Aggregating Mobility Surveys to Understand Intermodality: Evidence from 68 French Surveys

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Abstract

Intermodality refers to the combination of multiple transportation modes during a single trip. It can help reduce carbon emissions, especially in rural and peri-urban areas where public transit can be hard to reach by walking. Yet, since only about 1 % of trips in France are intermodal, studying this behavior is difficult. This study introduces MobiSurvStd, an open-source tool that standardizes French mobility survey data. With this tool, I combine data from 68 surveys conducted between 2008 and 2022 to build a detailed dataset representing travel patterns across France. The analysis shows that most intermodal trips combine car use with public transit. In these trips, the public-transit segment is more than 3 times longer than the car segment. Trips that start by car and continue with public transit often link outer areas to city centers, with trains and coaches being the most common transit mode used to access the network. The final part of this study links survey data with the actual locations of public-transit stops to test whether travelers choose the closest train station to their departure point. The results offer insights for transportation planners aiming to design multimodal hubs that make sustainable intermodal travel more convenient.

Keywords: intermodality; mobility surveys; survey standardization; park-and-ride.

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Highlights

- An open-source tool, MobiSurvStd, is introduced to standardize and aggregate 68 French mobility surveys (2008–2022). This harmonized dataset, representing over two million trips, enables national-scale analysis of intermodality and other rare travel behaviors previously difficult to study due to fragmented survey formats.
- Results reveal that 85 % of intermodal trips combine car and public transit, with cars mainly serving as access modes to the network. On average, the public-transit segment covers more than three times the distance of the car segment, and these trips typically connect rural or suburban origins to city centers.
- A spatial analysis that links survey data with transit-stop locations examines whether travelers use their nearest stop. Findings show proximity strongly drives train access choices, while tram and metro users often prioritize other factors, such as service quality and connectivity, over distance.

1 Introduction

Intermodality designates a transportation strategy where travelers combine multiple modes within a single journey. This approach offers efficiency advantages by allowing travelers to select the most appropriate mode for each sgement of their trip. For example, travelers might use private vehicles in low-density areas where roads are uncongested, switch to public transit in dense urban centers with frequent service, and opt for bicycles in congested urban areas.

Beyond improving travel efficiency, intermodality presents environmental benefits, particularly in low-density areas with poor public-transit coverage. Rather than completing entire journeys by car, travelers can use their car only as access mode to nearby public-transit stops, then continue the majority of their trip using more sustainable public-transit options. This modal combination can reduce considerably the overall carbon footprint of the journey, without increasing significantly travel time.

The potential of intermodality is particularly relevant in France, where the Service Express Régional Métropolitain (SERM) initiative aims to develop multimodal transportation hubs in peripheral and low-density areas. Well-served transit hubs would be created in rural and suburban locations, where private vehicles could efficiently connect travelers to these hubs.

Mobility surveys, commonly referred to as household travel surveys, serve as essential data sources for examining individual and household travel behaviors, including intermodal transportation patterns. These surveys support diverse research applications across the transportation field. For example, Ghimire and Bardaka (2024) use the U.S. National Household Travel Survey to investigate the use of walking and cycling among low-income households. Durand et al. (2016) analyze data from the California Household Travel Survey to explore the relationship between trip distance and walking access to public transit. Poulhès and Proulhac (2021) employ the Paris regional survey to quantify health benefits associated with the city's Low Emission Zone.

Comprehensive analyses of intermodality behavior remain limited in the existing literature. Previous research has typically focused on specific aspects of intermodal travel: the combination of public transit with bicycle (Kapuku et al., 2024; Moinse and L'Hostis, 2024), the propensity to travel by park-and-ride (Huang et al., 2022), or the choice of park-and-ride facilities (Webb and Khani, 2020; Irawati et al., 2022).

Given the relative rarity of intermodal trips, which account for about 1 % of all trips in France, aggregating data from multiple mobility surveys becomes essential to obtain sufficient observations for statistically robust analysis. To address the challenges posed by fragmented mobility survey data in France, this study introduces MobiSurvStd, an open-source library specifically designed to standardize French mobility survey data.

While Wittwer et al. (2018) developed a methodology for harmonizing mobility surveys across five European cities, this study represents, to the best of our knowledge, the first comprehensive attempt to systematically harmonize and aggregate regional mobility surveys at a national scale. This research thus fills a gap in the literature by providing a tool that enables two types of analysis. First, it facilitates the study of less prevalent travel behaviors, such as intermodality, that require large, aggregated datasets from multiple surveys to achieve statistical significance. Second, it provides the capacity to examine variations in travel behavior across regions and time periods.

Using the MobiSurvStd library, we construct a comprehensive dataset comprising 68 mobility surveys conducted between 2008 and 2022 in France, covering approximately 701 000 individuals and 1.84 million trips. Leveraging this extensive dataset, our research aims to examine the characteristics, patterns, and determinants of intermodal trips in France. We place particular emphasis on the spatial dimensions of intermodality, investigating the influence of urban density and access to transit infrastructure. The main part of our analysis focuses on trips combining public transit and car, which constitutes about 85 % of all intermodal trips.

2 Standardization of Mobility Surveys

In France, mobility surveys are conducted by multiple institutions, each using distinct formats and methodologies. Most surveys are administered by the CEREMA organization, for both urban and rural territories. In the Paris region, however, surveys are managed by *Île-de-France Mobilités*, the local transport authority, through the Enquête Globale Transport (EGT) (2010), which is conducted approximately once per decade. The Ministry of Ecology also carries out surveys at the national level, with the most recent one, the *Enquête Mobilité des Personnes*, which was conducted in 2019.

Efforts to standardize these surveys have been made, including CEREMA's introduction of the EMC^2 format in 2018 (e.g., Enquête Ménages Déplacements (EMC2), Marseille / Métropole Aix-Marseille-Provence, 2020). Before this standardization, however, CEREMA surveys used a variety of formats: EMD (e.g., Enquête Ménages Déplacements, Nice / Alpes-Maritimes, 2009), EDGT (e.g., Enquête Ménages Déplacements, Lyon / Aire métropolitaine lyonnaise, 2015), and EDVM (e.g., Enquête Ménages Déplacements, Creil / Sud de l'Oise, 2017). The absence of a unified framework complicates efforts to compare surveys across different regions or time periods. Figure 1 presents a geographical overview of 68 local mobility surveys conducted in France between 2008 and 2022.

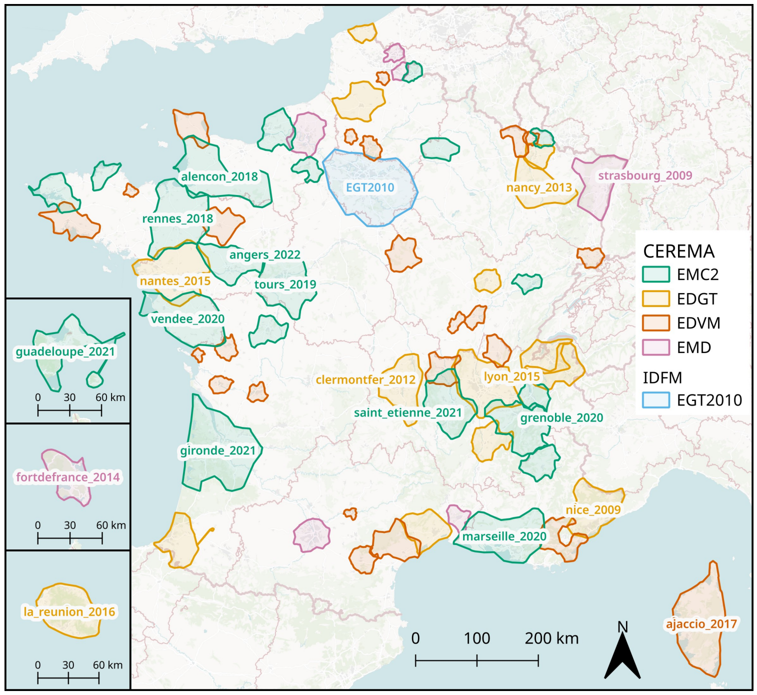

Figure 1: Mobility surveys in France

Note. This map shows the survey area for 68 surveys conducted between 2008 and 2022. Each color represents one of the 5 co-existing local survey formats, from CEREMA or Île-de-France Mobilités (IDFM).

To address the challenges posed by fragmented mobility survey data in France, this study introduces MobiSurvStd, an open-source Python library designed to standardize diverse survey formats into a unified structure (Javaudin, 2025). Although this study focuses on intermodality, MobiSurvStd offers broader applications, enabling researchers and practitioners to analyze mobility behaviors across individual surveys or aggregated datasets.

The standardized format integrates 286 variables, organized across six key categories: households, persons, trips, legs, cars, and motorcycles. Each variable is assigned a clearly defined data type and categorical variables include well-specified modalities to ensure consistency. However, due to inherent differences in the original survey designs, not all variables or modalities are universally available across the entire dataset.

Overall, this comprehensive dataset of 68 surveys encompasses approximately 701 000 surveyed individuals and includes information on roughly 1 841 000 trips. For the analyses presented in this study, we focus exclusively on the subset of variables that are consistently available across all surveys. These variables include individuals' age, gender, or professional occupation and trips' origin, destination, mode, purpose, distance.[1]

The combined 68 surveys cover approximately 62 % of the French population, with

[1]The code used in this study is publicly available in an open-access repository at `https://github.com/LucasJavaudin/intermodality-analysis`.

stronger representation of urban residents. To ensure the dataset accurately reflects the entire French population, sample weights are adjusted using key demographic and geographic variables. However, due to insufficient survey coverage, the most rural areas, which comprise about 2.5 % of the population, are excluded from the analysis.

The weighting process incorporates four variables: gender, age (divided into eight classes), professional occupation (divided into nine classes), and population density of respondents' home municipality (divided into six classes). This recalibration is implemented using margin calibration techniques (Deville and Särndal, 1992; Rebecq, 2016). All subsequent analysis and reported values in this study are based on these adjusted sample weights.

3 Characterization of Intermodality

3.1 General Characteristics

A trip represents a movement from an origin to a destination undertaken for a specific purpose, including work, school, shopping, or leisure activities. Each trip may be composed of one or more legs, where a leg constitutes a continuous segment using a single mode of transportation. For example, a home-to-work trip might consist of four sequential legs: driving to a parking facility, walking from the parking area to a nearby train station, traveling by train to a station near the workplace, and finally walking from that station to the final work destination.

This study defines *intermodal trips* as those containing at least two legs using different transportation modes, excluding walking legs. While many trips include short walking segments, these are not considered in the intermodal classification.

All public-transit modes, including buses, metros, and trains, are consolidated into a single "public-transit" category. Consequently, trips combining different public transit modes, such as bus and train, are not classified as intermodal. The mode categories considered in this analysis are car driver, car passenger, public transit, bicycle, and motorcycle.

This study focuses exclusively on "local trips", defined as trips with a Euclidean distance between origin and destination of less than 80 km. Longer trips, which typically involve different travel behaviors and modes such as high-speed trains or airplanes (Tan et al., 2022), are excluded from this analysis. Additionally, when comparing intermodal and unimodal trips, walk-only trips are excluded, as these typically cover short distances where intermodality is not a practical alternative.

Within the dataset comprising 68 mobility surveys, there are 17 298 intermodal trips, accounting for 1.2 % of all local trips. However, these trips represent a disproportionately larger share of total travel distance, constituting 4.6 % of the total Euclidean distance traveled. Intermodal trips exhibit significantly longer average distances (20.7 km) compared to unimodal trips (7.0 km, excluding walk-only trips).

Figure 2 illustrates the distribution of trip distances for both intermodal and unimodal trips. The density plot reveals that intermodality is primarily used for trips exceeding 5 km in length. When focusing exclusively on trips longer than 20 km, the share of intermodal trips increases substantially to 7.9 %.

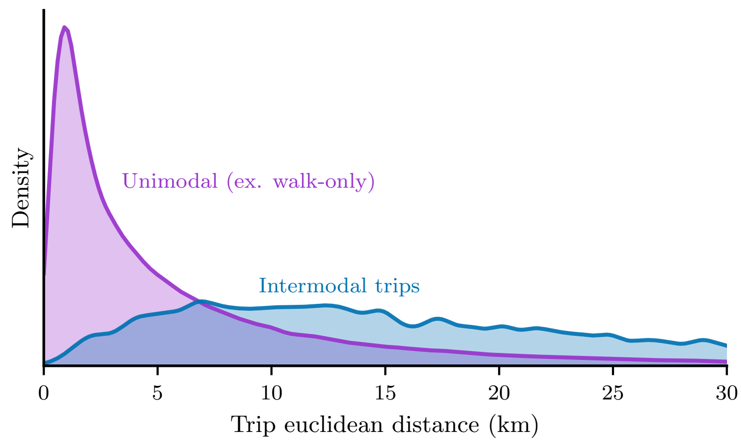

Figure 2: Density distribution of trip distances by trip type
Note. The density is estimated using kernel density estimation with a bandwidth factor of 0.03.

Each trip recorded in the surveys includes information about the purpose at both the origin and destination. We assign a single primary purpose to each trip by selecting the higher-ranked purpose based on the hierarchy established by Raux et al. (2018): Work, Education, Escorting, Service, Shopping, and Leisure. Figure 3 presents the distribution of trip purposes for both intermodal and unimodal trips.

The analysis reveals that work and education represent the dominant purposes for intermodal trips, accounting for 79 % of such trips. In contrast, these purposes constitute only 43 % of unimodal trips. While the cross-sectional nature of mobility surveys prevents direct observation of trip repetition, the predominance of work and education trips among intermodal journeys suggests that intermodality is primarily associated with regular, recurrent travel patterns. This finding may also reflect the fact that work and education trips typically involve longer distances, which could make intermodal solutions more attractive or necessary.

Intermodal trips can involve different combinations of modes. Figure 4 illustrates the prevalence of different mode combinations among intermodal trips. The data show a clear dominance of combinations involving public transit and cars. Specifically, 44.4 % of intermodal trips combine public transit with traveling as a car passenger, while 40.7 % involve

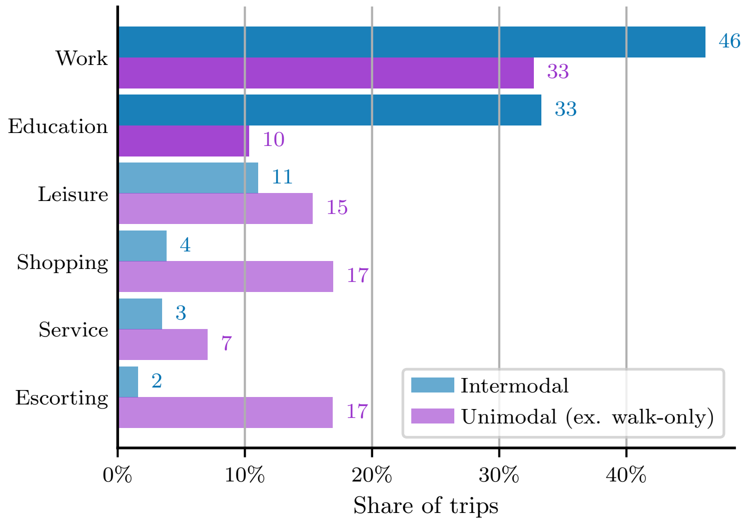

Figure 3: Distribution of trip purposes by trip type

using public transit and driving a car. These two categories together account for about 85 % of all intermodal trips. Public transit also appears in the third most frequent combination, where it is used in conjunction with bicycle, representing 6.3 % of all intermodal trips.

Another notable combination involves using a car both as a driver and as a passenger during different segments of the same trip, accounting for 4.9 % of intermodal trips. This pattern typically occurs in scenarios such as driving one's own vehicle to a ride-sharing meeting point and then continuing the journey as a passenger in another vehicle. The remaining intermodal trips involve other combinations, including the use of motorcycles or the integration of more than two different modes.

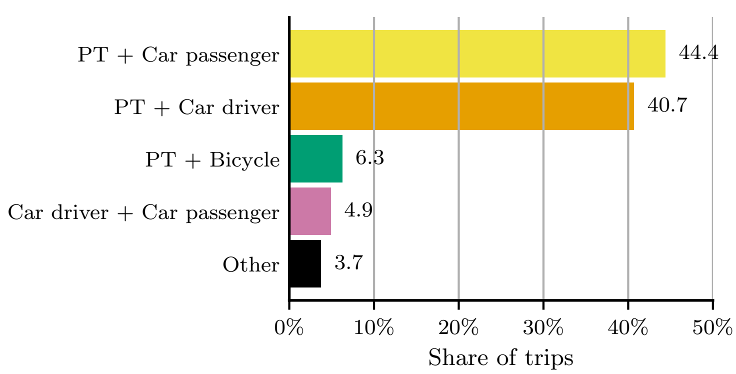

Figure 4: Distribution of mode combinations in intermodal trips

3.2 Public transit and car combinations

This subsection examines intermodal trips that integrate both public transit and car use, whether as a driver or passenger. For short, in the remaining, we call these trips *PT+Car*.

Figure 5 presents the distribution of the share of Euclidean distance by public transit for *PT+Car* trips. The data reveal that public transit accounts for the majority of distance traveled in most cases.

On average, these intermodal trips involve 18.6 km traveled by public transit compared to 5.2 km by car. This substantial difference indicates that cars primarily serve as an access mode to the public-transit network, particularly for individuals living beyond walking distance from transit stops. The car segment effectively functions as a "first-mile" or "last-mile" solution, bridging the gap between origin or destination locations and the public transit system.

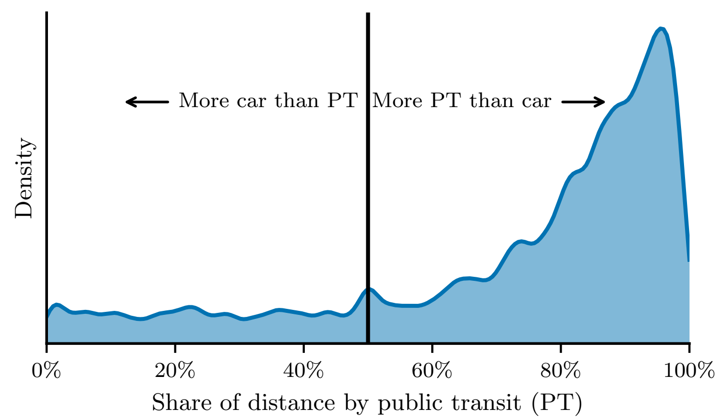

Figure 5: Distribution of public-transit distance share in *PT+Car* trips
Note. Walking distances are excluded from calculations. A 50 % share indicates equal distance traveled by public transit and by car.

Demographic analysis reveals that individuals making trips combining public transit with car passenger status exhibit distinct characteristics. A substantial 77 % of these travelers are either students or individuals without driving licenses, a proportion nearly four times higher than their 22 % representation among unimodal trip makers. This significant overrepresentation can be attributed to the transportation constraints faced by these groups. Students often lack access to personal vehicles, while individuals without driving licenses are legally prohibited from operating cars. As a result, both demographic groups must depend on others to transport them to public-transit access points, particularly when these points are located at considerable distances from their origins.

The analysis of public-transit modes used in combination with cars reveals interesting insights into intermodal travel behavior. We define the *PT-Car transfer leg* as the public-transit leg immediately preceding or following the car leg in *PT+Car* trips. The *transfer mode* refers specifically to the public-transit mode used during this PT-Car transfer leg.

Figure 6 illustrates the distribution of transfer modes used in *PT+Car* trips. The results show that trains (44 %) and coaches (21 %) are the predominant transfer modes. In the French context, these modes typically serve as a connection between peripheral areas and urban centers. However, their limited spatial coverage, with often only one train station per village or small town, necessitates the use of private vehicles to access these transit stops.

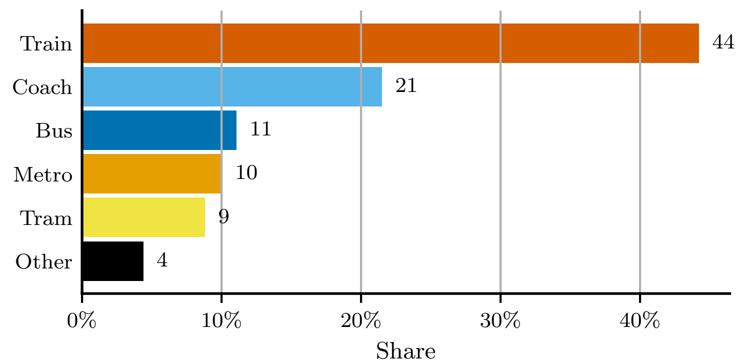

Figure 6: Distribution of public-transit transfer modes in *PT+Car* trips
Note. The chart displays the proportion of public-transit modes used during the transition between car and public-transit legs in either direction.

Buses play a relatively minor role as transfer modes in *PT+Car* trips, appearing in only 11 % of such trips. This stands in contrast to the overall prominence of buses in public-transit usage, where they represent 33 % of all public-transit legs. This indicates that car is more commonly used as an alternative to bus to reach major public-transit hubs, rather than being combined with bus services.

To analyze the spatial patterns of intermodal travel, this study employs the municipal classification system developed by INSEE, the French national statistics institute. INSEE categorizes municipalities into three primary density classes: rural, intermediate-density, and dense. To provide greater precision, we further subdivide the dense category using INSEE's definition of functional areas *(aires d'attraction des villes)*. This refinement allows us to distinguish between dense municipalities that serve as centers of their functional areas and those that do not.

We define the *Car*→*PT* trips as the *PT+Car* trips where the car component comes before the public-transit component. Table 1 presents the distribution of *Car*→*PT* trips according to the density classification of both origin and destination municipalities. The data reveal that 68.4 % of these intermodal trips originate from either intermediate-density or rural municipalities. Moreover, a substantial majority (54.8 %) of these trips terminate in dense municipalities that function as centers of their respective functional area.

Table 1: Distribution of *Car*→*PT* trip flows by municipal density classification

Origin \ Destination	Center	Dense	Intermediate	Rural	**Total origin**
Center	4.4	0.6	0.6	0.2	**5.7**
Dense	17.2	7.7	0.7	0.2	**25.9**
Intermediate	18.7	5.0	5.7	1.3	**30.7**
Rural	14.4	4.2	10.1	8.9	**37.7**
Total destination	**54.8**	**17.5**	**17.0**	**10.6**	**100.0**

Note. All values are expressed as percentages. The value of 18.7 in the third row indicates that 18.7 % of *Car*→*PT* trips originate in intermediate-density municipalities and terminate in dense municipalities that serve as center of their functional area.

Figure 7 provides a visual representation of these trip flows. The diagram clearly illustrates that intermodality primarily facilitates travel from low-density or intermediate-density areas to high-density urban centers. This pattern suggests that intermodal travel plays a crucial role in connecting peripheral areas with major urban hubs.

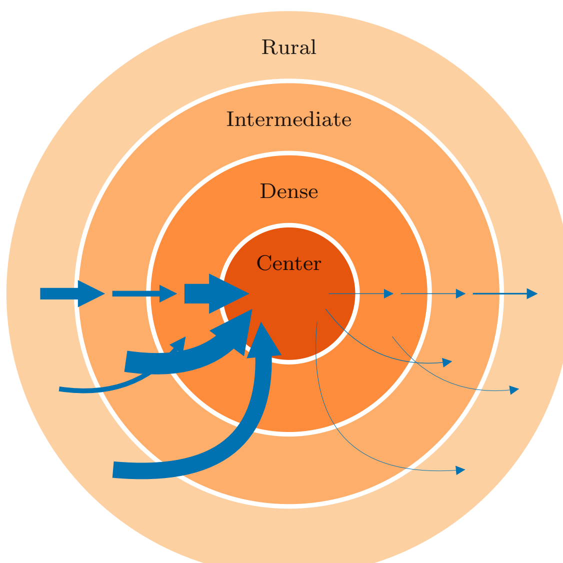

Figure 7: Spatial distribution of *Car*→*PT* trip flows by municipal density classification
Note. The width of each arrow is proportional to the number of trips. Flows between municipalities of identical density categories are not displayed. Municipal density classifications follow INSEE's definitions of density and functional areas.

3.3 Analysis of Nearest Access Stop Selection

This subsection examines the factors influencing travelers' choice of public-transit stops when transitioning between car and public transit modes. Such analysis can help predict traffic flows that could emerge with the development of new transit stops or the implementation of park-and-ride (P+R) facilities. This investigation holds particular relevance in the French context, where the upcoming expansion of train stations with multimodal facilities through the Service Express Régional Métropolitain (SERM) initiative is expected to reshape regional transportation networks in the coming years.

This analysis also provides a methodological basis for modeling park-and-ride trips. The potential applications of such modeling are demonstrated in the work of Yin et al. (2024), who evaluate the effects of Paris's driving restriction zone policy. They examine how people might use park-and-ride facilities to reach restricted areas without driving inside the zone. Their model assumes that park-and-ride users would drive to the nearest transit stop from their starting point. This nearest-stop assumption offers a reference point for comparing with the empirical findings presented in this study.

The mobility surveys used in this study present certain methodological limitations regarding spatial precision. Rather than providing exact coordinates for origins, destinations, and selected stops, the surveys locate these points within predefined zones. These zones vary in size, with an average area of approximately $6\,\mathrm{km}^2$. The Île-de-France survey represents an exception, employing a finer grid system of 100 m by 100 m, resulting in zones of $0.01\,\mathrm{km}^2$.

To supplement the survey data, this analysis incorporates comprehensive information on public-transit stop locations. These data were compiled by processing 461 General Transit Feed Specification (GTFS) files covering the entire French territory.[2] For the year 2025, the dataset identifies all public-transit stops served by at least one transit line, categorizing each stop by the mode it is served by, including train, tram, metro.

This analysis focuses on $Car{\rightarrow}PT$ trips where the first public-transit mode used is either train, tram, or metro. Our comprehensive public-transit stops database contains 1453 train stops, 602 tram stops, and 464 metro stops. For this analysis, we define *access zone* as the survey zones where travelers transfer transition from car to public transit.

Within each access zone, we identify all relevant transit stops corresponding to the reported transfer mode. For approximately 8 % of eligible trips, there is no stop that matches the reported transfer mode within the access zone, or within 50 meters of it. This discrepancy may result from either incomplete stop data in our database or potential reporting errors by survey respondents regarding their access zone or transit mode. These trips with

[2]These GTFS files were collected from `https://transport.data.gouv.fr/`.

missing stop information are excluded from further analysis.

Figure 8 illustrates an example of a valid trip included in our analysis. This example shows a trip where the traveler accessed the public-transit network by train, with a train station clearly located within the designated access zone.

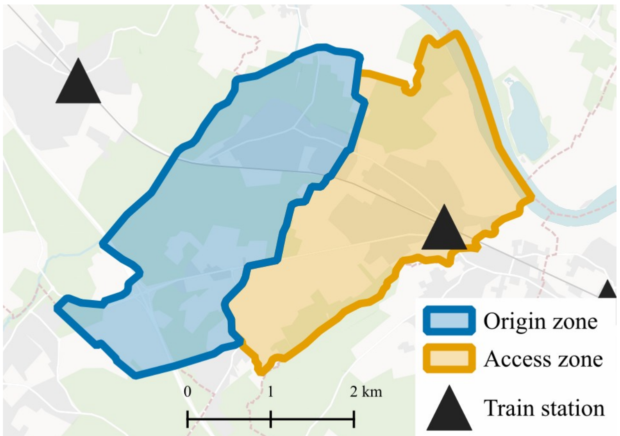

Figure 8: Example of origin and access zones for a trip with train as transfer mode
Note. The access zone (orange) is adjacent to the origin zone (blue). A single train station is located within the access zone, with additional train stations located near the origin zone.

To determine whether travelers use the closest stop to their origin, we employ a geometric approach that accounts for the zonal structure of our data. Since the exact origin location within each zone is unknown, we cannot directly identify the closest stop. Instead, we examine each vertex of the origin zone to determine the nearest stop.

When the closest stop for all vertices of the origin zone lies within the access zone, we conclude with confidence that the traveler used the nearest stop to their origin. Conversely, when the closest stop for all vertices is outside the access zone, we can confidently determine that the traveler did not use the nearest stop. For cases where some vertices have the closest stop inside the access zone and others have it outside, we cannot definitively determine whether the traveler used the nearest stop.

Figure 9 illustrates a scenario where this determination cannot be made. The location of the nearest station depends on the exact origin point within the zone: the station within the access zone is closest to the green dot, while the station outside the access zone is closest to the orange dot.

Table 2 presents the results of this analysis for train, tram, and metro access modes over all eligible $Car \rightarrow PT$ trips. For train access, we can definitively determine that travelers used the closest stop in 36.1 % of cases and did not use the closest stop in 34.3 % of cases. For the remaining 29.6 % of trips, we cannot make a definitive determination. However, given the relatively small size of the zones, it is reasonable to assume that in these ambiguous cases,

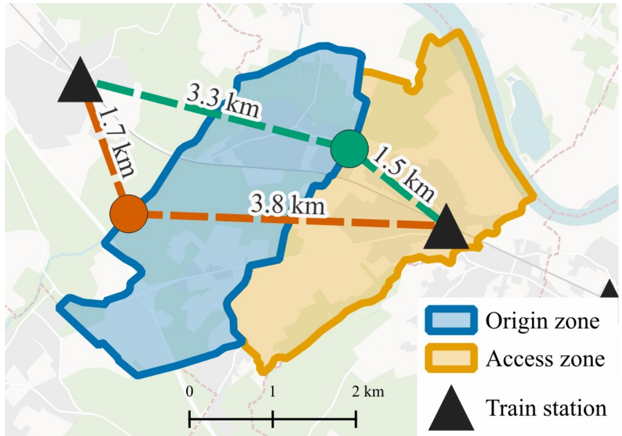

Figure 9: Ambiguity in determining nearest station for an example trip

Note. The nearest station depends on the exact origin location within the zone. If the traveler's origin is located at the green dot, then the station within the access zone is indeed the closest. If however the traveler's origin is located at the orange dot, then the closest station is outside the access zone.

travelers likely used either the closest stop or one very near to it. These findings align with the analysis of park-and-ride in Minneapolis by Webb and Khani (2020). They find that 49 % of surveyed users selected the park-and-ride facility that minimizes their driving time from origin.

Table 2: Share of *Car*→*PT* trips using the closest stop from origin by access mode

	Train	Tram	Metro
Definitely uses closest stop	36.1	8.2	19.5
Definitely does not use closest stop	34.3	68.6	59.0
Indeterminate	29.6	23.2	21.5

Note. All values represent percentage. For train access, 36.1 % of trips definitely used the closest stop, i.e., the closest train stop from all vertices of the origin zone are within the access zone.

In contrast to train access, our findings indicate that travelers typically do not use the closest stop for tram (68.6 %) and metro (59.0 %) access. Several factors may influence the choice of a different stop. Travelers might choose a stop that offers a more direct route to their destination rather than selecting the geographically closest stop, which might imply traveling in the opposite direction initially. The decision to bypass the nearest stop may reflect a preference for transit lines that offer better service frequency or more convenient transfers to reach the ultimate destination.

The quality of park-and-ride facilities might also play a significant role in stop selection. Factors such as the number of available parking spaces and the walking distance between parking areas and transit platforms can influence travelers' choices.

Finally, it is important to note that our analysis uses Euclidean distance to determine the closest stop, which represents a simplification of actual travel behavior. A more refined approach would consider actual travel time by car from the origin to potential access stops. The stop with the shortest travel time might differ from the geographically closest stop due to factors such as traffic congestion or the specific layout of the road network.

4 Conclusion

This study provides new empirical insights into intermodal travel patterns in France by leveraging a harmonized dataset of 68 mobility surveys. The findings reveal that intermodal trips are characterized by long distances, averaging 20.7 km, with the combination of car and public transit representing the dominant pattern (85 % of intermodal trips). The data show that car primarily serve as access mode to public transit in low-density areas, where travelers typically complete the majority of their journey using public transit. While proximity to origin strongly determines train stop choice, this factor is less relevant for trams and metro, suggesting that service quality and network connectivity play crucial roles.

These results offer guidance for transportation planners seeking to design more effective multimodal systems, particularly in the context of France's ongoing SERM infrastructure development. Through the development and application of the MobiSurvStd harmonization framework, this research establishes a methodological foundation for future investigations of complex and less common mobility behaviors.

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