefit more from scooter substitution than routes that are constrained mainly by long waits or poor connections.

4.4 Dissecting Bad Trips

Building on the system-wide patterns, this section shifts focus to individual trips to uncover specific inefficiencies and critical points that summary indicators may conceal. By examining detailed trip-level performance, we can identify exactly where the tourists are experiencing difficulties on the journey, helping to build an understanding of their weaknesses.

As discussed in Methodology, we will take a look at the highest-scoring and the median index trips from 4 types of route. Similar to previous section, the trips are chosen from one sample data set - Accommodation-Attraction OD pairs on weekend.

While Alba to San Leo has the highest average accessibility index, due to the spoke-and-hub nature of Rimini transportation, the first part of the journeys will be similar to our first analysed Alba-Mirabilandia route. Therefore, Viserba is chosen as origin with the second highest index to the mountain destination.

1. Worst case in general: Alba to Mirabilandia (Trip no. 5813 & 5505)
2. Operationally difficult: Rivazzurra to Italy in Miniature (Trip no. 1681 & 1305)
3. Nature destination: Viserba to San Leo (Trip no. 1865 & 1840)

4.4.1 Worst case in general: Alba to Mirabilandia

1. Worst case: Trip 5813 - Index 27166 - Departure 9:56

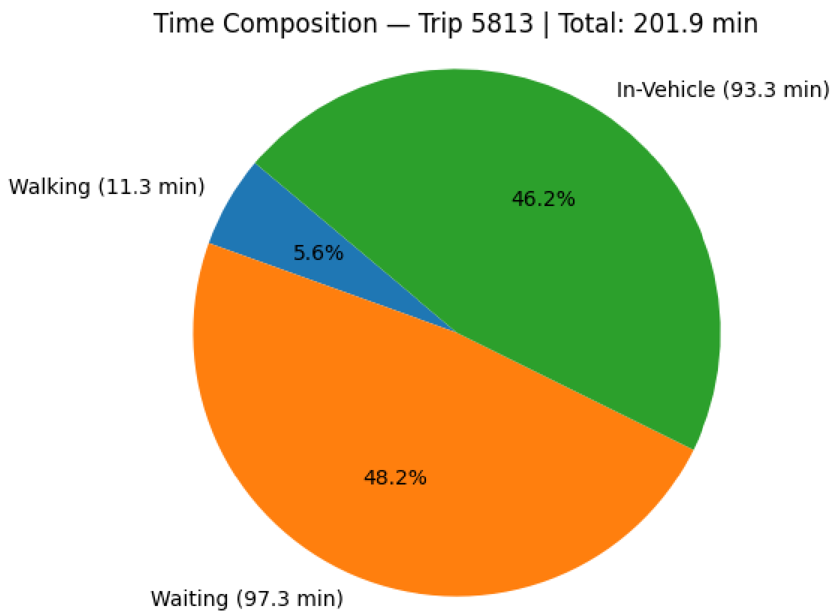

Figure 18a: Time composition - Trip 5813

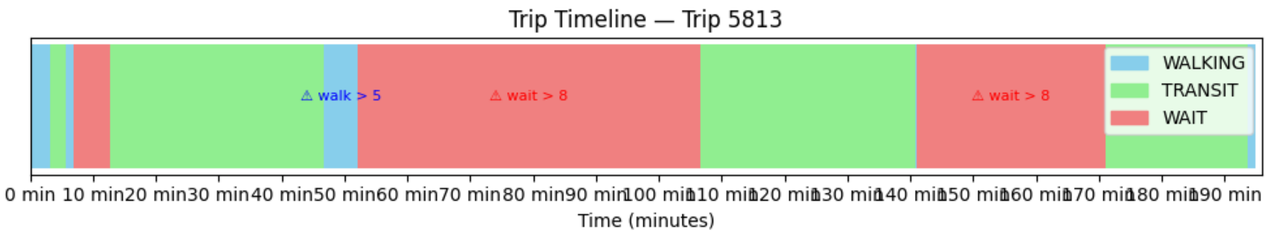

Figure 18b: Trip breakdown - Trip 5813

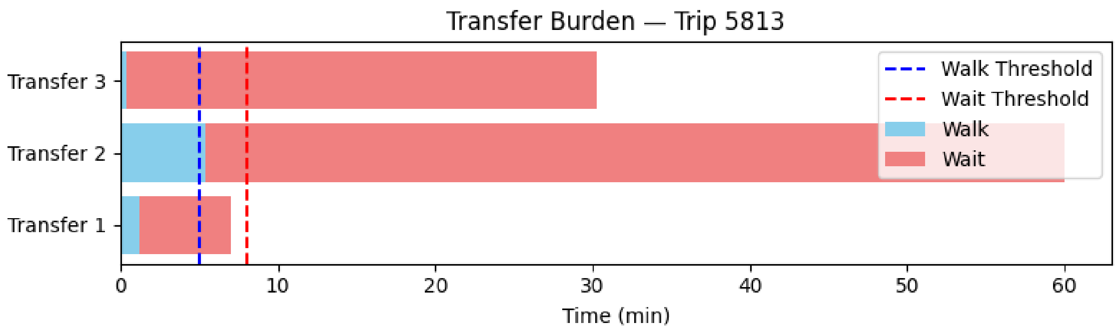

Figure 18c: Micromobility analysis - Trip 5813

This trip high waiting time (48% of total duration) indicates that connections between modes are substantially uncoordinated. This combining with 3 transfers means travellers are wasting an unacceptably long time. Specifically, waiting time at the 2nd and 3rd transfers are 30 and 55 minutes respectively. Walking times are positive, with only the 2nd transfer slightly longer than 5 minutes.

The in-vehicle time of 93.3 minutes represents 46% of the total 201.9-minute duration, highlighting the possibility of a significant improvement in efficiency and user experience by tackling these long wait.

2. Median: Trip 5505 - Index 14788 - Departure 15:44

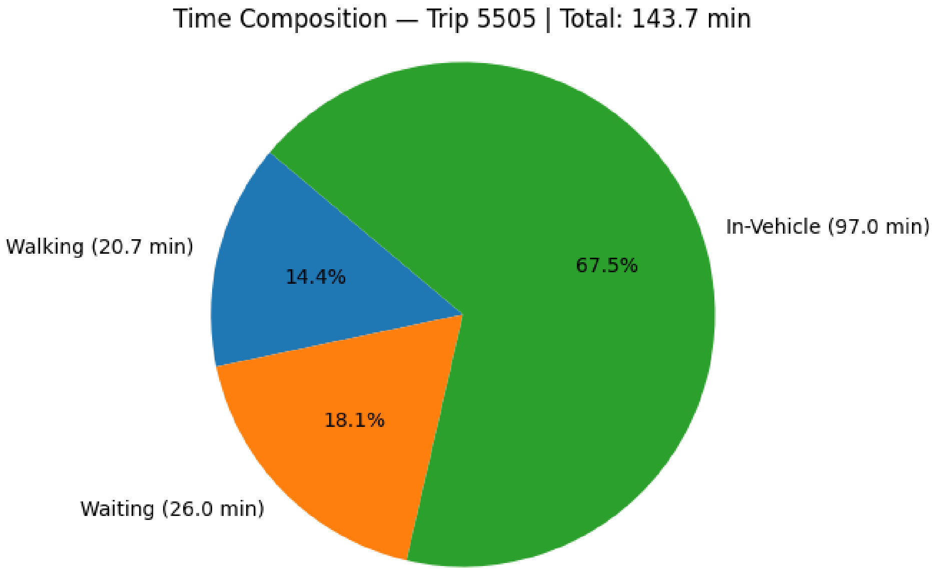

Figure 19a: Time composition - Trip 5505

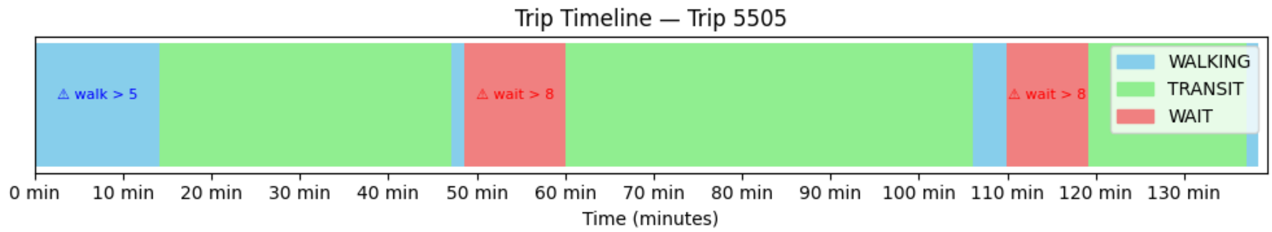

Figure 19b: Trip breakdown - Trip 5505

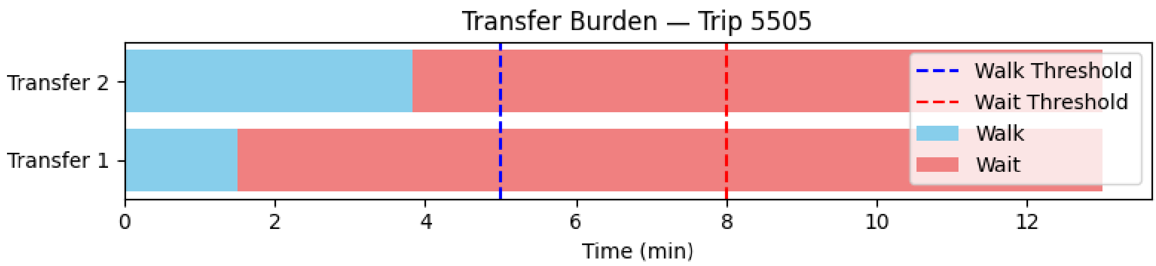

Figure 19c: Micromobility analysis - Trip 5505

The first positive point is this journey only require 2 transfers. However, while less severe than the worst case, the waiting time remains much longer than ideal at 9 and 11 minutes. Moreover, visitors need to walk 14 minutes to board the first transport mode. However, this is the only long walking segment, and subsequent transfer walking times remain minimal.

These two trips illustrate that while the strategic placement of transport modes minimise walking between transfers, the scheduling remains a critical bottleneck, leading to extended wait in many cases.

4.4.2 Operational Friction: Rivazzurra to Italy in Miniature

1. Worst case: Trip 1009 - Index 10341 - Departure 10:39

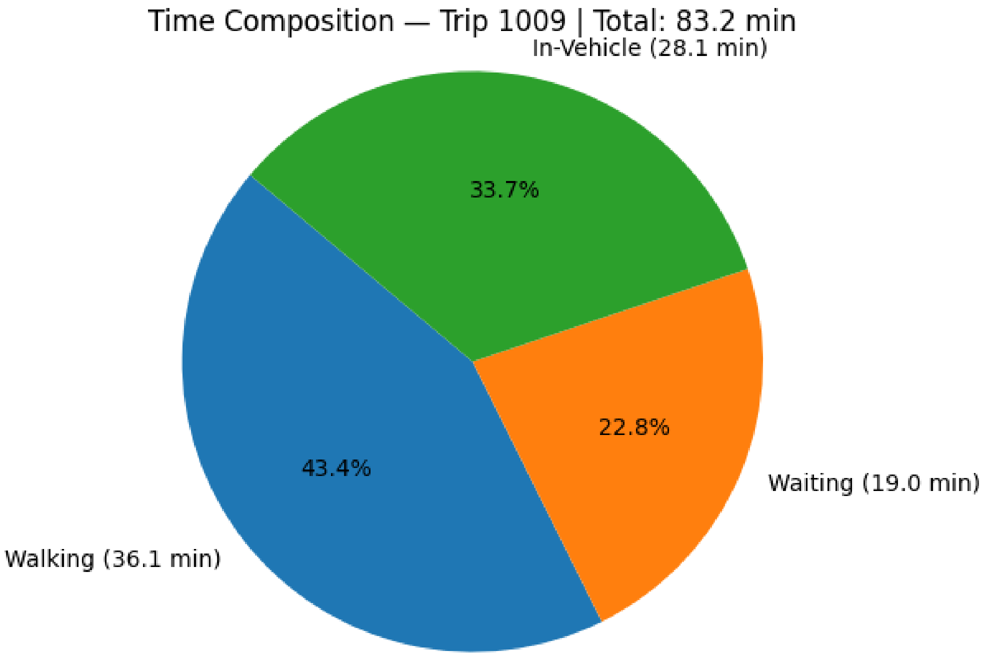

Figure 20a: Time composition - Trip 1009

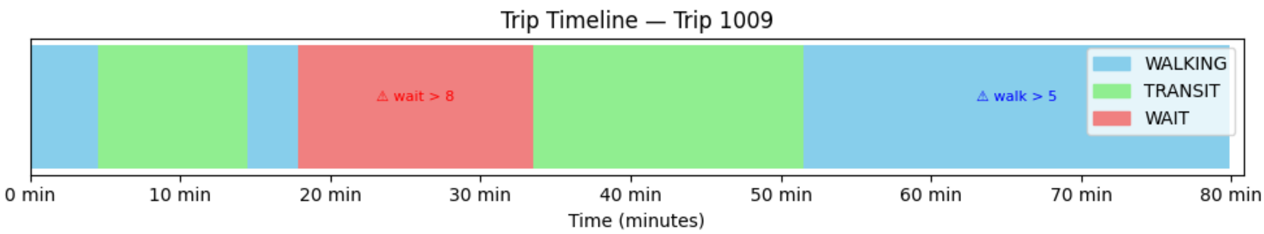

Figure 20b: Trip breakdown - Trip 1009

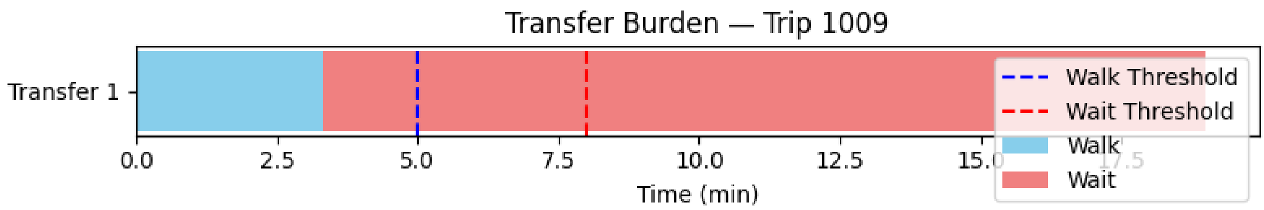

Figure 20c: Micromobility analysis - Trip 1009

The trip consists of mostly walking and waiting time. While visitors only need to transfer once, they spend 43.4% of the total journey walking and 22.8% waiting at this single transfer point. Among the walking legs, first-mile and transfer is within ideal range, but the last-mile segment accounts for 28.3 minutes. When transferring from the first to the last transit, travellers have to wait 19 minutes, which is more than twice longer than they ideally want to.

2. Median: Trip 992 - Index 7590 - Departure 12:09

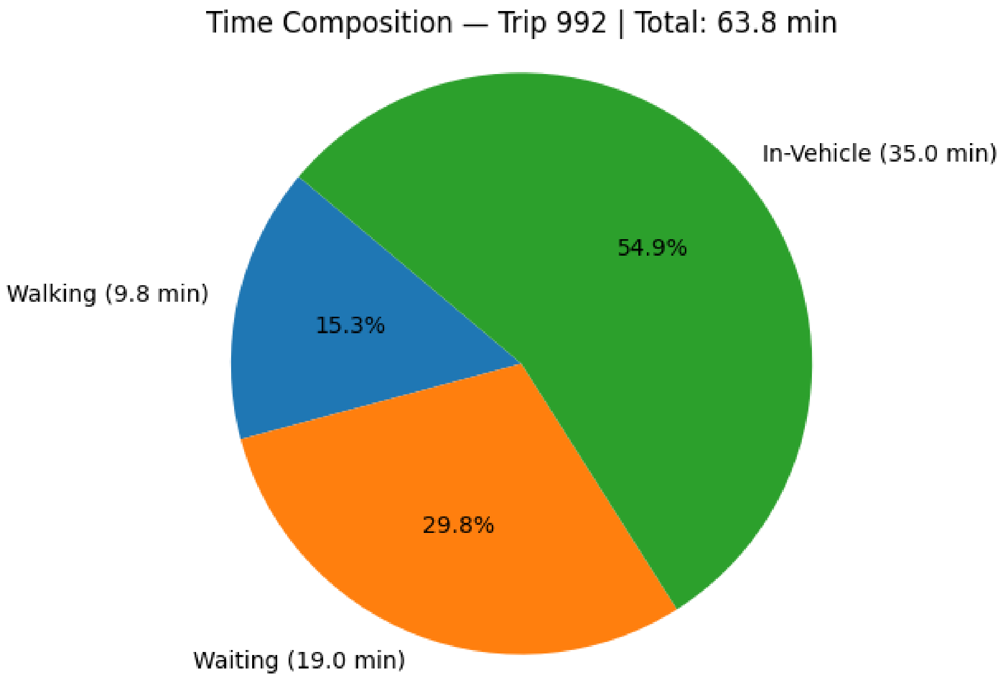

Figure 21a: Time composition - Trip 992

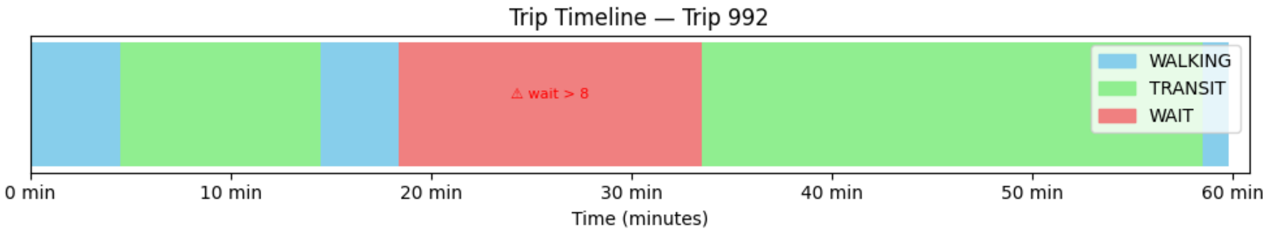

Figure 21b: Trip breakdown - Trip 992

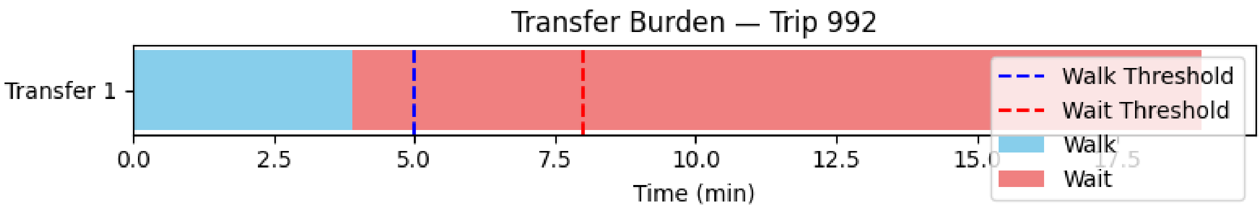

Figure 21c: Mobility analysis - Trip_992

This trip is shorter overall, with walking time limited to only 9.8 minutes total. The major issue here is the long transfer wait which remains 19 minutes.

Overall, while the connection design is acceptable (trips typically involves one transfer), scheduling and the access to the final destination remain significant barriers to good utility.

4.4.3 Nature Destination: Viserba to San Leo

1. Worst case: Trip 1865 - Index 17334 - Departure 15:11

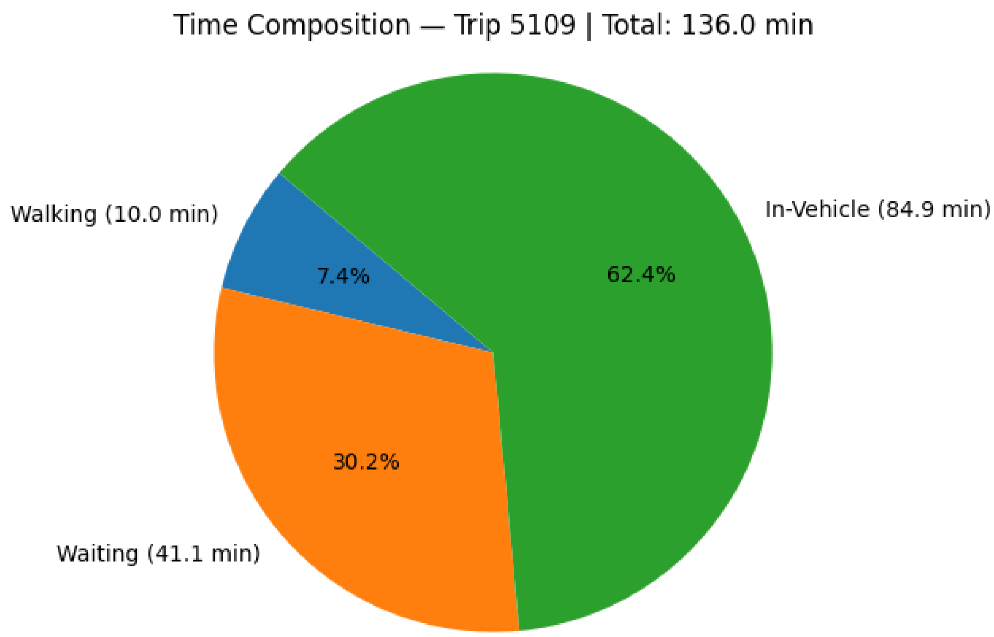

Figure 22a: Time composition - Trip 1865

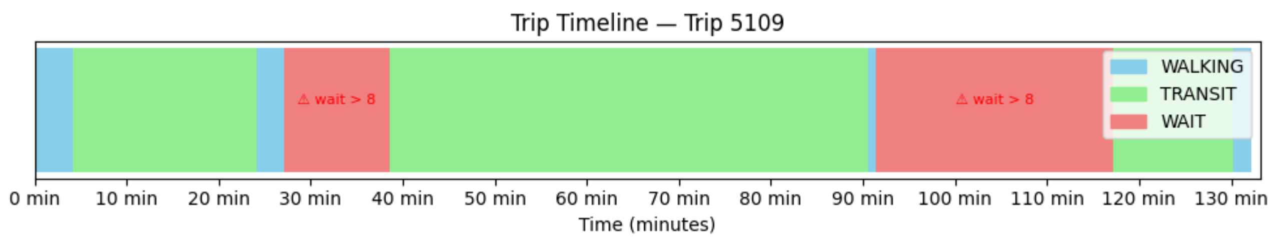

Figure 22b: Trip breakdown - Trip 1865

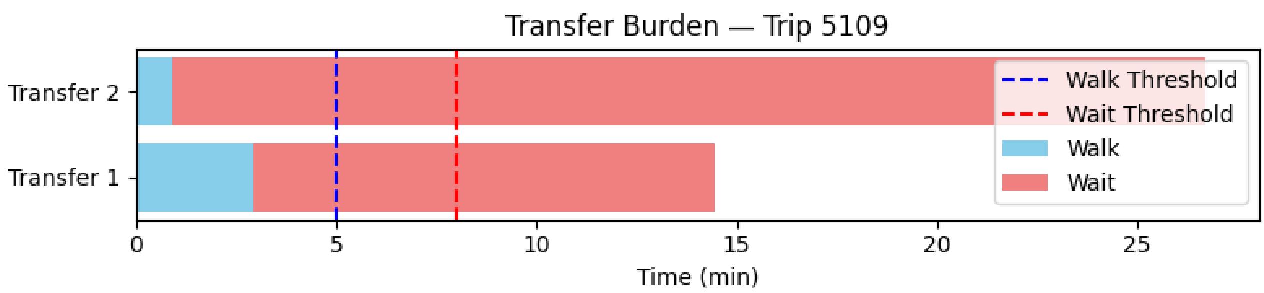

Figure 22c: Mobility analysis - Trip 1865

Total duration of the trip is long, but in vehicle time accounts for 60.2% of the 154-minute journey. Walking segments are only 11.9% of total time (18 minutes), and there are 2 legs with slightly longer time than optimal, but not a serious burden. A greater obstacle lies in transfer steps, where travellers need to change mode twice, and at each stage the wait exceeds ideal range at 27 and 16 minutes respectively.

2. Median: Trip 1840 - Index 11954 - Departure 17:07

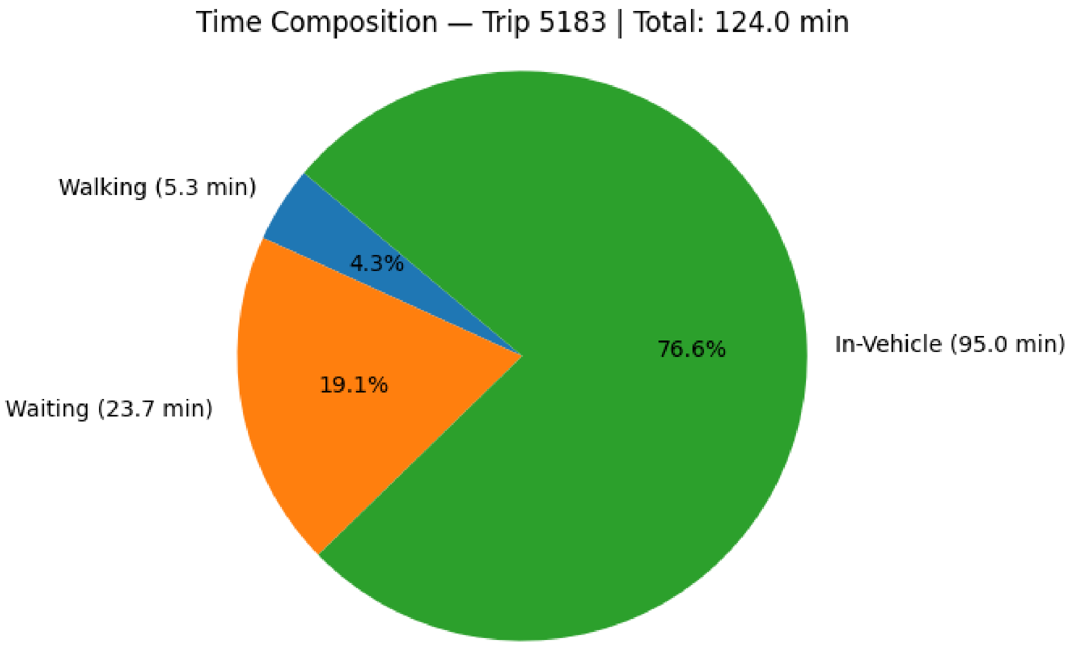

Figure 23a: Time composition - Trip 1840

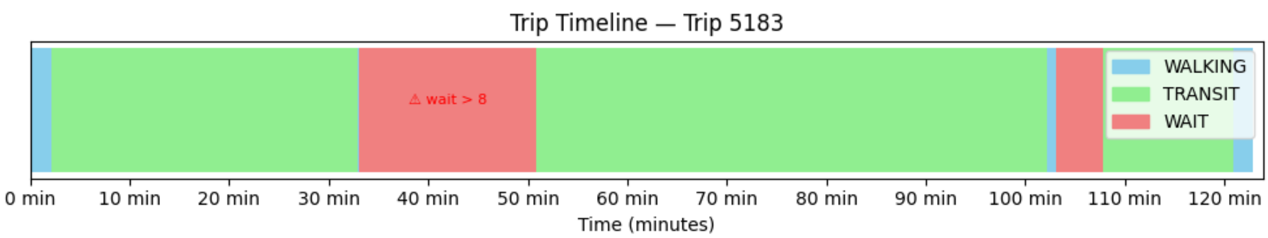

Figure 23b: Trip breakdown - Trip 1840

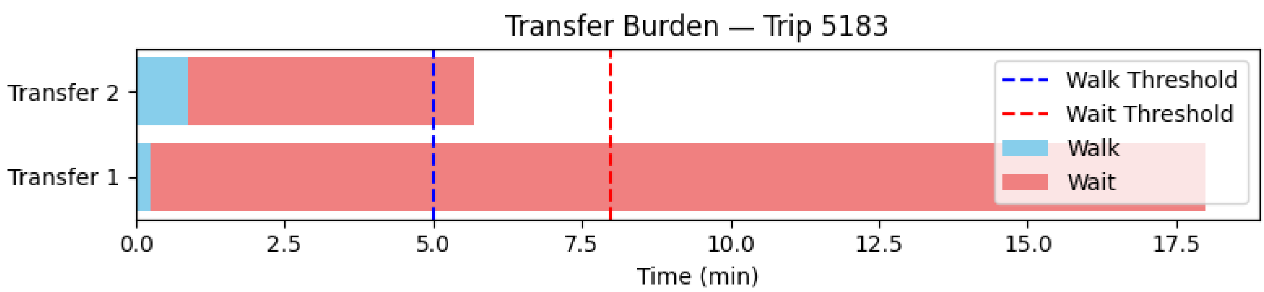

Figure 23c: Mobility analysis - Trip 1840

This trip has similar characteristics as the worst case, albeit milder. Despite a high proportion of vehicle time and short walking, it suffers from multiple transfers and long waits. Notably, while only one transfer involves a prolonged wait, it is 17 minutes, much above the ideal time.

The similarities between worst case and median-index trips imply consistent configuration of the multimodal transit on this route. Low walking time means good physical connectivity is already present, and any operational or scheduling changes could yield a system-wide improvement.

4.5 Systemic Patterns

Having identified the detailed components of under-performing trips, this next phase examines whether these weaknesses consistently appear at the route level. Moving beyond isolated cases, we can find out which routes are structurally prone to inefficiencies and which types of weaknesses dominate.

4.5.1 Worst case in general: Alba to Mirabilandia

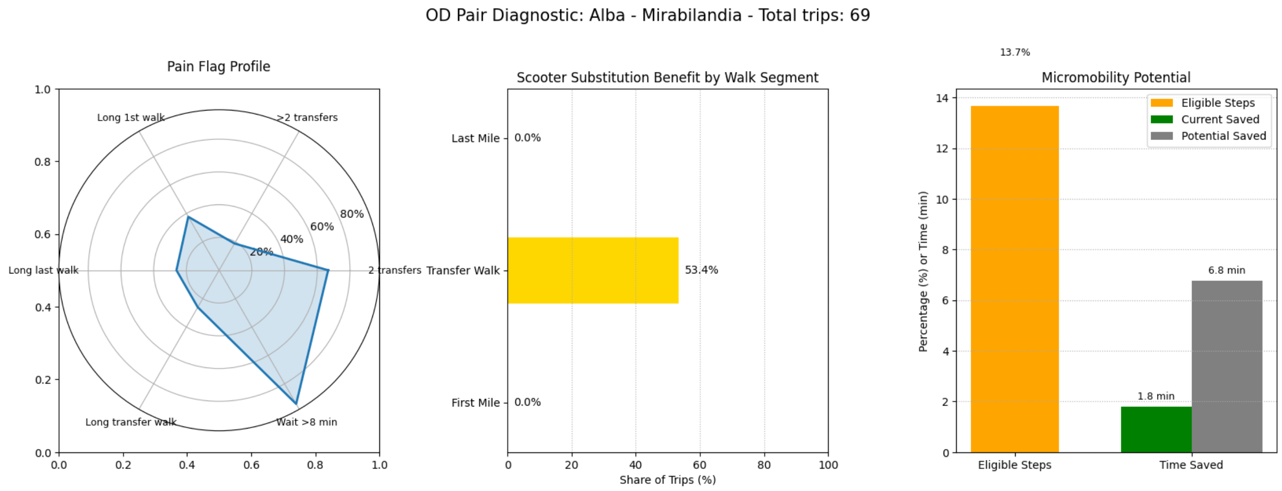

Figure 24: Route profile - Alba to Mirabilandia

The most prevalent weaknesses on this route are high wait time (94%) and having two transfers (66.7%). More significantly, 18.8% of the trips involve three or more transfers, and 37.7% of the trips also include a long first-mile walk. These overlapping weaknesses suggest that travellers on this route experience compounded burdens, especially transferring multiple times and having to wait long at some or all of them makes the overall journey particularly unattractive.

Moreover, micromobility does not help alleviate the ingress issue, as none of the trips receive first-mile segment benefit (or last-mile - both Alba and Mirabilandia are outside of the Lime service zone). While scooters can be used during the transfer on 53.4% of the trips, the average time saving is minimal at 1.8 minute. The gap between current average savings and the potential savings of 6.8 minutes per trip highlights the reduced contribution of scooter service under the existing coverage.

Looking back, the individual trip patterns are reflected here, specifically high prevalence of long wait times and multiple transfers. This alignment reinforces that these are not isolated cases but structural weaknesses, demanding adjustment in better transit line management to minimise the number of transfer and the ensuing wait time.

4.5.2 Operational Friction: Rivazzurra to Italy in Miniature

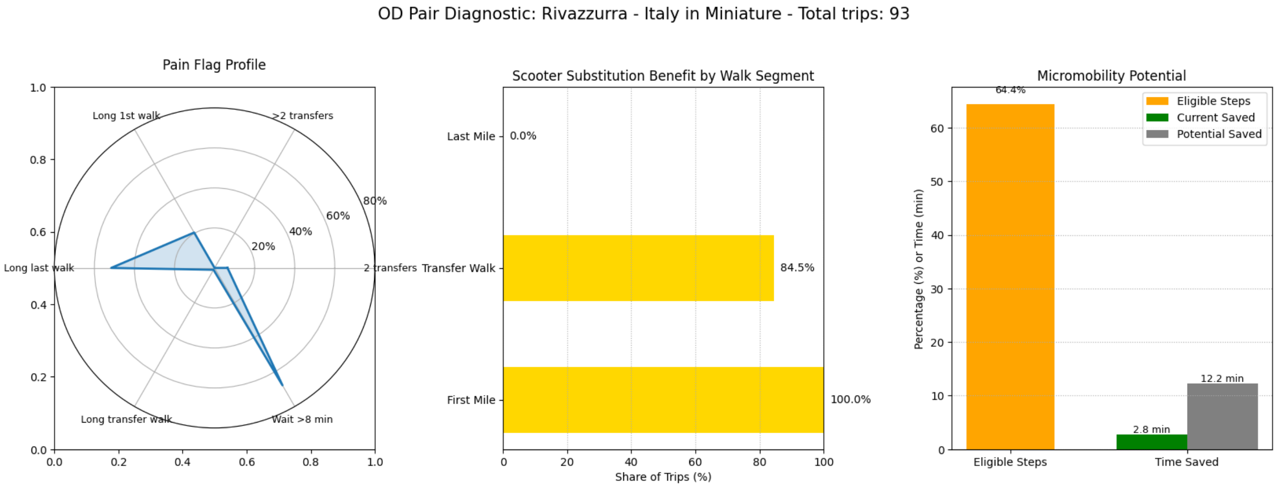

Figure 25: Route profile - Rivazzura to Italy in Miniature

This route shows relatively low structural friction in terms of transfers, with most trips requiring only one transfer or less, and minimal walking during those. However, 68% of trips still suffer from long wait times, highlighting a scheduling inefficiency. Additionally, 52% of the trips suffer from long last-mile walk and 20% involves long first-mile walk.

While the first-mile walk of all trips can benefit from scooter substitution, the average time saving is not much at only 2.8 minutes. This is because ingress accounts for a smaller portion of the walking time. The main pain point (egress) is currently outside of coverage and not eligible for scooter use. If scooters were available up to Italy in Miniature, the potential saving could reach 12.2 minutes per trip, significantly higher than present level.

Comparing to individual trips, these weaknesses are confirmed to be widespread, with dominant issues being long wait times and long last-mile walk. This emphasises the need to address scheduling and expand last-mile micromobility coverage.

4.5.3 Nature Destination: Viserba to San Leo

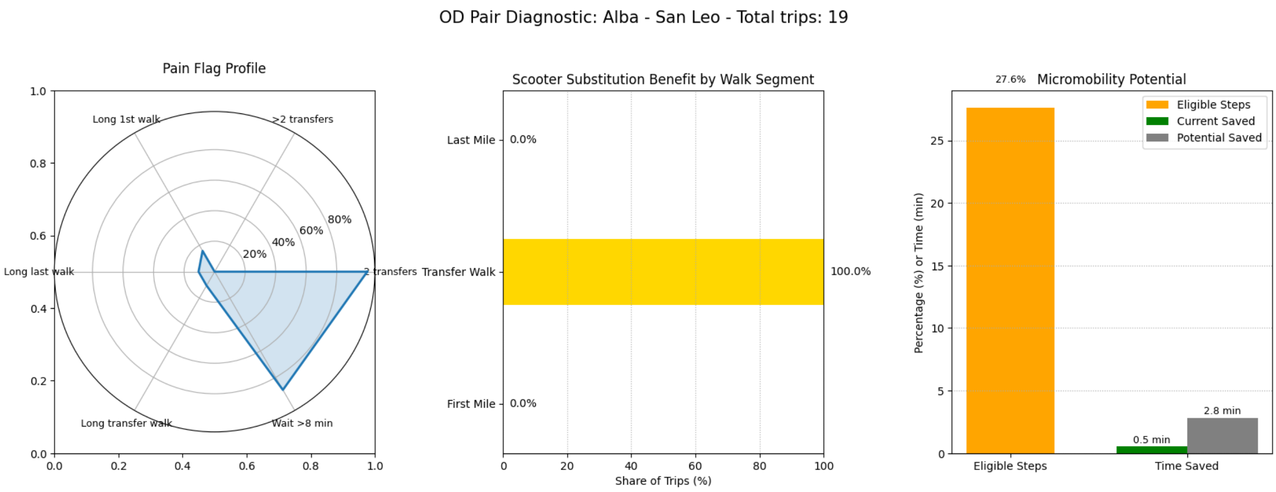

Figure 26: Route profile - Viserba to San Leo

The journeys from Viserba to San Leo are particularly weak at the transfer stage. Almost all trips require two transfers, and 90.3% suffer from extended waiting times. Walking related burdens are focused on the first-mile (48.3% of the trips), with 16% of trips experiencing long transfer walk segments. Even so, micromobility provides relatively modest time savings (average 2 minutes now and 3 minutes potentially), rendering this service unable to improve user experience on this route. Combining with the frequency of only 31 trips per day, this reflects the limited utility of this public transit route for travellers to aim to explore this mountain attraction.

As also demonstrated in the individual trips, the stable structure of this multimodal route makes its weaknesses straightforward: rigid transfer configuration and poor schedule coordination. Given the limited potential for micromobility improvements, it is evident that targeted interventions should focus primarily on operational and scheduling adjustments.

While this section only analyses three out of 70 attraction routes, it illustrates how route-level weaknesses can be identified by going from individual trip diagnostics to aggregated indicators. The findings from these three routes provide important insights, and a comprehensive suggestions for the area-wide transit system would be possible once the full set of routes has been examined. This insight supports prioritising targeted improvements where they would have the most widespread impact.

Chapter 5

Discussion

The primary aim of this study was to develop an evaluation framework to quantify tourist accessibility using multimodal transport. The accessibility index served to compare multimodal routes for their overall efficiency with weighted burdens for different components of the trip. The study also demonstrated that using Google API, it is possible to model the user's journey door-to-door, with individual segments for vehicle, walking and waiting. The addition of Lime service zone helps assess micromobility potential as a part of the multimodal trip. With more detailed data, it would be possible to justify the benefits of integrating rental scooters into the structure of multimodal transit.

With the obtained segmented multimodal trip data, trip-level analysis can explore specifically which element in the multimodal options underperform and require adjustments, and build a strength-weakness profile for each route. This serve as the foundation to identify major inefficiencies in the public transport system as a whole. These data can help prioritise areas that need improvement (such as northern accommodation zones or peripheral attractions). It also highlights operational obstacles such ass scheduling issue that leads to long wait times, which can support better transit line design and management.

5.1 Key Findings

System-level analysis reveals that gateway routes are generally consistent and well-planned, shown by the stable accessibility index. Moreover, long physical distance are visible in the high proportion of in vehicle time versus walking and waiting within a trip. These long vehicle times also soften the weighted effect of other burdens, rendering the accessibility index highly dependent on the distance. However, there are variabilities which were not explored in depth in this thesis.

On the other hand, attraction routes show greater variability and typically have worse performance on weekdays, especially for peripheral destinations like Mirabilandia and San Leo. Due to shorter distances and higher proportions, walking and waiting times impact the whole experience more heavily than gateways.

Regarding service availability, many routes have wide temporal coverage with early morning and late night trips, excluding Forlì airport which does not operate in odd hours. Some peripheral points of interest (San Leo, Misano and Mirabilandia) have last services quite early in the day, and discontinuous departures. Having said that, the majority of gateway and attraction routes maintain an adequate service, with good hourly frequencies.

From the accommodation viewpoint, central zones like San Giuliano and San Giovanni perform average to well on both gateway and attraction access. Southern zones (Rivazzurra, Alba) are benefiting from the Metromare, improving hotel-side accessibility considerably compared to similar zones to the north. These areas - Torre Pedrera, Viserba, Rivabella - consistently underperform, reflecting thin network coverage. The opportunity matrix also exhibits no quadrant shift between weekday and weekend, indicating that while there are changes, they are not substantial enough to improve or worsen these routes' utility for tourists.

Detailed analysis of the three attraction routes confirms that long wait times and multiple transfers are dominant weaknesses, with long walking burdens as a secondary barrier. Long wait times are usually the result of poor schedule coordination, or the uneven frequency between different modes. Moreover, for trips with multiple transfers (especially San Leo and Mirabilandia), this suggests low importance these destinations command during the transit line design process.

While not as prominent as wait time, walking barriers do exist, specifically for first and last-mile segments. This shows that transit modes arriving directly at the attractions are not frequent enough. Instead, many will get visitors to a major stop, from which they have to make their way on foot. Detrimentally, the current Lime service coverage do not provide much assistance to alleviate this issue. The low time savings of 1.8 to 2.8 minutes are mainly due to lack of coverage of the service.

Despite these seemingly low benefits, scooters do offer strong potential to reduce walking time, as seen in the separate micromobility analysis. However, these improvements are heavily dependent on geographic placement of the origins and destinations. The greatest gains appear in central accommodation zones which are already well-connected, while struggling routes see marginal improvements. The weak correlation between time savings and accessibility index further underlines this point: micromobility enhances already good access, but does not compensate for those with poor connectivity.

5.2 Reflecting on the Mobility System

Rimini's public transport system is doing well on multiple aspects, however, there are much room for improvement if the city looks to leverage these strengths to multiply the PT user base. The gateway routes are objectively reliable and well planned, making it straightforward for tourists to arrive in the city with public transit. This is important, since if visitors cannot use public transit to get to the city, private vehicle would be the obvious mode choice, and it limits all further opportunity to promote or encourage transit use during their stay.

Furthermore, the central zones and attractions have a big advantage in high concentration of transport infrastructure (lines and stops) and the convenience of micromobility. This ensures tourists staying in the centre have a smooth time getting to their hotel and visiting points of interests. Expanding on this, recent investments in transit infrastructure, most notably the Metromare line, has successfully improved efficiency and connectivity of the multimodal system where it passes. Yet, this focus on central corridors reinforces a hub-and-spoke structure that results in highly unequal accessibility between central and peripheral points of interest, as well as between the central (and improved southern) accommodation zones versus the northern zones. Consequently, visitors are discouraged from venturing to more distant destinations, leading to overcrowding in central areas.

On the temporal dimension, many routes have high frequency and long operation time window, allowing tourists flexibility and freedom to visit different attractions. However, while frequency may be adequate on average, gaps on peripheral routes undermine the practical usability and reduce flexibility, forcing users to stick to safe choices.

Operational inefficiency (scheduling and coordination of stop locations) lead to more transfers within a trip, high wait times during the transfers, and long walking segments. Waiting and walking are viewed with considerably more dissatisfaction than vehicle time by tourists. In a different aspect, less than ideal frequency of transit that reach peripheral attractions means there are much fewer realistically agreeable trips than can be put together on Google Maps. These high values would deter potential users from embracing public transportation.

A compounding factor to the walking issue is the lack of micromobility service coverage surrounding peripheral attractions. The mode is also completely outside of the multimodal transit system, which leads to potential scenarios of micromobility versus public transit, instead of their complementing each other on longer journeys. However, the accessibility dimensions also account for waiting and transfer components, so scooters alone is not the answer to Rimini's PT challenges, though it would be an invaluable addition to the system.

Finally, a notable strength, and a foundational element of this study, lies in the role of digital route-planning platforms such as Google Maps. Tourists rely on such platforms to navigate the transit system of an unfamiliar destination. The integration of multiple modes, detailed schedules and real time transit updates, greatly reduces informational barriers and enhances confidence in using public transport. This digital infrastructure greatly contributes to the adoption of public transportation among Rimini travellers.

5.3 Policy and Design Strategy

Building on these structural tensions, it is essential to consider where limited resources should be directed: toward reducing operational frictions such as wait times and transfers, or toward expanding spatial coverage to peripheral and inland zones. These choices define the future balance between reliability, equity, and adaptability in Rimini's transport strategy.

Since the central zones have an existing well-linked public transport infrastructure, now is the time to pivot towards improving access to peripheral attractions and the northern accommodation zones. This can be achieved by building a rapid transit line similar to Metromare from Rimini to Torre Pedrera. If Rimini is ready to breakaway from the hub-and-spoke design, a shuttle bus geared towards travellers would be a great addition. This high-frequency and attraction-oriented loop can connect the coastal accommodation zones with nearby attractions such as Italy in Miniature, Mirabilandia and San Leo.

Another important point of focus is improving connectivity between different bus, train & tram lines. This is especially important to reduce the number of trips with many transfers and long wait time. Wider placement and increased number of stops would also reduce first and last-mile walks or walking between modes. These would make more trips on Google Maps realistically agreeable to tourists, especially those that are not operationally viable due to long inactive segments. These improvements would greatly benefit inland destinations such as San Leo, OltreMare/Aquafan or Misano Circuit, making these distanced venues more attractive.

Micromobility could become an integral part of this multimodal system if their service is expanded to cover inland and northern areas. More importantly, the Mobility-as-a-Service (MaaS) model is necessary to encourage this usage in conjunction with other traditional modes. Currently, besides their native app, Lime vehicles do show on Google Maps, but as a standalone option. Ideally, all modes need to be presented together as one connected journey to encourage tourists to make use of them. As ambitious as it sounds, Rimini could invest in a MaaS app which enables one-stop route search and payment services for all transit modes in the journey.

While this study cannot go in-depth into the choice of adjustments and their implementation, it would be logical to approach this with a phased prioritisation strategy. Short-to-mid term operational measures, such as schedule coordination, additional stops, and improved line design, can enhance tourist satisfaction at relatively low cost. A dedicated shuttle service connecting peripheral attractions and northern zones would also be a relatively low-effort investment that yield impactful improvement. In the longer term, larger investments such as extending Metromare to the north, integrating Lime service into the system, or a MaaS platform can be gradually developed, supporting greater accessibility for all zones and enhance flexibility in the public transport system.

5.4 Contribution to Literature and Destination

This study contributes to the existing literature in several ways. First, it shifts the focus from the more commonly studied resident population towards tourist accessibility. Second, while many multimodal transport studies target metropolitan areas with well-developed transit networks, this research proposes an integrated evaluation framework that works with a mid-sized, seasonal destination. It adds to the small but growing segment focusing on tourist cities with less comprehensive transit infrastructures.

Methodologically, the data-driven approach combines GTFS-based public transport data with micromobility service into an integrated accessibility evaluation. This approach captures the full door-to-door journey and explores the potential synergies and gaps between traditional transit and micromobility options. Furthermore, by explicitly separating in-vehicle time, walking segments, waiting time, and transfer penalties, the accessibility index builds on the "interconnectivity ratio for different mode chains" concept by Krygsman et al. (2004), providing a more in-depth representation of travel burdens as experienced by tourists.

Practically, the resulting accessibility data provide Rimini tourism board and urban planners with empirical evidence to prioritise infrastructure investments. By identifying specific transfer routes where multimodal coordination underperforms, planners can better allocate resources, such as additional shuttle bus, micromobility expansion, improved information visibility, or synchronised service frequencies. Ultimately, this study supports Rimini's strategic goals of reducing car dependency, mitigating seasonal congestion, and building a diversified tourism economy.

5.5 Limitations and Areas for Further Research

Due to the scope of the study, multiple limitations have been mentioned throughout. The most glaring is the breadth of data. Due to API limits and the large number of routes, the study only examined 2 days in June. A more inclusive set of dates should provide a more representative snapshot of Rimini's public transport system, allow for seasonal variations in service patterns and enable more accurate findings.

The framework relies heavily on Google Directions API, whose algorithmic black box limits control on how the multimodal trips were constructed. And since the routes were queried before they happen, no real-time operational reliability such as delays or disruptions were taken into account, which are critical to practical accessibility assessments and policy planning. A more extensive study, in collaboration with Rimini's operators, could integrate real-time GTFS feeds and develop a custom routing engine (with ArcGIS or OpenTripPlanner) to explicitly control the multimodal trip creation.

Moreover, the accessibility index, while component-weighted, still heavily depends on vehicle time. Further study could expand on this by analysing the index over distance to explicitly examine efficiency independent of travel distance.

Micromobility data is the weakest point. Since the data only consists of Lime service zone, many assumptions had to be made with regard to fleet availability, vehicle status and operational constraints. Therefore, the model is a rough estimation of time savings. If access to detailed fleet info is available, it would allow more accurate calculation of benefits, providing a firm justification to encourage its integration into the multimodal infrastructure.

Finally, other user-oriented dimensions such as pricing, perceived comfort or usability were not analysed in this study. Future research could incorporate these qualitative factors to enrich the accessibility evaluations, enabling suggestions on both the system design and user experience.

Chapter 6

Conclusion

This study aims to develop an evaluation framework to measure tourist accessibility using multimodal transportation, and test the practical application by assessing the transport system of the coastal city Rimini.

The result suggests that the journeys from gateway to Rimini are generally well planned and reliable. While travel time might be long, that is due to physical distance. On the other hand, tourists using PT to visit different attractions encounter varying experiences, with long wait times, multiple transfers, or significant walking distances to peripheral venues. These are also systemic pain points on other routes, highlighting poor schedule coordination and stop placement. Among accommodation areas, it is visible that central and southern zones benefit from good connectivity, added by Metromare, whereas the northern zones underperform due to thinner bus network. The rough analysis of micromobility usefulness reveals significant time saving potential, but service concentration in the centre means it boost already well linked routes, while under-serving poorly connected sections.

To address these weak points, Rimini can improve coordination (schedule and stop location) between different bus, train & tram lines to address operational inefficiencies. If large investments are available, extending the Metromare or setting up shuttle services connecting accommodations and attractions in the northern zones will support access equity. While requiring more commitment, an integrated interface (MaaS model) for the whole system integrating micromobility would significantly enhance tourist accessibility.

The study added a data-driven evaluation framework to the tourism transportation literature, and analysed Rimini - a mid-sized, seasonal destination instead of a major tourist hub. The integration of aggregated public transport feed and micromobility data provides a new angle of analysis, and shows potential in quantifying the combined accessibility performance to and within the destination. The result identified several areas for improvement in the organisation and management of the city’s public transit network.

Due to the scope of the research and data availability, there are numerous limitations: small date sample, dependence on Google algorithm, surface-level analysis of the index, exclusion of perceptual dimension, and low-level micromobility data. Future research could expand on this with more representative date selection, use of open-source routing engine, in-depth exploration of the index, taking into account comfort, integration and info-mobility features, and acquire proprietary micromobility data.

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