International Journal of Tourism Research

WILEY

RESEARCH ARTICLE OPEN ACCESS

Designing Public Transportation Services for Car-Dependent Rural Destinations: An Application in the Case of the Ebro Delta (Spain)

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Received: 30 December 2023 | **Revised:** 23 January 2025 | **Accepted:** 17 April 2025

Funding: This work was supported by Spanish Ministry of Science, Innovation and Universities (PID2020-112525RB-I00), Generalitat de Catalunya and Department of Research and Universities of the Catalan Government (2021-SGR00657), Provincial Council of Tarragona, Spanish Ministry for Universities (C21.I4.P1/AEI/10.13039/501100011033) and Martí i Franquès Doctoral Programme from Rovira i Virgili University (2019PMF-PIPF-29).

Keywords: car-dependent mobilities | decarbonising tourism mobilities | GPS-tracking | public transport | rural destinations | travel behaviour

ABSTRACT

This paper proposes a method for developing alternative transportation policies in car-dependent rural areas, supporting the United Nations' decarbonisation goals and aiming to mitigate the impacts of drive-tourism in sensitive regions. After analysing tourist travel patterns, examining the proliferation of parking lots, identifying key tourist infrastructure, and cataloguing the existing public transport network in a case study of the Ebro Delta, we suggest two strategies to reduce reliance on private vehicles. The first involves introducing a new circular hop-on hop-off bus service for tourists, linking the primary tourist assets. The second strategy enhances and enlarges existing regular public transport by covering essential tourist areas through transfers. Both strategies integrate with the current bicycle lane network, connecting key tourist locations. This research offers a practical example of designing tourism mobility policies in rural destinations and yields insights into designing tourist-focused public transport in similar areas.

1 | Introduction

In response to the climate crisis, the United Nations aims for carbon-neutral emissions by 2050, a target that includes decarbonising tourism and related transportation (Bursa et al. 2022; Verbeek and Mommaas 2008). This objective poses unique challenges for rural and natural destinations, characterised by low tourist demand density, limited transportation infrastructure, and heightened post-Covid-19 demand. These challenges are particularly critical in environmentally sensitive areas lacking substantial human and economic resources (Dickinson and Robbins 2007; Juschten and Hössinger 2020).

To reduce car-dependency in rural and natural destinations, new policies must be formed from research on tourist travel patterns. This includes understanding tourist arrival methods, internal movement, reasons for choosing specific modes of transport, and the role of cars in their visit (Connell and Page 2008; Hall et al. 2017; Le-Klähn et al. 2015). Despite increased research in tourist mobility, rural areas pose unique methodological

challenges, including low population density, vast geographical areas, decentralisation, limited data availability, restricted analysis options, and often reduced political interest (Hardy 2022; Paulino et al. 2020). This emphasises the critical need for academic research in these contexts.

This research aims to mitigate the negative impacts of self-drive tourism by proposing public transport options for visitors to rural destinations, particularly focusing on the Ebro Delta, a rural natural destination in the Western Mediterranean. Within this context, the article's research objectives are as follows:

1. Identify the main patterns and key challenges associated with car-dependent tourist mobility in the Ebro Delta with the current increase in visitors in the post-pandemic context.
2. Develop and apply a methodology to diagnose the deficiencies in public transport for tourist mobility in rural areas.
3. Develop and apply a system to design new proposals or improvements to the existing public transport system, which satisfies tourist mobility needs within rural destinations.

To meet these objectives, diverse data collection methods were used to compensate for the scarcity of specific tourism mobility data in the area. The methods include GPS tourist tracking, tourist guidebook content analysis, and systematic inventory of certain infrastructures, such as car-parking facilities, accommodation supply, and existing public transport links. These data contribute to understanding the role of cars in destination visits and align tourist travel patterns with tourism infrastructure. Using these data, the study identifies key tourist areas by clustering accommodation hubs, attractions, and parking lots and then contrasts the results with the current public transport network. This enabled the identification of needs for implementing collective transport alternatives to private cars. Based on these findings, the study proposes two public transport alternatives: a tourist-tailored hop-on-hop-off circular bus line and an improved and more extensive regular bus network. The study offers a reproducible methodology for designing tourist-oriented public transport systems in other rural car-dependent destinations.

The remainder of the paper is structured as follows. First, Section 2 frames the study by presenting a literature review in regard to sustainable mobility transitions in rural areas, the characteristics of car-dependent rural destinations, and the optimisation of accessibility to these kinds of destinations by improving the public transportation infrastructure and service. Section 3 explains the research method employed, including the details about the study area, the data collection, and the process followed for the new bus route proposals. Section 4 presents the findings after applying our method, including the database compilation with the current resources and transport infrastructure, the definition of assets clusters by proximity and relevance as the basis for bus route calculation, and the calculations of the bus routes. Finally, the conclusions outline the theoretical contribution of this research and its planning and management implications, address the study's limitations, and make recommendations for further research.

2 | Background

2.1 | Transition to Sustainability Mobility in Rural Destinations

Applied research on sustainable mobility transitions usually focuses on daily mobility in cities, often neglecting rural areas and overlooking leisure and tourist mobility (Poltimäe et al. 2022). However, leisure mobility constitutes half of transport in developed nations (Becken and Hay 2007); thus, it is crucial to include tourism in the shift to greener transportation (Böhler et al. 2006; Scuttari et al. 2013; Signorile et al. 2018). The key to this transition is reducing the reliance on private cars by offering diverse sustainable travel options. This means providing reliable, proximal, and highly frequent public transport, and implementing restrictions to help move away from the car-orientated status quo (Tsavachidis and Le Petit 2022).

Besides contributing to climate change emissions, car usage introduces additional issues and externalities in rural and nature-based destinations. Motorised vehicles can harm rural and natural environments, causing issues like soil, air, and water deterioration, noise disruption to wildlife, harm to flora and fauna, and even overcrowding and visitor conflicts in areas with limited capacity (Leung et al. 2018; Monz et al. 2021).

To mitigate these consequences, many natural areas now proactively manage visitor flows, particularly motorised vehicle mobility (Medina-Chavarría et al. 2022). Alternatives are offered like different attractions or activities, environmental information, delimited transit and parking zones, or deterrent measures like access fees, vehicle limits, or motorised access bans. However, these initiatives also lead to associated challenges linked to decision-making by affected stakeholders and funding, particularly in rural areas with few economic and human resources (Medina-chavarria et al. 2023). Thus, sustainability strategies must include, *inter alia*, a shift towards encouraging environmentally friendly transportation within the destination (Böhler et al. 2006; Bursa et al. 2022; Peeters and Schouten 2006; Verbeek and Mommaas 2008).

2.2 | Car-Dependent Destinations

Private cars provide greater independence and freedom to access places otherwise inaccessible by bus or train, such as rural areas, where low population density results in deficient and infrequent public transportation (Böhler et al. 2006; Bursa et al. 2022; Carson and Waldhoer 2011; Connell and Page 2008; Dickinson and Robbins 2007; Dickinson et al. 2009; Hardy 2003; Zhao and Yu 2020). In addition, it is necessary to consider tourists' limited knowledge of alternative transportation means (Lew and McKercher 2006).

The transport chosen to reach a destination influences intra-destination choices (Masiero and Zoltan 2013). In many inbound holidays, private cars are common, leading to on-site mobility by car (Böhler et al. 2006; Zamparini et al. 2022). On the flip side, expected on-site mobility affects the transport mode from home to the destination (Bursa et al. 2022). A tourist's choice of transportation is influenced by the destination characteristics,

especially in rural areas with limited options, where cars are often the only viable choice (Bursa et al. 2022).

The intrinsic traits of rural areas result in limited, uneven, and dispersed service components and recreational facilities compared to more massified or urban destinations (Paulino et al. 2020). The widespread attractions in this kind of destination, together with the use of private cars, lead to diverse movements and touring behavior as tourists connect different points of interest. This makes travel patterns harder to predict compared to more compact destinations (Connell and Page 2008; Lew and McKercher 2006; Paulino et al. 2020, 2021; Smallwood et al. 2012). Indeed, self-drive tourists independently navigate destinations fueled by real-time information, making spontaneous stops at points of interest due to the freedom and autonomy of personal vehicles. This leads to unpredictable travel patterns, schedules, visits, and activities (Carson and Waldhoer 2011; Hardy 2003, 2006; Hardy and Gretzel 2011; Prideaux and Carson 2003).

However, the availability of basic infrastructure and tourism facilities, particularly accommodation, affects destination consumption (Chhetri and Arrowsmith 2008). This promotes a symbiotic relationship between towns containing services and surrounding attractions, pushing tourists to follow the hub-and-spoke travel pattern from their accommodation location (Lue et al. 1993). Constrained by the selected base camp, tourists visit surrounding attractions, considering other factors such as their attractiveness level and characteristics, their spatial distribution regarding accommodation and other attractions, main routes, and the distance to reach them (Dredge 1999; Lew and McKercher 2006; Mckercher and Lau 2008; Paulino et al. 2020, 2021; Shoval et al. 2011).

When considering attractions, specific sites are not the only items to consider. Self-drive tourism is a touring behaviour that favours the creation of scenic routes. The scattered distribution of attractions across a destination, coupled with the distinctive physical features and landscapes of rural and nature-centric locales, encourages tourists to appreciate the journey between attractions, making it an attraction in itself (Hardy 2003).

2.3 | Public Transport as an Alternative to Cars in Rural Destinations

There is a notable lack of academic literature and practical experiences that incorporate tourism and its flows into the sustainable planning of mobility at urban and/or regional scales. This may be attributed to the traditional tendency of tourism and mobility planning to operate as fields with limited interaction (Scuttari et al. 2013; Zamparini 2021). Moreover, the limited existing literature tends to focus on urban areas (La Rocca 2015) or national-scale analyses (Coppola et al. 2020), although only a few examples exist of practically integrating tourist flows into urban and regional sustainable mobility planning. Most transport studies and policies tend to be focused on daily commuter mobilities, without coping with challenges and opportunities related to leisure mobilities not linked with daily activities (Gronau and Kagermeier 2007). Subsequently, although tourism has significantly increased demand for public transportation, urban and regional planners have not responded with a corresponding expansion in service availability (Albalate and Bel 2010; Gutiérrez et al. 2019).

Recent literature on public transport and tourism tends to focus on studies and experiences related to urban tourism. In contrast, there is less research analysing the role of public transportation in promoting sustainable mobility in rural destinations (Le-Klähn and Hall 2015; Poltimäe et al. 2022; Zamparini 2021), particularly in destinations within the Global South (Permana et al. 2024). This gap is evidently linked to the inherent challenges of collective public transportation in low-density areas with limited mobility demand, as is characteristic of rural regions (Smith et al. 2018; Tomej and Liburd 2019; Waleghwa and Ioannides 2024). These challenges hinder both the existence and viability of public transportation services designed to support tourism in such contexts.

The existence of self-driving tourism proves that the mobility demand exists. Previous research evidences that where services are perceived to be adequate, there is potential for public transport use in leisure time (Gronau and Kagermeier 2007; Gutiérrez et al. 2019). Moreover, other complementary services can have a positive impact on flow management, help prevent overcrowding, and promote the use of public transportation and active modes. Examples include park-and-ride facilities, services integrated with shuttle systems, or bike-sharing programs (Curtale et al. 2021). However, the supply of public transport is often nonexistent or deficient, particularly in rural areas. Accessibility to and within a destination can be optimised by developing a public transportation infrastructure network or improving connectivity between the network and tourist facilities (Gutiérrez and Miravet 2016; Kinsella and Caulfield 2011; Le-Klähn and Hall 2015). Following Gronau and Kagermeier (2007), this development or improvement of public transport should be done by focusing on the demand side, considering its individual attitudes and preferences for a better understanding of traffic planning. In this respect, the public transport demand of tourists within a destination is influenced by various factors (both tourist attraction factors and obstacles), which should steer the structure of the transport system to improve accessibility, such as luggage transport, the accessibility to the destination by public transport, full-service travelling packages, functionality to accessing the sites, time cost or other profile determinants, such as travelling with kids (Böhler et al. 2006; Gattuso and Malara 2018; Gronau and Kagermeier 2007; Gutiérrez and Miravet 2016). According to Böhler et al. (2006) short-haul travellers travelling by car in 80% of cases show a positive attitude towards reaching their destination by public transport if additional free services were included, such as luggage carriage and door-to-door organisation. Additionally, once at their destination, they would be willing to forgo using their own car if other options were available. However, rural areas may find it difficult to integrate tourist mobility and public transport, especially considering the different needs of accessibility to stops/stations between locals and tourists, and the expansive nature of such areas that complicates alternative mobility options (Juschten and Hössinger 2020).

A high quality of service is essential to convince tourists to use local bus services; but this quality should not be perceived only as frequency, but also as appropriate routing minimising the

necessity to change buses and a sufficient connection with the attractions' catchment areas (Gutiérrez et al. 2019). Thus, their offered routes and complementary services must cover the tourists' needs. As the bus routes are designed for locals (Albalate and Bel 2010; Gronau and Kagermeier 2007), scheduled bus services are just slightly helping to reduce car use, enabling people without cars to reach certain destination areas. However, enhancing the existing services could increase their attractiveness (Guiver et al. 2007).

Bus services offer personal benefits by motivating tourists with scenic views from double-decker or open-top buses and eliminating the need to drive in unfamiliar areas. Some nature-based destinations have introduced tourist-specific public transport, such as the Moorsbus in the North York Moors (UK), the shuttle bus in the Natural Park of Cabo de Gata-Níjar (Spain) or the numerous single or multiple day tours around Ireland offered both by public and private companies (Guiver et al. 2007). Also, hop-on hop-off bus services are renowned for providing stress-free, reliable, and efficient tourist transportation and have demonstrated their effectiveness in major tourism cities by enhancing tourist experiences through optimised routes that ensure comprehensive coverage of key attractions (Ismail et al. 2017; Yuo et al. 2023). Balancing the interests of users, service providers, and local authorities is crucial for route optimisation in order to maximise both accessibility and operational efficiency (Yuo et al. 2023). These services also benefit areas where tourist sites are distributed over sprawling rural landscapes. Hop-on hop-off bus services facilitate access to destinations and significantly influence tourist mobility patterns (Sigala 2019).

Prior studies focusing on rural nature-centric destinations emphasise the importance of fostering collaboration between lodging providers and public transportation companies to ensure that tourists can reach their accommodation conveniently from central bus or train stations (Lane et al. 2022). In line with this, Poltimäe et al. (2022) propose a holistic approach to developing mobility services that integrates the varied motivations and needs of both locals and tourists in rural areas. This approach holds potential benefits by capitalising on temporal variations in travel demand between locals and tourists and optimising the utilisation of the vehicle fleet. They recommend a connected and flexible mobility set integrating diverse solutions attuned to temporal and spatial mobility patterns. This should include conventional public transport integrated with door-to-door or small-scale mobility solutions, together with complementary measures such as car-sharing, accessible information on routing, booking, and ticketing, as well as cooperation, shared values, and trust among involved parties. Going one step further, Gattuso and Malara (2018) and Gronau and Kagermeier (2007) highlight the need for cooperation within the entire tourism sector to invest in providing greater access to sites, reducing the overall travel costs and promoting new marketing ways to disseminate the public transport service. In any case, the evidence suggests that there is still a long way to go in research, practice, and mobility policy for promoting sustainable tourism mobility in rural areas. Current research also emphasises the need for stakeholders to adopt greater awareness and engagement in favour of sustainable tourism mobility and to more decisively support the measures required to transition toward it (Waleghwa and Ioannides 2024).

As a final synthesis, Table 1 presents and summarises the main publications in scientific journals contextualised in this section that directly or indirectly reference public transportation services for tourist mobility in rural areas. The table includes publications focused on diagnosing visitor mobility challenges and patterns, literature reviews, case studies, and proposed actions or policies in various territorial contexts. However, it also helps to highlight a significant lack of empirical studies, as well as conceptual and practical applied research. Therefore, there is considerable potential for further exploration in this field.

3 | Methodology

This study employs a GIS-based method to visualize and contextualize tourist mobilities in the area. It assesses the current public transport system to pinpoint areas with high car usage. As shown in Figure 1, the initial step involves creating a comprehensive GIS database by amalgamating diverse data. Key data sources include the Spanish National Geographic Institute (IGN 2023) for base maps, road characteristics, administrative and natural boundaries, and OpenStreetMap for street layouts and parking areas. Additional data on current public transport, including bus stops and routes, is added also, along with photointerpretation and manual digitization for different types of parking spaces. Finally, spatial data on tourist behavior are collected via GPS tracking, complemented with surveys.

This extensive database is the basis for identifying clusters of tourist assets. The goal is to pinpoint locations requiring bus stops to effectively satisfy tourist demand. These proposed stops are seamlessly integrated into the existing road network, facilitating accurate route calculations between clusters. Then, this information is used to optimize the current public transport system, either by proposing improvements or by introducing new, tourist-centric transportation options as needed.

This GIS-centric methodology guarantees a detailed, data-driven analysis that ensures proposed changes align with actual tourist movement patterns and needs, thus enhancing the effectiveness of the public transport system. In this study, we employed QGIS for spatial data visualisation and manipulation, along with various R libraries for advanced data analysis (mainly “sf,” “osmdata,” “osmr,” among others).

3.1 | Study Area

The Ebro Delta, recognised as one of the most significant wetlands in the western Mediterranean, harmonises diverse ecosystems and traditional human activities. Its exceptional natural value and the need to preserve its fragile equilibrium led to its designation as a Natural Park in 1983 and a UNESCO Biosphere Reserve in 2013 (Figure 2).

Following its designation as a Natural Park, the Ebro Delta has imposed motorised access restrictions in vulnerable zones and

TABLE 1 | State of the art of public transport as an alternative to cars in rural destinations.

Authors	Title	Main contribution for this research
Curtale et al. (2021)	Traffic Congestion in Rural Tourist Areas and Sustainable Mobility Services. The Case of Ticino (Switzerland) Valleys	The introduction of park-and-ride integrated with a shuttle service or a bike-sharing system, might have a strong impact in reducing traffic congestion. An increase in parking cost would further decrease the use of private vehicles, in favour to alternative solutions.
Dickinson and Robbins (2007)	Using the car in a fragile rural tourist destination: a social representations perspective	Explores how travel patterns in rural destinations reflect a social representation of mobility, identifies the implications this has for sustainability transportation in destinations.
Gronau and Kagermeier (2007)	Key factors for successful leisure and tourism public transport provision	Rethink the transport policy focusing on the leisure and tourists' demand. Importance of additional efforts in the areas of marketing, transparency and quality of public transport provision.
Guiver et al. (2007)	Do buses help meet tourism objectives? The contribution and potential of scheduled buses in rural destination areas	Scheduled buses achieve modest modal shift from cars, allow access to the countryside for people without cars and generate spending in local economies.
Gutiérrez and Miravet (2016)	The determinants of tourist use of public transport at the destination	Tourists' use of public transport at their destination based on profiles and the mode of transport used to reach the location. Tourists who arrived by private car were the least likely to use public transport once at their destination.
Juschten and Hössinger (2020)	Out of the city–but how and where? A mode-destination choice model for urban–rural tourism trips in Austria	Destination and transport mode choices as a combined choice in the context of urban–rural tourism, with a greater understanding on the factors driving tourist decisions.
Le-Klähn and Hall (2015)	Tourist use of public transport at destinations—a review	Main topics and issues of research in public transport and tourism, including how public transport is used by tourists at destinations in different contexts.
Permana et al. (2024)	The (un)sustainability of rural tourism travel in the Global South: A social practice theory perspective	Provides evidences on sustainable travel challenges in Global South, explore and understand tourists' rural travel practices in Bali and identifies sustainable travel opportunities.
Poltimäe et al. (2022)	In search of sustainable and inclusive mobility solutions for rural areas	Social inclusivity, economic viability, and environmental impacts of novel mobility solutions applied in European rural areas. Findings claim for the integration of the needs of various user groups, including tourists.
Sigala (2019)	Supporting Tourists' Mobility in Wine Destinations: The Hop-On Hop-Off Bus in Swan Valley, Western Australia	Practical implications of tourists' mobility in wine destinations by analysing the rational and feasibility of a hop-on hop-off bus service and their impact on tourists' mobility patterns and behaviour.
Smith et al. (2018)	Defining sustainable transport in rural tourism: experiences from the New Forest	Understanding visitor practices could help to improve sustainable transport provision in rural destinations, but there is a limited scope to influence meanings associated with visitor travel and travel skills.
Tomej and Liburd (2019)	Sustainable accessibility in rural destinations: a public transport network approach	Develops an original algorithm for evaluating sustainable accessibility of tourist attractions within regional rural destinations.
Waleghwa and Ioannides (2024)	"Everyone Wants to Drive There": Challenges to Transport Sustainability in Rural Tourism Destinations	Identifies practitioners' representations and proposals for sustainable mobility in two rural Swedish destinations. The results illustrates that they have not yet begun transitioning to a low carbon transport future.

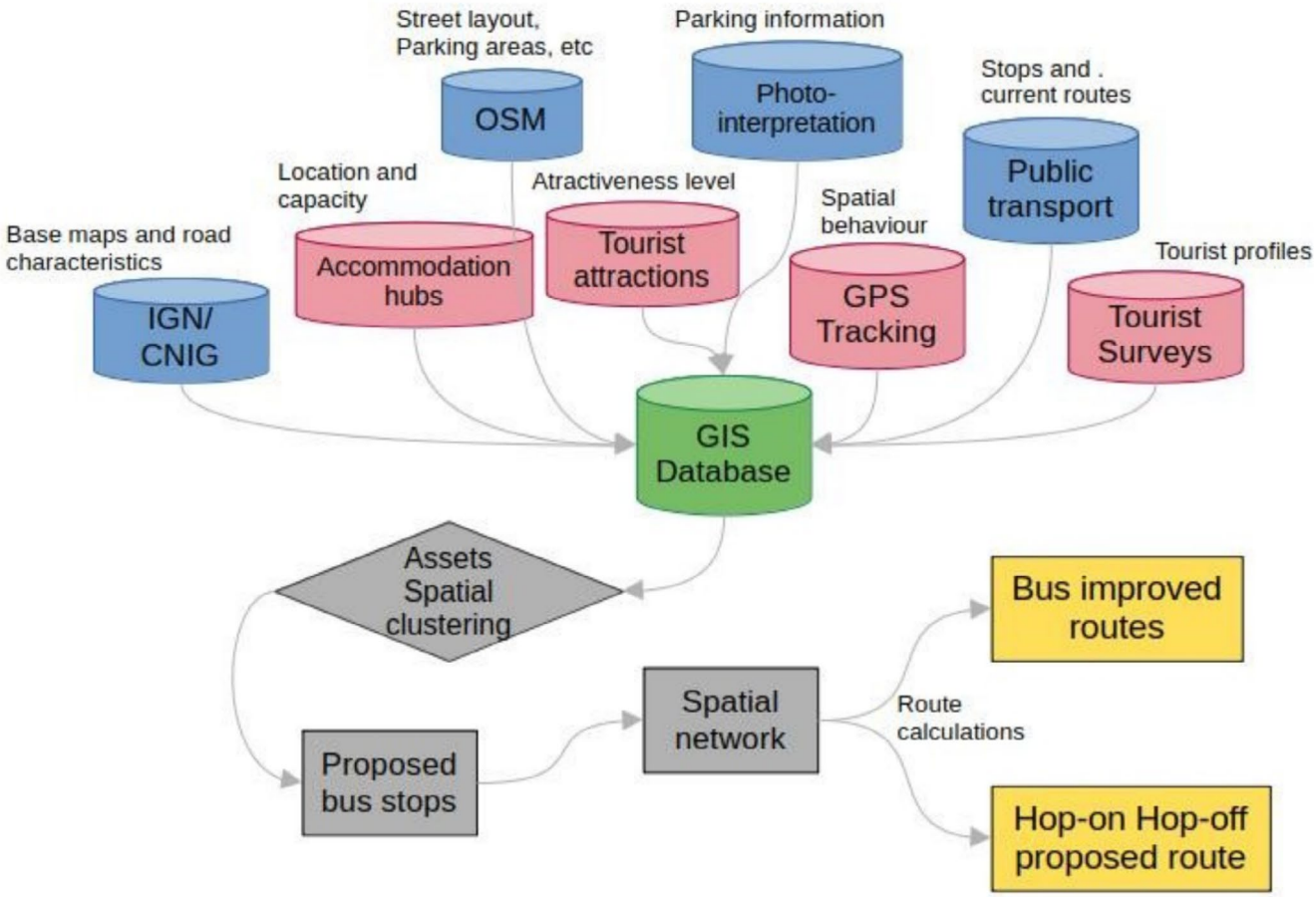

FIGURE 1 | Overview of the GIS-based proposed methodology. Data layers feed into a GIS database, supporting spatial clustering and network analysis to propose new bus stops and routes tailored to tourist demand. *Source:* Authors.

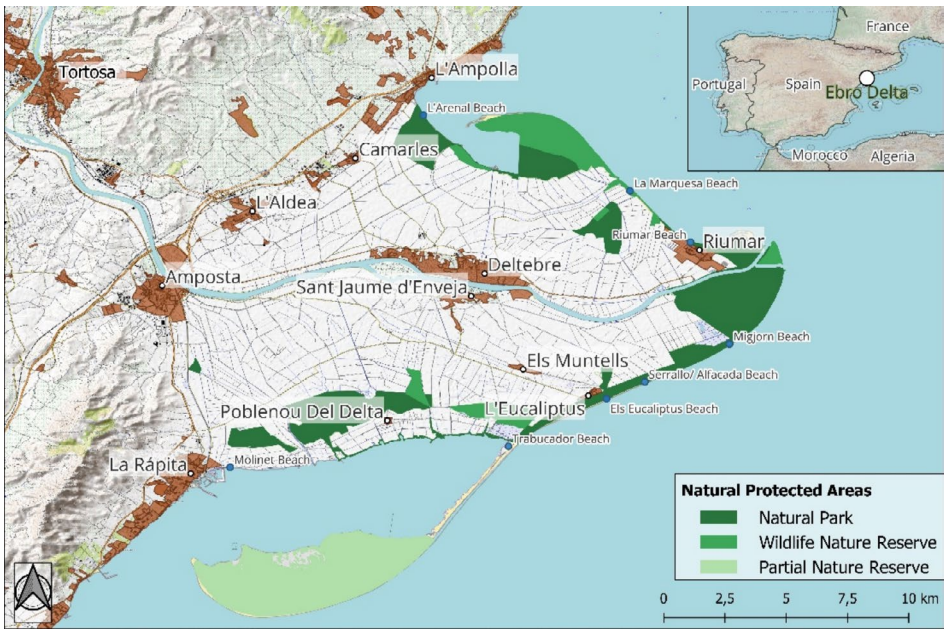

FIGURE 2 | Location map of the Ebro Delta. *Source:* Authors.

promoted cycling tourism as a tranquil, eco-friendly alternative. Despite these efforts, aspects such as the rural setting, insufficient public transport, and significant distances between attractions have prompted tourists to favour motorised vehicles for exploring the delta, establishing it as a typical self-driving destination. The post-pandemic rises in tourists seeking open and less crowded

FIGURE 3 | Aerial view of a spontaneous parking area in a fragile zone. Cars and camping-cars are frequently seen circulating and parking along the Trabucador beach, affecting its delicate ecosystem. *Source:* Natural Park of the Ebro Delta.

destinations have increased self-drive tourism in the region, posing a significant risk to its delicate natural balance (Lebrun et al. 2022; Margalef Callau 2021). Consequently, the natural delta beaches receive substantial vehicle traffic and controversial practices such as camping or rallying with vehicles (Figure 3). Despite implementing several vehicle regulations to curb the impact of vehicles on the natural environment (Medina-chavarria et al. 2023), such measures can pose economic constraints in some rural municipalities like those in the delta, forcing the withdrawal of such measures as seen in the case of el Trabucador. Moreover, these measures do not effectively curb the rise in self-drive tourism in the Ebro Delta; they merely redistribute the tourist load to different parts of the delta (Figure 4). This alleviates pressure on specific beaches but does not significantly reduce the carbon footprint, as tourists continue to visit the area by car.

3.2 | Data Collection

3.2.1 | Accommodation Hubs

The primary accommodation hubs within the influence area of the Ebro Delta destination were identified using official sources (Paulino et al. 2020). The data encompassed the number of beds across various lodging options, including hotels, campsites, hostels, bed and breakfasts (B&Bs), and apartments, within each population nucleus. This granularity enabled pinpointing accommodations within their specific areas, acknowledging that municipalities often comprise multiple population nuclei (Table 2). Locations offering fewer than 300 beds were not considered accommodation hubs and were consequently excluded from further analysis.

In the GIS, the accommodation hubs are described as the centroids of these main built-up areas.

3.2.2 | Tourist Attractions

Attractions were identified by systematically analysing the content of various tourist guidebooks of different origins and covering multiple territorial scales (Table 3). Despite the surge in digital information, travel guides still significantly influence tourism and effectively indicate tourist preferences. The importance of each attraction was assessed according to how frequently it is mentioned, and the emphasis given to it in these guides. Subsequently, attractions were categorised into four levels: international, national, and local attractiveness, and residual attractions not consistently included in all guides (Paulino and Prats 2013). In the GIS, tourist attractions have been characterised as the centroids of specific buildings, beaches, and other points of interest.

3.2.3 | GPS Tracking and Surveys

Data on tourist travel patterns was collected in July and August 2022 through GPS tracking, complemented by surveys. Participants, chosen via simple random sampling at the main accommodation hubs within the Delta, represented typical mobility and visit patterns in the Ebro Delta (Paulino et al. 2020).

FIGURE 4 | During the summer, Marquesa beach is heavily populated with cars, reflecting a significant increase in visitor traffic. *Source:* Authors.

TABLE 2 | Table including the accommodation hubs located in, at the entrance, and around the Ebro Delta.

Accommodation hub name	Available beds	Location in relation to the destination
L'Ametlla de Mar	13,286	Around the Delta
L'Ampolla	4384	At the Delta entrance
Riumar	4085	At the Delta
Ràpita, La	3858	At the Delta entrance
Deltebre	2450	At the Delta
Alcanar Platja	2438	Around the Delta
Cases d'Alcanar, Les	1710	Around the Delta
Eucaliptus	1350	At the Delta
Perelló Mar, El	1285	Around the Delta
Tortosa	753	Around the Delta
Poble Nou del Delta	694	At the Delta
Sant Jaume d'Enveja	535	At the Delta
Amposta	320	At the Delta entrance

Source: Authors.

Once participants agreed to participate and after verifying that they were at least 18 years old, they were briefed on the study's objectives. They were then equipped with a GPS device, model QStarz BT-Q1000XT, to be carried during their area visits (Zheng et al. 2019). These devices were programmed to record spatial and navigational data (latitude, longitude, altitude, speed, and direction) at 10-s intervals, suitable for mobility studies across different transport modes. Alongside GPS tracking, participants filled out a survey detailing socio-demographic information and aspects of their stay. The GPS devices were collected when participants returned to their accommodations.

Data from the 16 GPS devices was downloaded after each session using Qtravel PC Suite, version 1.55.003, provided by QStarz software. Track quality and usability were assessed for coordinate accuracy, appropriate timing, and distance measurements. From this process, 101 valid GPS tracks were chosen and matched with individual profiles from the survey data (Table 4).

Preparing and analysing the GPS tracks involved several key steps (using R):

1. Cleaning the GPS data by removing any erroneous or irrelevant data points (outliers) from tracks to ensure the accuracy of subsequent analyses.
2. Smoothing GPS inaccuracies and signal jitters by reducing data noise to improve the representation of the tourists' actual paths.
3. Segmenting the GPS tracks into individual trips by detecting changes in direction, speed, or long pauses, indicating the start or end of a trip.
4. Identifying stops by calculating the median of a set of data points within a moving window along the track, helping to pinpoint when and where tourists stopped moving. Stop durations were calculated in minutes.

TABLE 3 | Attractions categorised according to tourist guidebooks.

Attractiveness level				
International (I)	**National (II)**		**Local (III)**	**Residual (IV)**
Trabucador beach	Ecomuseum	Eucalyptus beach	MónNatura Delta	Serrallo beach
Punta del Fangar	Marquesa beach	Zigurat viewpoint	de l'Ebre	Sant Joan tower
Poblenou del Delta	Bassa de les Olles	Boat trip to the	Musclarium	Fangar bay
La Ràpita	viewpoint	Ebro mouth	Ullals de Baltasar	Gràcia island
	Migjorn viewpoint	La Tancada observatory	Sant Jaume d'Enveja	Riet Vell
	Migjorn beach	Riumar beach		Els Muntells
	Punta de la Banya	Deltebre		L'Embut viewpoint
	Amposta	Casa de Fusta museum		Deltaventur park
	Pont del Través viewpoint	L'Encanyissada lagoon		

Note: Based on Paulino and Prats (2013).
Source: Authors.

Calculating descriptive spatial metrics for each track, reporting them, and analysing the created outputs (points for stops), linestrings for segments (Figure 5). The analysis focused on track, track segment, and stop aggregated metrics. This made it easier to ascertain the mode of transport used, measure stop durations, and identify the most frequent segments. Stopping points were correlated with tourist attractions identified by analysing tourist guidebook content in order to identify the most visited tourist attractions, the time tourists spend visiting, and the main routes used to reach them. Finally, the most frequent segments, including speed reduction and short stops, were correlated with the road network to identify scenic routes.

3.2.4 | Current Public Transport Services

A comprehensive analysis was conducted of the existing public transport options in the Ebro Delta using the data from the official websites of Hife, the bus service provider, and Rodalies de Catalunya and Renfe, the train service operators. This information included the locations of bus and train stops/stations and the service frequencies for each pair of stops during the peak tourist season in summer (Table 5).

To depict the public transport network, we digitised the bus stops as a GIS point layer. Subsequently, we used the "osrm" package to calculate routes between these stops, leveraging OpenStreetMap data for practical reasons. To ensure the reliability of these calculated routes, a manual verification was conducted. This step was crucial to confirm that the routes derived from OpenStreetMap data accurately represented the actual public transport paths.

This study section was pivotal in assessing and visualising the current state of public transport, together with the spatial coverage and frequency of each route. It afforded valuable insights into the mobility infrastructure available in the Ebro Delta and into detecting the more car-dependent areas.

3.2.5 | Parking Lots Inventory and Capacity Estimation

The study includes an inventory and capacity estimation of parking lots in the Ebro Delta. This was particularly challenging as many of these parking areas are neither formally planned nor managed by any administrative body. Consequently, the data on these parking facilities were not readily available through conventional sources. Parking lots were identified through Open Street Maps and complemented via photointerpretation and fieldwork. This research uses theoretical models to estimate vehicle density in different parking configurations, namely (1) planned, (2) forced, and (3) spontaneous parking areas.

In each case, parking spaces have been estimated theoretically and contrasted with empirical counts made in aerial imagery, to account for the requisite non-parking spaces essential for functional vehicle circulation. The planned parking areas show the typical elements of parking lots, such as asphalt, parking delimitation lines, and others. These areas are engineered for optimal space utilisation and accessibility. We postulate that approximately 70% of the total area is allocated for parking spaces, with the remaining 30% dedicated to vehicular movement. Based on an average occupancy of 6–7 vehicles per 100 m^2 in such organised environments, we estimate a density of 42–49 vehicles per 1000 m^2. The forced parking areas have been developed in response to unanticipated demand, and do not show the typical elements of planned parking, just poles and ropes delimiting the areas where parking is allowed. These parking spaces are less efficient than planned areas, yet more organised than spontaneous ones. Here, we estimate that 60% of the area is utilised for parking. With a density of 5–6 vehicles per 100 m^2, we estimate approximately 30–36 vehicles per 1000 m^2. Spontaneous parking areas are characterised by their ad-hoc nature and complete lack of predefined structure. The vehicle density in these areas is the most variable. If 50%–70% of the area could be utilised for parking, with a broader range of 4–8 vehicles per 100 m^2, our estimates suggest a density range of 20–56 vehicles per 1000 m^2. Finally, average values of the defined ranges were used.

3.3 | New Bus Stop Proposals and Network Calculations

3.3.1 | Clustering of Tourist Resources

Hotspot identification is managed by the geometric clustering of parking areas, attractions, and accommodation hubs in the Delta. This was achieved by calculating all straight-line

TABLE 4 | Tourist's profile included in the sample of the GPS tracks.

Variable	Item	%
Frequency of visit	Repeated visit	62.4
	First visit	37.6
Sex	Male	42.6
	Female	57.4
Age interval	18–25 years old	3.0
	26–35 years old	10.9
	36–45 years old	27.7
	46–55 years old	27.7
	56–65 years old	25.7
	65 years old to more	5.0
Residence area	Catalonia	58.4
	Rest of Spain	26.7
	Foreigner	14.9
Education level	Primary School	6.9
	Secondary School	27.7
	University	65.3
Work status	Employed/Self-employed	86.1
	Pensioner	9.9
	Other	4.0
Group structure	Couple	40.6
	Family group	44.6
	Friends	12.9
	Solo	2.0
Group size	1 person	2.0
	2 people	46.5
	3 people	21.8
	4 people	20.8
	5 or more people	8.9
Accommodation type	Campsite	18.8
	Hotel	80.2
	Other	1.0
Number of nights	1 night	28.7
	2 nights	30.7
	3 nights	11.9
	4 nights	6.9
	5 nights	6.9
	6 or more nights	14.9

Source: Authors.

distances using Delaunay triangulation. Distances under 750 m were then filtered out. Subsequently, two buffer zones of 500 and 750 m (considered walking distances) around the resulting graph were created to define clusters of resources.

In these clusters, we established a prioritisation process consisting of excluding isolated and insignificant hotspots in the broader context of regional tourist mobility, such as isolated residual attractions and small isolated parking lots. Furthermore, we included significant transportation hubs, like the main train station in l'Aldea, which facilitates arrival at the destination via public transport, and the Amposta bus station, a key transfer point to other local bus lines.

In these prioritised hotspots, new bus stops were proposed with specific criteria: only considered in areas lacking current bus services and exclusively for tourist attractions of international or national interest (Categories I and II, as detailed in Subsection 3.2.2). The centroid of each identified area was then pinpointed and aligned to the nearest paved road crossing that area.

This method revealed key areas for tourist activity, including accommodation hubs, renowned attractions, transport hubs, and both dense and unplanned parking lots. Areas with a single planned parking lot or residual attractions were not considered in this phase.

3.3.2 | Spatial Network Creation and Design Process

This methodology included proposed and existing bus stops in the road network and calculating segments between nearest stops across paved roads suitable for bus access. This facilitated identifying various potential routes and their segments, laying the foundation for extracting useful metrics for transportation planning. These metrics include factors such as route length, estimated travel times, and connectivity between key tourist attractions and accommodation hubs.

When designing new routes, multiple roads were suitable in some cases. This involved manual assessment to include segments based on a set of predefined criteria, such as the identified scenic routes.

4 | Results

In this section, we present the findings after applying our method, all organised into three subsections. First, we detail the database compilation, emphasising its role in creating detailed maps of current resources and transport infrastructure, which is vital for identifying improvement areas. Second, we define clusters, exploring how attractions, accommodation hubs, and parking areas are grouped by proximity and relevance, forming the basis for our proposed public transport enhancements. Finally, we unveil the calculated routes using the proposed system, providing insights into how these new paths could potentially transform mobility within the Delta.

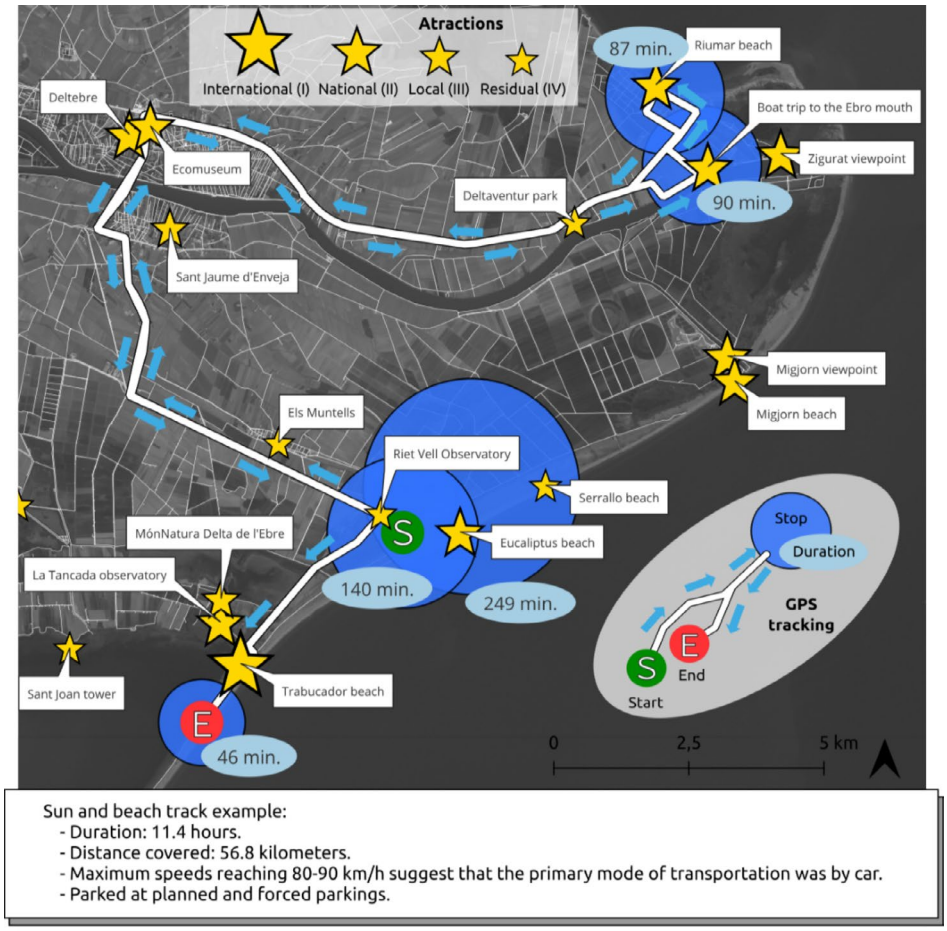

FIGURE 5 | Example of the collected tracks spatial behaviour (corresponding to "GRATET-GPS02-2022-07-25_01_16" track). *Source:* Authors.

4.1 | A Comprehensive Mobility Database for the Ebro Delta

Data encompassing infrastructures, parking lots, current transportation links, and tourist travel patterns have been mapped to comprehensively analyse their effect on the current tourist mobilities at the destination, together with the requirements to avoid trips by car (Figure 5).

The area features a primary train station in *l'Aldea*, servicing both long-distance and short-distance trains. This connectivity facilitates tourists traveling to the destination via public transport and supporting the promotion of public transport usage within the destination. This train station is well connected by bus or short-distance trains to several towns (herein accommodation hubs) at the entrance to the delta or in its surroundings. However, accommodation hubs within the deltaic platform have limited connectivity to the *l'Aldea* main station. Tourists arriving by train to reach their accommodation place in the Delta need to add an extra bus transfer. Moreover, the infrequent bus service to these accommodation hubs results in extended waiting time for transfers or, in some cases, a complete lack of service during certain hours or days. This means that the main public transportation services predominantly cover the area surrounding the Ebro Delta, whereas only three low-frequency bus lines penetrate the Delta itself (Figure 6).

Having reached their chosen accommodation hub, whether around, at the entrance, or within the Delta, tourists have limited public transport options for visiting attractions in the Ebro Delta. The current bus lines only link two major towns at the Delta's entrance with the six inhabited villages in the Delta. Consequently, there is no cross-delta connection between these towns or to attractions outside the urban areas.

Analysing the current public transport options, with the location of accommodation hubs and attractions, reveals why tourists need to rely on their own cars to visit the destination. This is evidenced by the numerous large parking lots around the main attractions in the Ebro Delta, many of which lack formal planning. In fact, after examining the tourist travel patterns with GPS tracking devices, the speed data confirm that the majority travel by car, highlighting the Ebro Delta's status as a car-dependent destination.

4.2 | Clustering of Tourist Hotspots

We effectively identified key tourist areas based on the infrastructure and behaviour patterns depicted in Figure 6. Resulting from the clustering process, Figure 7 illustrates the outcome of triangulating nearby attractions, parking lots, accommodations, and stops frequented by tourists, along with the prioritised hotspots. This selective approach led to the proposal of seven

TABLE 5 | Public transport frequency within the Ebro Delta and its influence area.

Stops	Weekly frequency	Type
Amposta-la Ràpita	428	Bus
La Ràpita-Alcanar Platja	252	Bus
La Ràpita-Les Cases d'Alcanar	176	Bus
Alcanar Platja-Les Cases D'alcanar	252	Bus
Amposta-L'aldea	222	Bus
L'aldea-Camarles	78	Bus
L'aldea-Camarles	58	Train
Amposta-Tortosa	392	Bus
L'aldea-Tortosa	244	Bus
L'aldea-Tortosa	140	Train
Amposta-Masdenverge	60	Bus
Masdenverge-Santa Bàrbara	40	Bus
Tortosa-Santa Bàrbara	46	Bus
Santa Bàrbara-La galera	60	Bus
La Galera-Godall	60	Bus
Camarles-L'ampolla	58	Train
L'ampolla-L'ametlla de Mar	133	Train
Amposta-Deltebre	44	Bus
Deltebre-Riumar	8	Bus
Riumar-Càming L'aube	8	Bus
Amposta-Sant Jaume D'enveja	20	Bus
Deltebre-Sant Jaume D'enveja	76	Bus
La Ràpita-Poble Nou del Delta	20	Bus
Els Muntells-Eucaliptus	20	Bus
Sant Jaume D'enveja-Els Muntells	40	Bus

Source: Authors.

new bus stop locations, aimed at mitigating car dependency in the Ebro Delta by enhancing the accessibility and coverage of the public transport network.

4.3 | Strategic Route Planning: Two Proposals

Having identified the existing bus stops and strategically proposing new ones for the 17 prioritised hotspots, we calculated the feasible routes between these stops. All the stops are accessible through paved roads suitable for bus access. However, one hotspot necessitates preliminary work due to insufficient space for a bus to turn around.

After calculating the routes, we formulated two key strategies: (1) establishing a new hop-on hop-off circular bus line serving the detected hotspots (Figure 7), and (2) enhancing the frequencies and reconnection of existing public transport services and introducing new lines to facilitate connections between most hotspots, albeit with transfers (Figure 8). These strategies align with our initial objectives to improve accessibility and reduce car dependency in the area.

The hop-on hop-off proposal outlines a network of 37 km, with an estimated journey time of 1 h and 32 min (Figure 8). This estimation assumes an average travel speed of 50 km/h and a 3-min stop duration at each location. The route is designed to connect 17 identified hotspots. This includes the main accommodation hubs at the entrance and inside the delta, the most frequented sites, all relevant attractions and key transport hubs, all linked by this single bus route. This proposal makes it easier for tourists to reach their destination via public transport. It also streamlines connections between accommodation hubs and areas of interest and makes visiting multiple attractions in one day feasible. The strategy provides an efficient and convenient public transport option, which is more attractive than using private vehicles.

The second proposal takes advantage of the regular bus lines and introduces some tourist mobility needs, while still providing an attractive service for residents (Figure 9). First, deficient lines need to be reinforced. To ensure that tourists can travel conveniently from home to their accommodation using public transport, the bus connections from the main train station to the municipalities considered accommodation hubs need to be improved by adding frequencies during the tourist seasons. This strategy should be extended to all lines entering the delta platform, since they are currently the most deficient. Second, some existing lines should be modified. In the case of the Ebro delta, two bus lines on the right margin should be connected by adding two extra stops. Thus, the *Amposta-La Ràpita-Poble Nou del Delta* line and the *Amposta-Sant Jaume d'Enveja-els Muntells-L'Eucaliptus* line should become one circular line adding two additional stops at Casa de Fusta and Trabucador beach. Finally, a new bus line should be created to connect the towns of L'Ampolla and Deltebre, stopping at several hotspots. Like in the first option, this proposal connects the main hotspots except for the right side of the Ebro mouth. However, with this option, tourists must transfer between the different line services.

5 | Discussion and Conclusions

The debate around car-based mobility within destinations is intensifying, especially in rural and nature-based areas, where the negative externalities are becoming increasingly apparent (Leung et al. 2018; Monz et al. 2021). In environmentally sensitive regions, destination managers are beginning to implement vehicle access restrictions (Medina-chavarria et al. 2023). However, these measures alone are insufficient to address the broader issues associated with high car usage in such destinations. While vehicle regulations pose their own

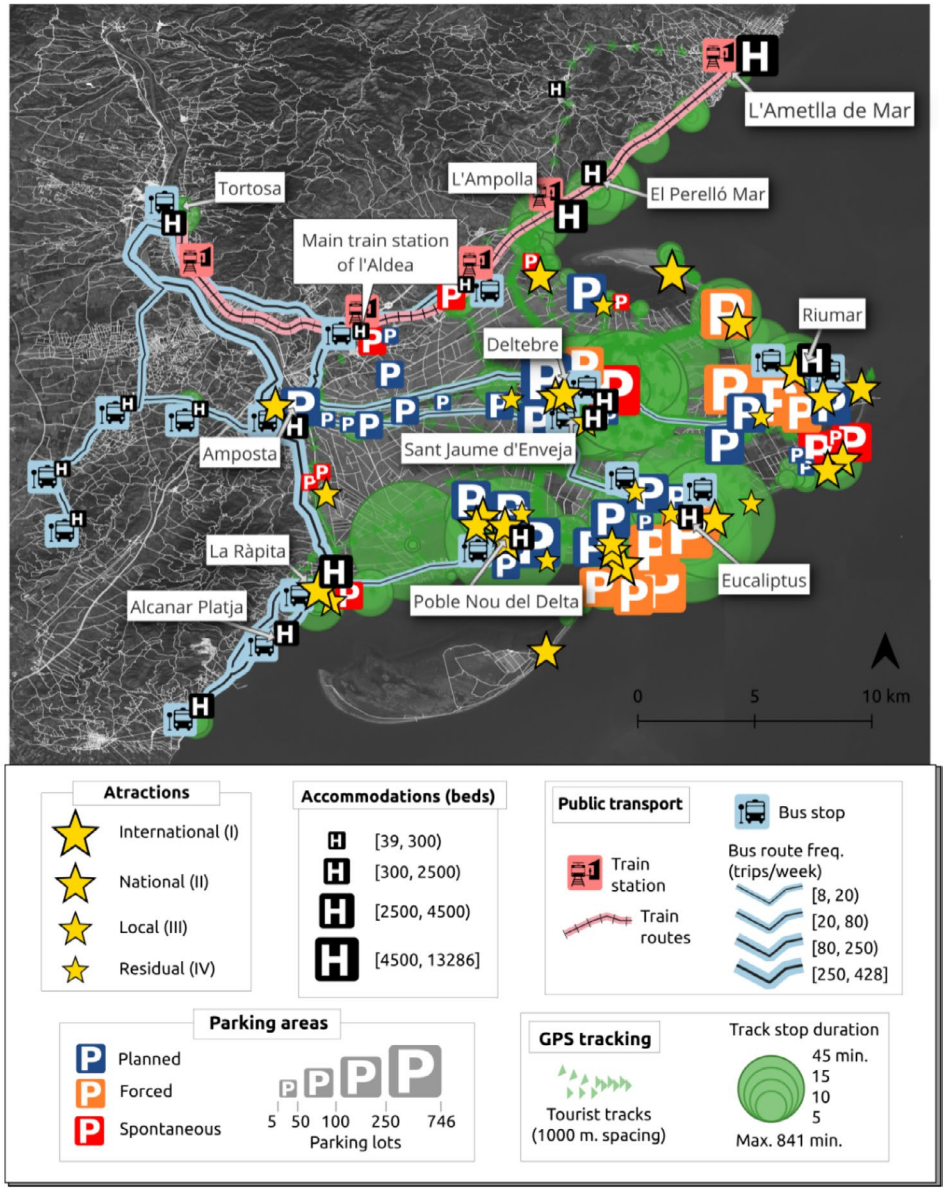

FIGURE 6 | Public transport infrastructure, parking lots, tourist attractions, accommodation hubs, and areas where tourists ($n = 101$) spend more time in the Ebro delta. *Source:* Authors.

set of challenges, they do not substantially reduce car dependency in rural areas unless they are part of a broader range of alternative policies. To move towards more sustainable strategies, it is essential to address the car dependency issue head-on. This can be achieved by promoting environmentally-friendly transport within these destinations, thereby reducing both the carbon footprint and tourism's impact on the landscape (Böhler et al. 2006; Bursa et al. 2022; Peeters and Schouten 2006; Verbeek and Mommaas 2008).

Rural destinations are often heavily reliant on cars, primarily due to a lack of comprehensive public transportation networks for both accessing and exploring these areas (Bursa et al. 2022; Connell and Page 2008; Dickinson and Robbins 2007; Dickinson et al. 2009; Zhao and Yu 2020). Research suggests that to appeal to the 80% of short-haul travellers who are positively inclined towards public transport (Böhler et al. 2006), it is essential to provide connectivity that encompasses travel from their homes to the destination, convenient arrival at their chosen accommodation, and the ability to visit desired attractions with both flexibility and time efficiency (Böhler et al. 2006; Bursa et al. 2022; Carson and Waldhoer 2011; Hardy 2003).

This research has developed and applied a methodology for designing new tourist bus services in sprawled and car-dependent rural destinations. A GIS-based approach has been validated in the case of Ebro Delta, and it could be adaptable and replicated in other rural destinations to help identify public transport needs according to diverse tourist mobility patterns, tourist hotspots, and transport facilities.

In this study, we have highlighted the significant role of strategic planning in maintaining a focus on sustainability, particularly

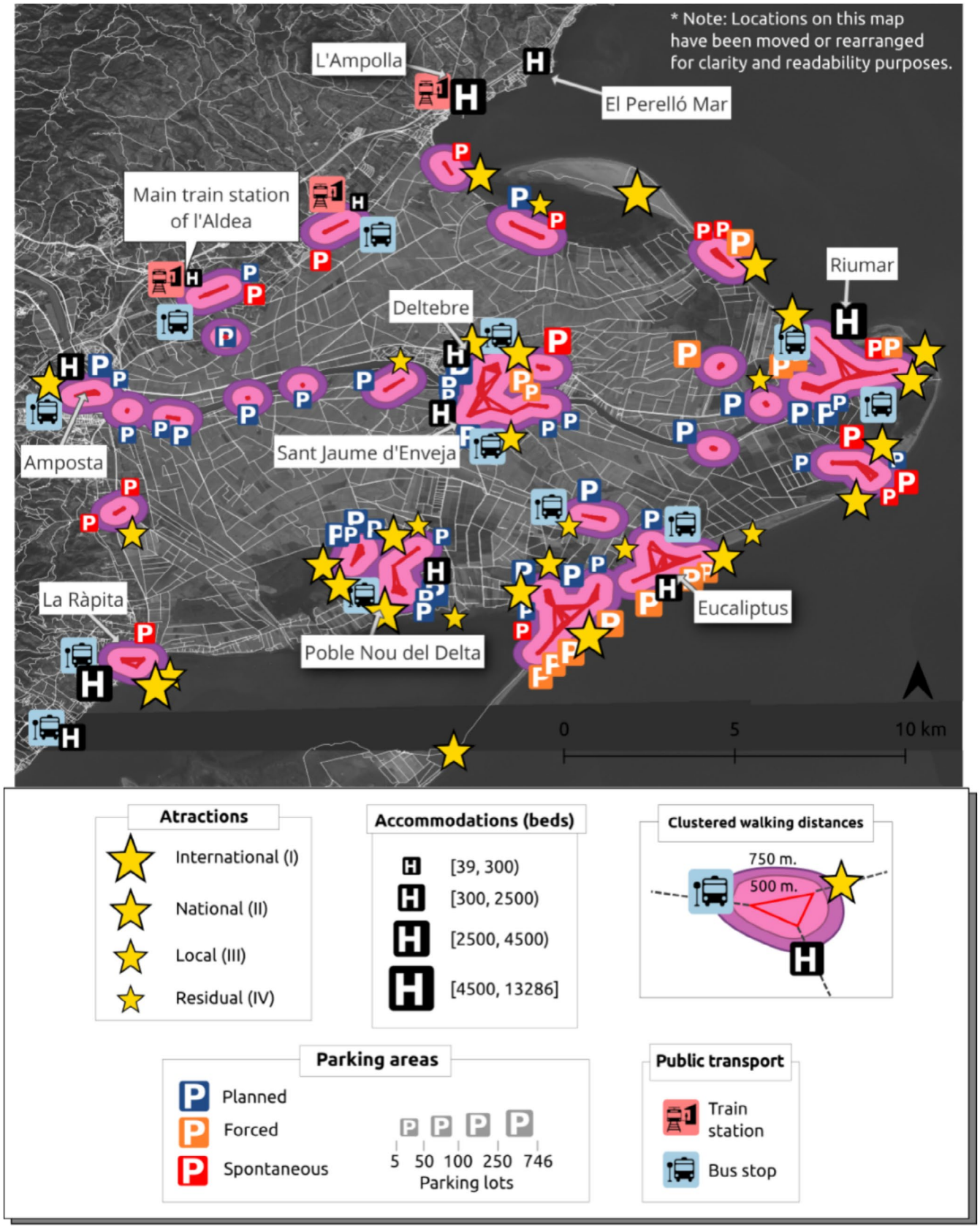

FIGURE 7 | Identification of the tourist hotspots. *Source:* Authors.

in sensitive environments like the Ebro Delta. Our research underscores the importance of incorporating sustainability into every aspect of tourism and transportation planning. In such delicate ecosystems, well-thought-out strategies cannot only mitigate existing challenges but also contribute to developing innovative and attractive tourism resources.

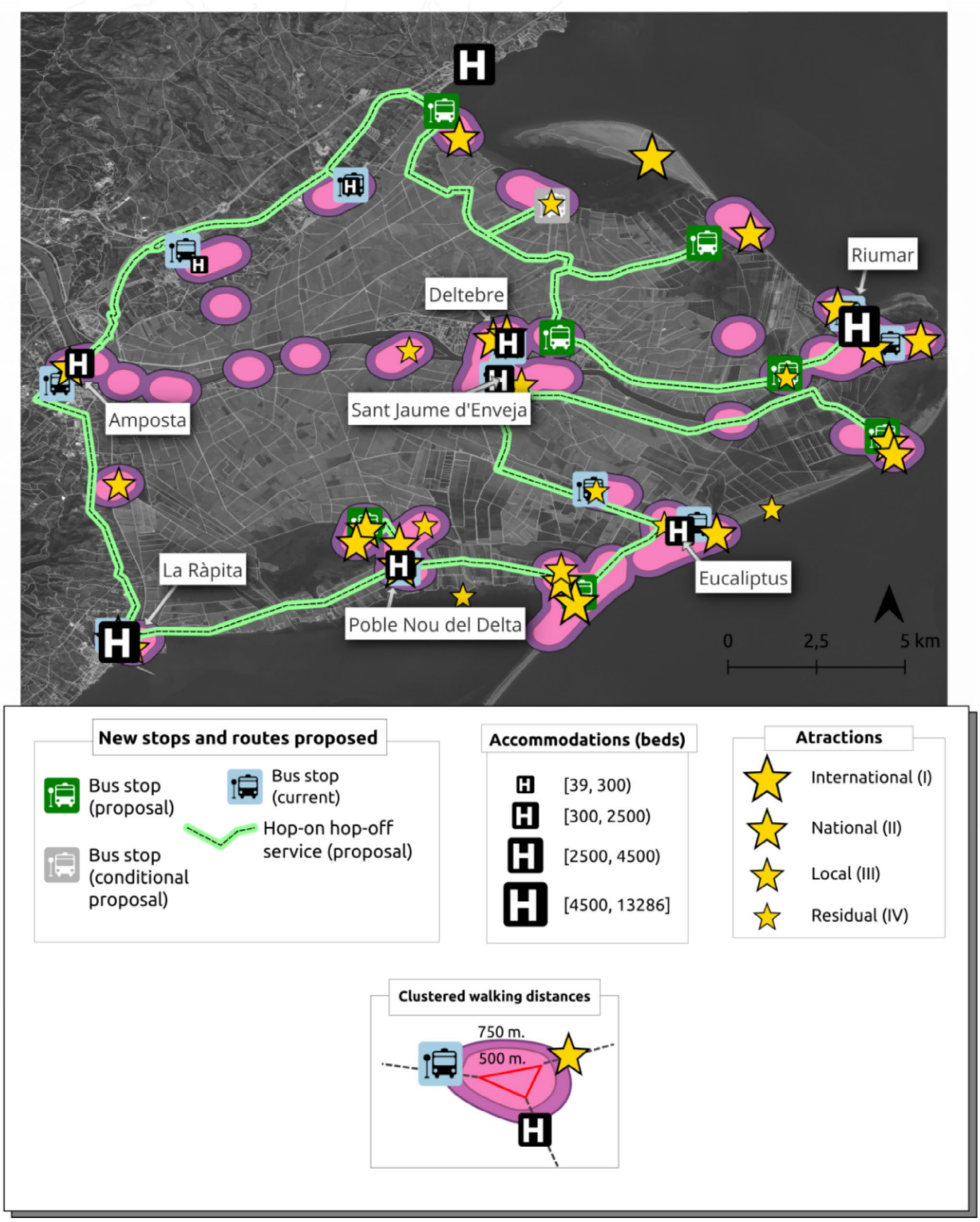

FIGURE 8 | Proposal 1 consisting of an optimal hop-on hop-off bus line connecting all the prioritised hotspots and the main bus and train station. *Source:* Authors.

5.1 | Methodological Insights

This research delves into the complexities of compiling and utilising spatial GIS data and methods to address car-dependency in rural destinations. The methods used versatile and powerful GIS techniques for collating, analysing, and visually representing complex spatial data. This is crucial for synthesising diverse data sets into coherent, actionable insights, particularly in the context

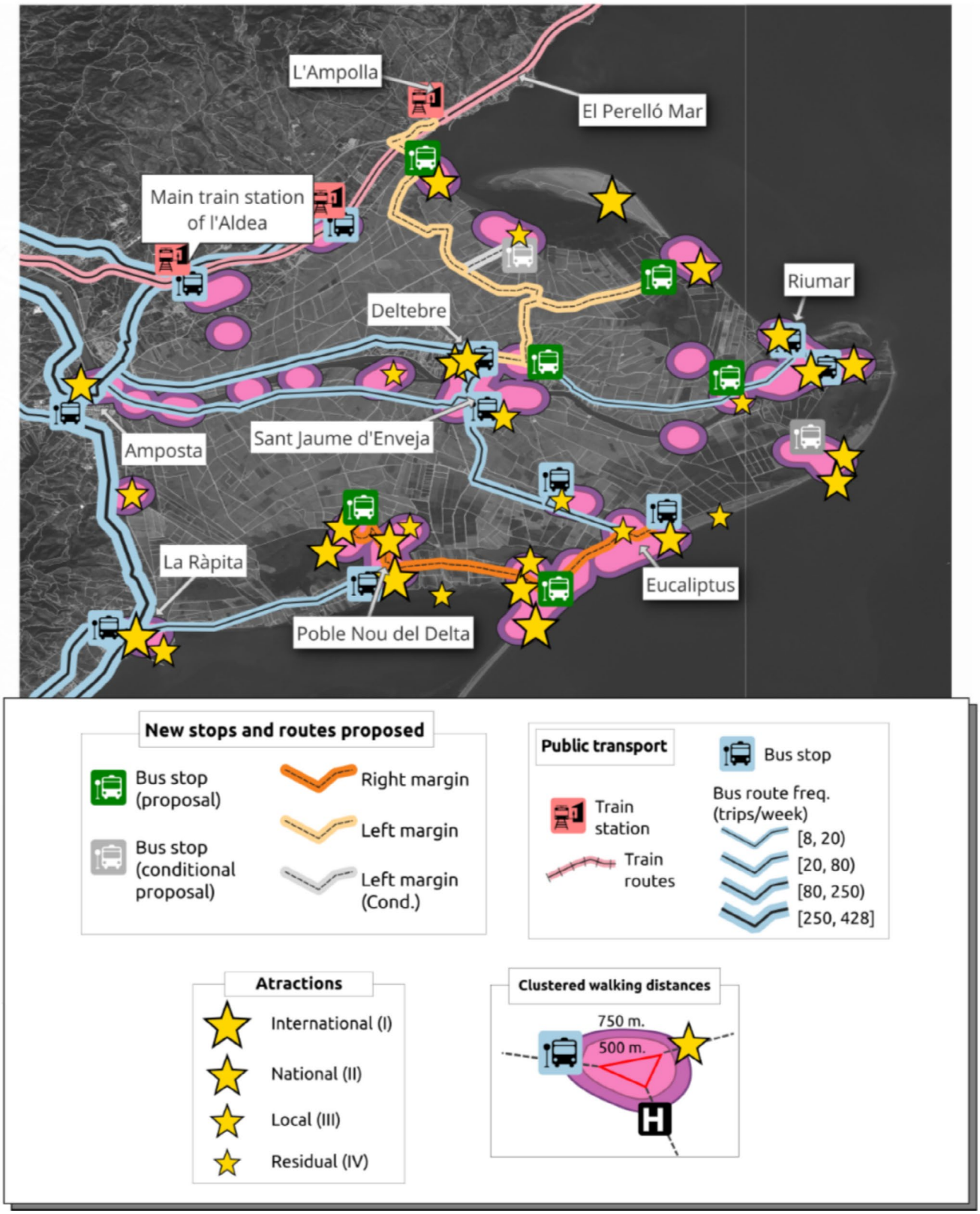

FIGURE 9 | Proposal 2, consisting of the improvement of regular bus lines including stops to most prioritised hotspots. *Source:* Authors.

of understanding and addressing the intricate mobility patterns in rural and sprawled tourist destinations, like the Ebro Delta. The spatial clustering of tourist and transportation amenities using Delaunay triangulation proved to be a simple and practical approach.

Despite Spain's abundance of spatial transport and mobility data, the study acknowledges a gap in specific datasets needed for extensive fieldwork and the integration of various data sources for comprehensive analysis. This data compilation is not only a valuable tool for planners, but also for understanding

underlying mobility issues that allow resolving transportation challenges. The methods proposed here, or others that may emerge, are not merely technical exercises, but rather essential steps in developing effective and sustainable mobility strategies. This research thus contributes not only to the specific context of the Ebro Delta, but also to the broader fields of transportation and tourism planning, where accurate and comprehensive data is fundamental to informed decision-making.

The methodology emphasizes understanding tourist mobility patterns through approaches like GPS tracking, analysis of parking lots, public transport networks, and spatial distribution of tourist attractions.

5.2 | Resulting Proposals and Implications

This methodology has been applied to the Ebro Delta, a rural destination identified as car-dependent owing to its inadequate public transportation, the prevalence of parking lots, and observed travel patterns. Furthermore, given the rural and natural characteristics of the destination, its most popular and well-known attractions are outside urban areas, further complicating the development of alternative mobility options (Juschten and Hössinger 2020). Applying our method supported the design of two potentially viable proposals for addressing the mobility and ecological challenges facing this destination, exacerbated by climate change: (1) A Hop-on Hop-off service and (2) enhancing the current public bus system.

The first proposal considers that a Hop-on Hop-off service could alleviate visitor concerns about the reliability, accessibility, and frequency of public transportation. It effectively responds to the dispersion of attractions, as highlighted by Paulino et al. (2020), by enhancing connectivity between these sites and accommodation hubs and incorporating scenic routes (Hardy 2003). Additionally, integrating it with existing bus and train services facilitates access to the destination via public transport (Lane et al. 2022). This tourist-centric service offers the unique advantage of allowing passengers to board and disembark at various stops, with the added appeal of views from double-decker or open-top buses, thus increasing its attractiveness to tourists (Guiver et al. 2007). Designing hop-on hop-off bus services requires a comprehensive approach that encompasses technological integration, user experience, and continuous route optimisation (Ismail et al. 2017). In the context of the Ebro Delta, it is essential to consider the area's unique geographical and cultural characteristics. The design should be user-centred, adaptable, and responsive to the tourists' diverse needs.

The second proposal enhances existing transportation lines by increasing their frequency and incorporating specific measures tailored to tourists' needs. This approach would enable visitors to maintain their freedom of movement while expanding their mobility options. Additionally, it would introduce new connections and increase service frequencies, benefiting both tourists and residents (Poltimäe et al. 2022).

Both proposals offer increased convenience for a segment of visitors who would prefer not to drive in an unfamiliar area if viable alternatives were available (Böhler et al. 2006; Guiver et al. 2007). They are also appealing to potential visitors who lack access to private transportation. However, the second proposal might encounter challenges due to the complexity of managing multiple transport lines, which may mean tourists have to make transfers and seek additional information about transportation links and schedules (Lew and McKercher 2006). Selecting the most appropriate proposal requires the expertise of transportation planners and analysts who must consider the various factors affecting the two potential solutions. Applying a decision support system here is particularly apt, as it merges quantitative data from comprehensive network analysis with qualitative assessments from transportation experts. The significance of designing these new routes extends beyond mere route creation; it initiates a crucial dialogue on their necessity, benefits, and potential drawbacks. Consequently, the proposed routes could act as a catalyst for discussions among various stakeholders, including local authorities, tourism operators, environmental groups, and the local community. These processes should be necessary to evaluate route feasibility and make amendments that balance tourist convenience, environmental sustainability, and community well-being.

5.3 | Limitations and Future Work

This study has certain limitations that warrant consideration in future research. Firstly, there is room for refining certain methodologies, such as in estimating parking lot capacity, especially in unplanned areas. This can be achieved by incorporating additional empirical data, leading to more accurate capacity predictions. The spatial clustering of tourist and transportation amenities using Delaunay triangulation could also be compared with other methods to determine their efficacy in different scenarios. Future studies might explore more sophisticated spatial analysis techniques, like kernel density estimation or network analysis (network instead of straight-line distances), to further refine our understanding of tourist flows and transportation needs. Such comparative analysis would not only validate the current approach but also potentially reveal new insights, contributing to a more nuanced and comprehensive understanding of spatial dynamics in rural destinations.

Secondly, the data on travel patterns used herein reflects tourist mobility exclusively during the high season, implying that the proposed bus line is primarily applicable to the summer. As suggested by Poltimäe et al. (2022), future research should investigate whether tourist visitation behaviour varies during other times of the year. Such insights would be crucial for adapting the proposals and determining the appropriate variations among seasons.

Thirdly, the absence of certain amenities in rural destinations often requires that tourists bring varied equipment and essentials for their day trips, such as luggage, sports equipment, or bikes. This makes private car usage highly convenient, especially for families with children (Böhler et al. 2006; Poltimäe et al. 2022). Moreover, providing reliable, accessible, and frequent public transport should be complemented by efforts to promote healthier mobility habits, such as cycling (Tsavachidis and Le Petit 2022). Future research should address the travellers

need for additional services by identifying key locations for essential services and including designated spaces in public transportation specifically for this purpose.

Finally, to progress, it is vital to build on this research through ongoing exploration and collaboration (Poltimäe et al. 2022). Subsequent studies could organise focus groups connecting various local stakeholders, including experts, business owners, and community representatives, enabling a dialogue to assess proposed strategies. Expert involvement in the planning process aligns with transportation research findings, leading to more tailored and effective solutions, particularly in complex environments like the rural area of the Ebro Delta. Such collaborative approaches deepen understanding of the local context, facilitating the development of practical solutions aligned with the unique destination needs. By engaging in these dialogues and incorporating a wide range of perspectives, future research can pave the way for more nuanced and effective strategies in sustainable tourism and transportation planning. This will benefit the Ebro Delta and also serve as a model for similar car-dependent rural destinations trying to balance tourism growth and environmental conservation.

Acknowledgments

Research funded by the Provincial Council of Tarragona and Department of Research and Universities of the Catalan Government, Generalitat de Catalunya (grant number 2021-SGR00657). Isabel Paulino has been funded by the postdoctoral Margarita Salas fellowship program of the Spanish Ministry for Universities, through the European Union NextGenerationEU Funds (C21.I4.P1/AEI/10.13039/501100011033). Maria E. Medina-Chavarria received funding from the Martí i Franquès Doctoral Programme at Rovira i Virgili University (2019PMF-PIPF-29).

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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