



Optimizing intermodal commuting by way of detours and breaks



Evidence of micromobility users in France

Dylan MOINSE



Background

All detours and breaks observed in mobility patterns are the result of a search for time-distance based-optimization, making it appear as a **positive value [1]**.

- In literature, **detours** from a location, expressed by circuitry, and **breaks**, made necessary to change the transport mode, are almost always seen as **undesired**.
- Detours and breaks counterintuitively contribute to the **optimization** process of movement.

The scientific literature dealing with the relationship between **micromobility detours** and **route optimization** is very limited:

- Coupled with a knowledge gap regarding micromobility usage, particularly **personal and shared e-scooters**;
- Passengers combining cycling and rail favor the most **convenient train stations**, rather than the nearest ones **[2; 3]**:
 - Avoiding transfers and accessing a train/tram/bus station providing better frequency, comfort and facilities.
- The main motive reported is **transfer station avoiding [4]**;
- Bicycle-train travelers are willing to cycle an **extra 10 minutes** to avoid transfers **[5]**.

[1] L'Hostis, A. (2017). Detour and break optimising distance, a new perspective on transport and urbanism. *Environment and Planning B: Planning and Design*, SAGE Publications, 441-463. DOI: 10/gddwqw

[2] Krizek, K. J., & Stonebraker, E. W. (2010). Bicycling and Transit: A Marriage Unrealized. *Transportation Research Record*, 2144(1), 161-167. DOI: 10/bph39f

[3] Jonkeren, O., Kager, R., Harms, L., & te Brömmelstroet, M. (2021). The Bicycle-Train Travellers in the Netherlands: Personal Profiles and Travel Choices. *Transportation*, 48(1), 455-476. DOI: 10.1007/s11116-019-10061-3

[4] Rijsman, L., van Oort, N., Ton, D., Hoogendoorn, S., Molin, E., & Tejl, T. (2019). Walking and Bicycle Catchment Areas of Tram Stops: Factors and Insights. *6th International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, 1-5. DOI: 10.1109/MTITS.2019.8883361

[5] Nieves, P. (2018). *How do train-cyclists navigate? : Exploring bike-train route choice behavior in the Amsterdam Metropolitan Area* [Master Thesis, FMG Urban and Regional Planning]. <https://scripties.uba.uva.nl/document/667739>

Mixed-method framework

Development of a “customized” investigation [6]: Combining **objective** and **perception**-oriented methods to provide complementary two-sided analysis [7].

a) Questionnaire

- **Purpose:** Characteristics and locations of intermodal trips by micromobility and public transport in Europe;
- **Target population:** Micromobility-and-ride travelers;
- **Data collection:** Online (flyers in nine stations);
- **Period:** April 2022 – January 2023;
- **Software:** ©LimeSurvey;
- **Ethical considerations:**
 - SNCF Gares & Connexions;
 - GDPR.

b) Go-along interviews

Mobile interviews generating “**micro-geographies**” of meaning [8] and innovative method advocated for studying the emergence of **micromobility solutions** [9].

2 exploratory ride-along interviews among over 46 volunteers:

- e-scooter with regional train (PCTE1);
- e-scooter with metro (PCTE2).



Source: D. Moïnse (2022) ©

217 Sample 2

[6] Paugam, S. (2012). *L'enquête sociologique*. Presses Universitaires de France - PUF.

[7] Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. *Educational Evaluation and Policy Analysis*, 11(3), 255-274. DOI: 10/cjqt52

[8] Bergeron, J., Paquette, S., & Poullaouec-Gonidec, P. (2014). Uncovering landscape values and micro-geographies of meanings with the go-along method. *Landscape and Urban Planning*, 122, 108-121. DOI: 10.1016/j.landurbplan.2013.11.009

[9] Pages, T., Lammoglia, A., & Josselin, D. (2021). Les nouveaux modes de déplacement individuel doux basés sur l'électrique. Attractivité et insertion modale. *Territoire en mouvement Revue de géographie et aménagement*. <https://journals.openedition.org/tem/8135>

Sampling

Once the questionnaire responses were cleaned up (N=2,189), the sampling process captured full responses that comprised the last intermodal journey with geographical coordinates, with access and/or egress, escaping the nearest (Voronoi) station (**n=129**) or a **stated break** (n=110), and with a work or educational-related purpose.

Spatial analysis using GIS:

- Transit stations partitioned by the **Transit Voronoi diagram** (T-VD) [10];
- Tessellation visualization in Euclidean metrics [11];
- Escaping Transit Voronoi Station (**E-TVS**).

Detours

Breaks

129

110

Legend

Built environment

- Railway station
- Subway station
- ◇ Tramway station

Boundaries

- Voronoi diagram
- Municipality boundaries

Surveyed micromobility-and-ride

- To or from Lille Flandres (station: regional and high-speed trains)
- To or from Lille Europe (station: high-speed trains)
- To or from Lille CHR (stop: regional trains)

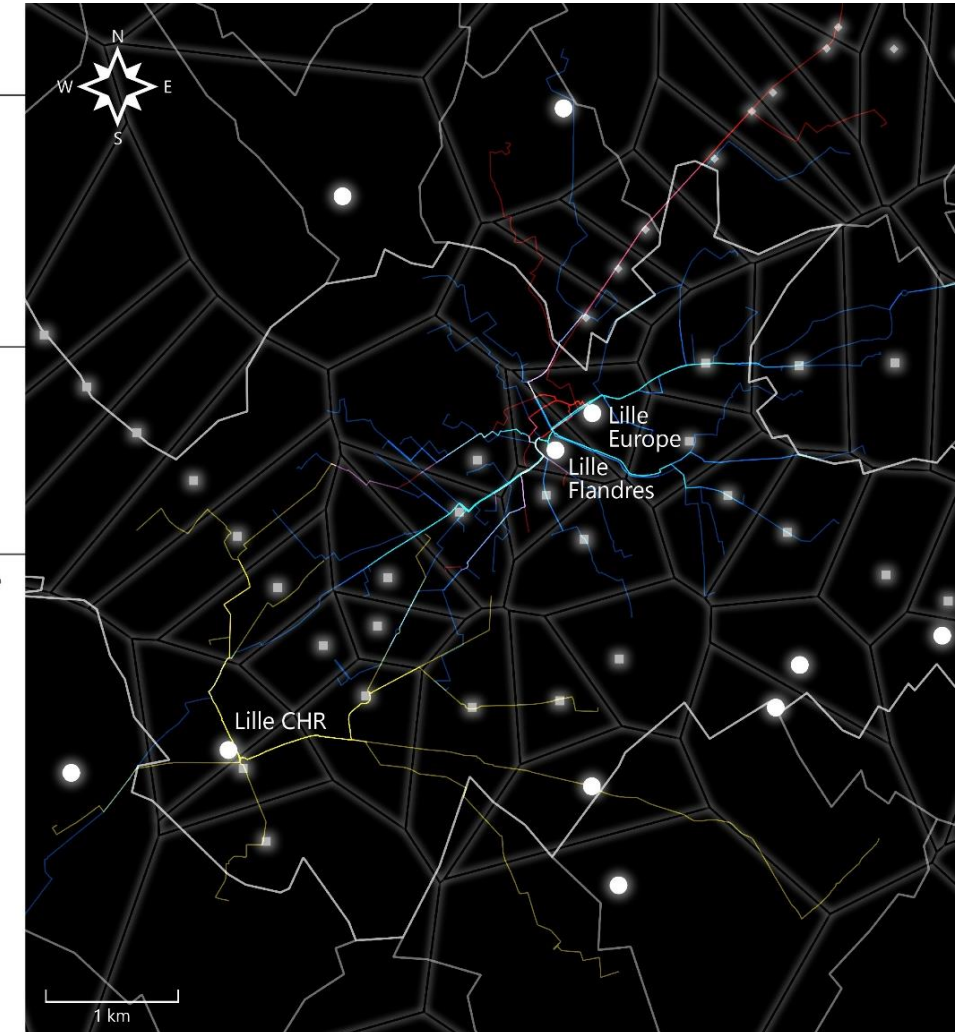


Fig. 1: Map of the respondents' itineraries beyond the defined Voronoi polygon

Source: D. Moïnse (2023) ©

[10] Chen, B. Y., Teng, W., Jia, T., Chen, H.-P., & Liu, X. (2022). Transit Voronoi diagrams in multi-mode public transport networks. *Computers, Environment and Urban Systems*, 96, 101849. DOI: 10/gr2dqg

[11] Mota, D. R., Takano, M., & Taco, P. W. G. (2014). A Method Using GIS Integrated Voronoi Diagrams for Commuter Rail Station Identification: A Case Study from Brasilia (Brazil). *Procedia - Social and Behavioral Sciences*, 162, 477-486. DOI: 10/gr2dqg

1. Detours and distances

a) Extended station neighborhoods

Application of the **85th percentile** value of the cumulative distribution to assess the social acceptability **access/egress distance** [12].

- **Walk-and-ride** reaches 1.3 km in the 75th percentile (n=49 segments);
- Impact area of the stations approximately **3.8 km** in both directions overall (n=262 segments):
 - 4 to 5 km for the conventional bicycle (n=124);
 - 2 to 4 km for the folding bicycle (n=30);
 - 2 to 3 km for the e-scooter (n=71).
- The distribution suggests a 1-km pedestrian and a **3- to 4-km cycling radius**.

Sample (n=262)

Subsample (n=170)

3.8 km

5.7 km (E-TVS)

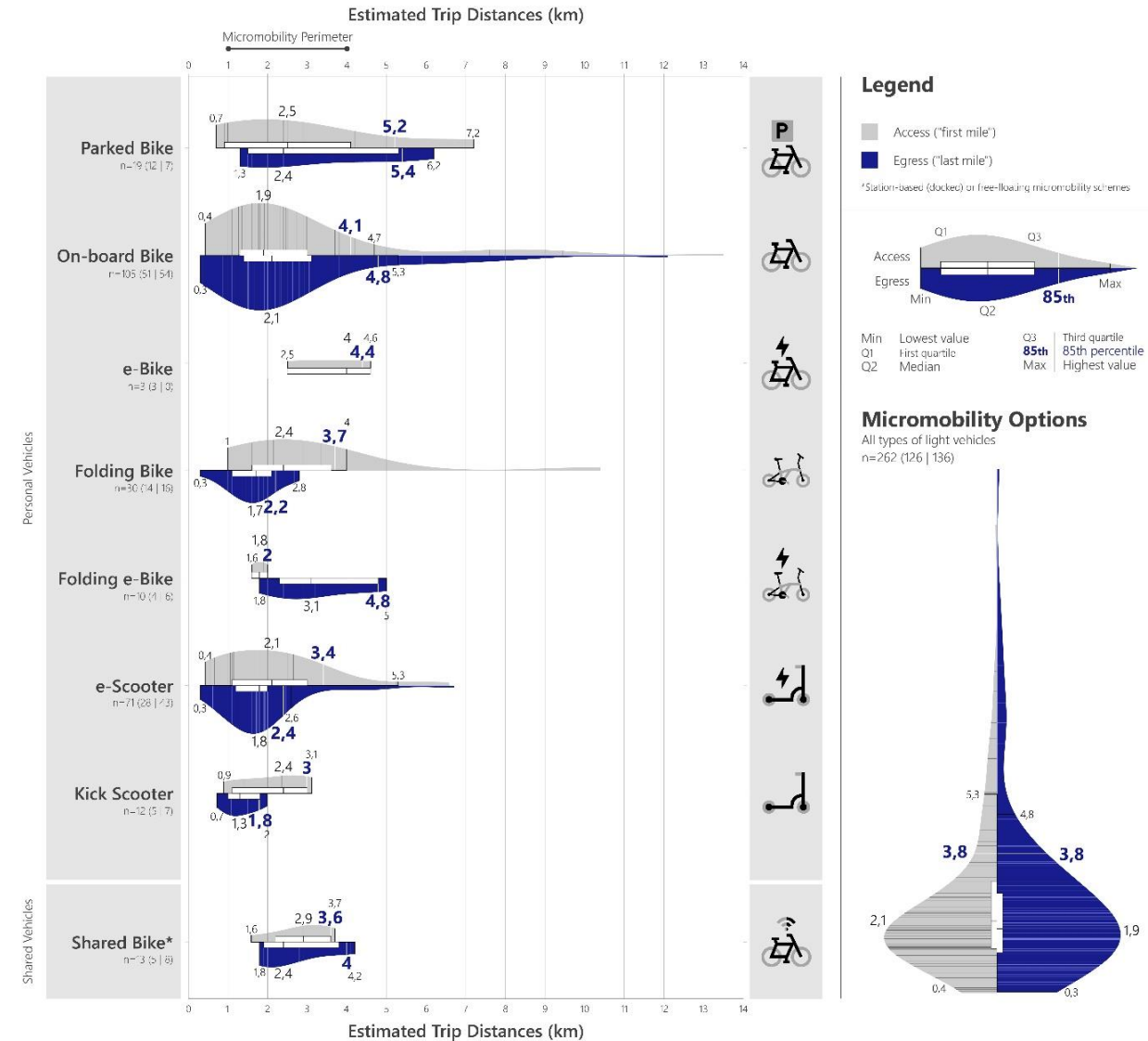
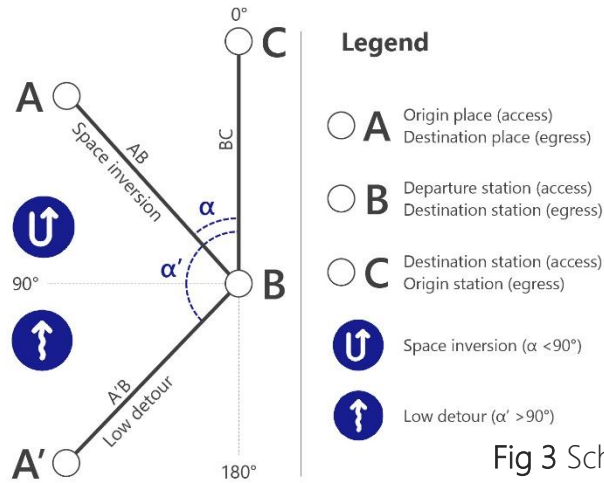


Fig. 2 Violin plot of access and egress distances by micromobility

Source: D. Moïnse (2023) ©

2. Angle patterns



Legend

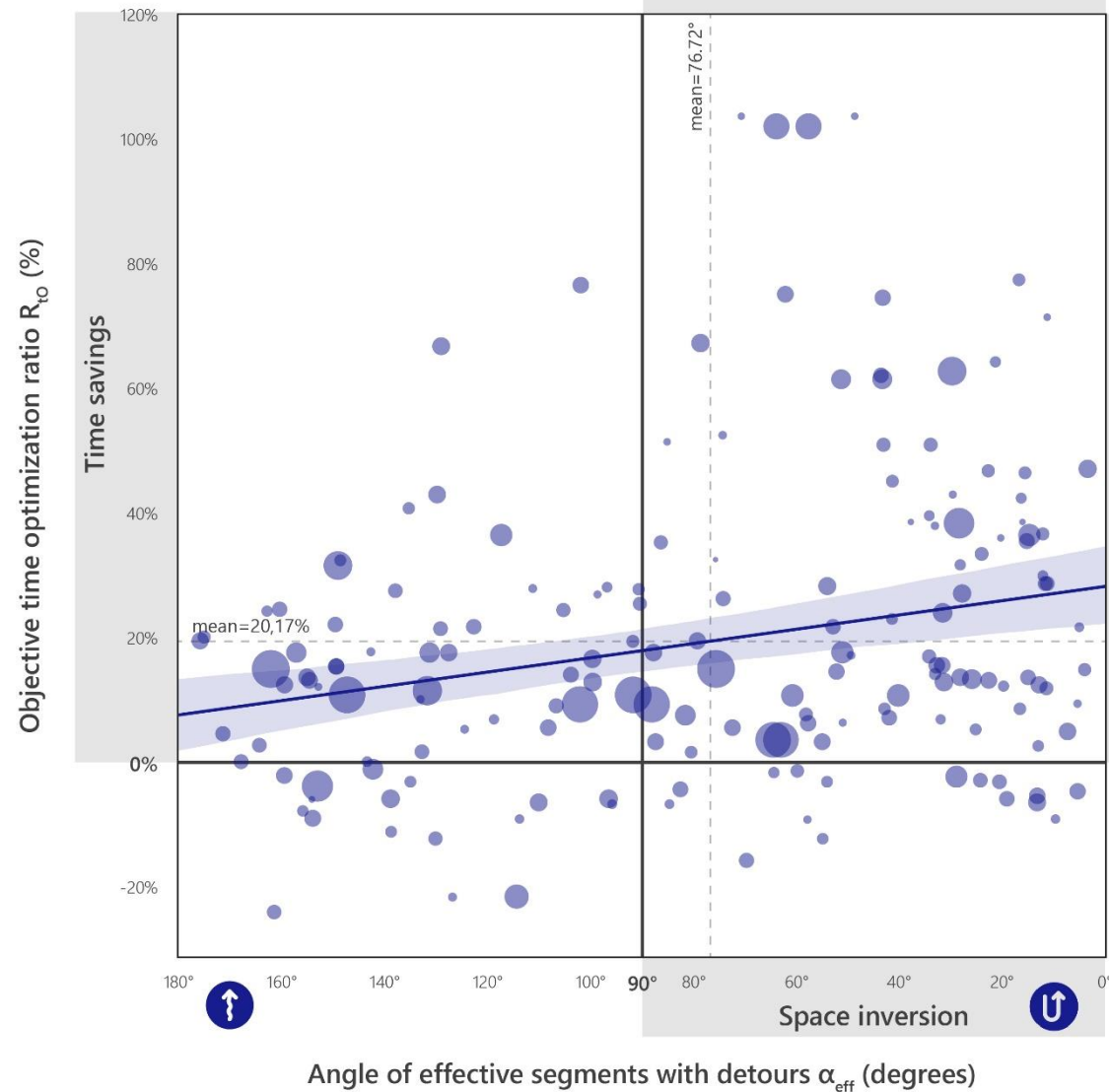
-  A Origin place (access)
Destination place (egress)
-  B Departure station (access)
Destination station (egress)
-  C Destination station (access)
Origin station (egress)
-  Space inversion ($\alpha < 90^\circ$)
-  Low detour ($\alpha' > 90^\circ$)

Angles (α) of the E-TVS routes by analyzing the role of space inversion [16].

Fig 3 Scheme of angle shapes

Generally, **effective detour-based routes** in access or egress (α_{eff}) exhibit a **space inversion** pattern (76.7°), unlike alternative routes (α_{alt}) with low detours to the destination (110.5°).

The linear regression model demonstrates a **positive relation** between an angle approaching **space inversion** and the objective **time savings** of an effective route (R_t^0).







n=170

Legend

Type of effective segment:

-  Access leg
-  Egress leg

Access and egress kilometer difference between **effective detour routes (eff)** and the **Euclidean (eud)** ones:

-  80 km difference
-  30 km difference
-  10 km difference
-  5 km difference
-  1 km difference

Regression analysis:

— Linear regression

$$y = -0.0012x + 0.2921$$

$$R^2 = 0.0594$$

Objective time optimization ratio:

$$R_{t_0} = \frac{t_{t_0}^{\text{alt}}}{t_{t_0}^{\text{eff}}}$$

$$t_{t_0} = t_{\text{access}} + t_{\text{waiting}} + t_{\text{onboard}} + t_{\text{egress}}$$

Fig. 4 Linear regression model crossing angle patterns and time savings

Source: D. Moïse (2023) ©

3. Optimization strategies

a) Classification of E-TVS strategies

This statistical assessment sets the analyzed commutes in relation to the kilometer and time saving:

- X-axis: R_{km} (kilometer saving);
- Y-axis: R_t^P (time saving);
- Z values: $km_{alt} - km_{eff}$

Four types of E-TVS route profiles emerge.

Profile C (time and km savings) contains 84/129 (**65%**) intermodal journeys involving a detour.

By grouping together intermodal routes showing at least time (**Profile A**) or distance savings (**Profile B**), or both (**Profile C**), **95%** of itineraries are included.

Legend

Type of detour:

- Detour 1 (transfer saving)
- Detour 2 (attractive station)
- Detour 3 (reduced transit time)

Access and egress kilometer difference between effective detour routes (eff) and the alternative (alt) ones:

- 30 km difference
- 10 km difference
- 5 km difference
- 1 km difference

Kilometer optimization ratio:

$$R_{km} = \frac{km_{alt}}{km_{eff}}$$

$$km = km_{access} + km_{transit} + km_{egress}$$

Perceived time optimization ratio:

$$R_t = \frac{t_{alt}}{t_{eff}}$$

$$t = 1.8 \cdot (t_{access} + t_{egress}) + 2.8 \cdot t_{waiting} + 1 \cdot t_{transit}$$

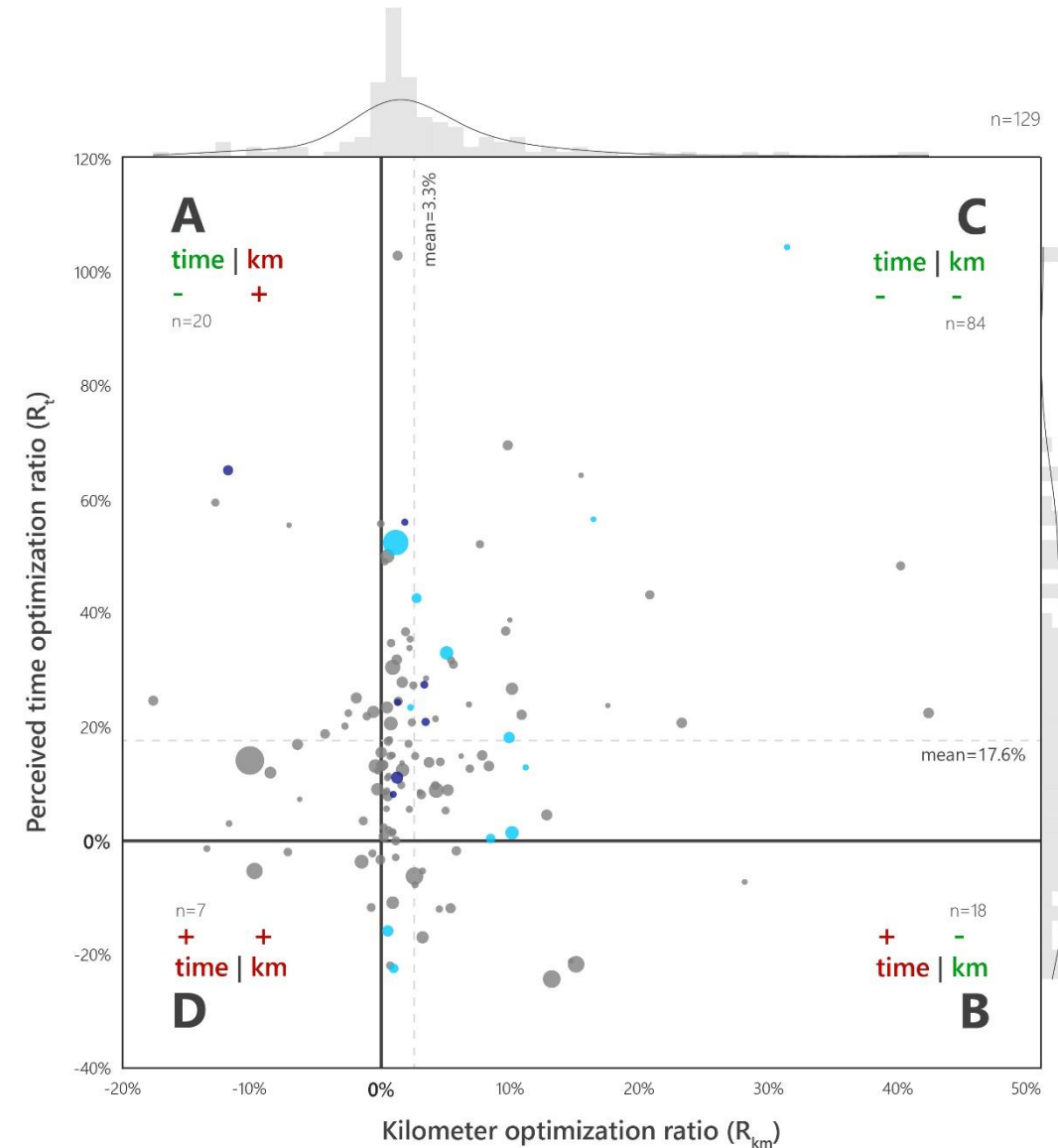


Fig. 6 Clustering of intermodal journeys comprising detours

3. Optimization strategies

b) Classification of **break**-based strategies

Break necessarily occurs when accessing a station. Intermediate time related to waiting transit as an opportunity to **optimize the trip chain** and to conduct **additional activities** during the trip.

Supermarkets and other shops are the most popular activities for trip chaining on the micromobility access leg [19].



"I can stop at the station because there is a bakery. [...] I save time, clearly, I would not have the same energy to shop at local stores if I drove the same way." (PCTE1).

Fig. 7: Participant showing the bakery along the way to the Lille Flandres station

Source: D. Moïnse (2023) ©

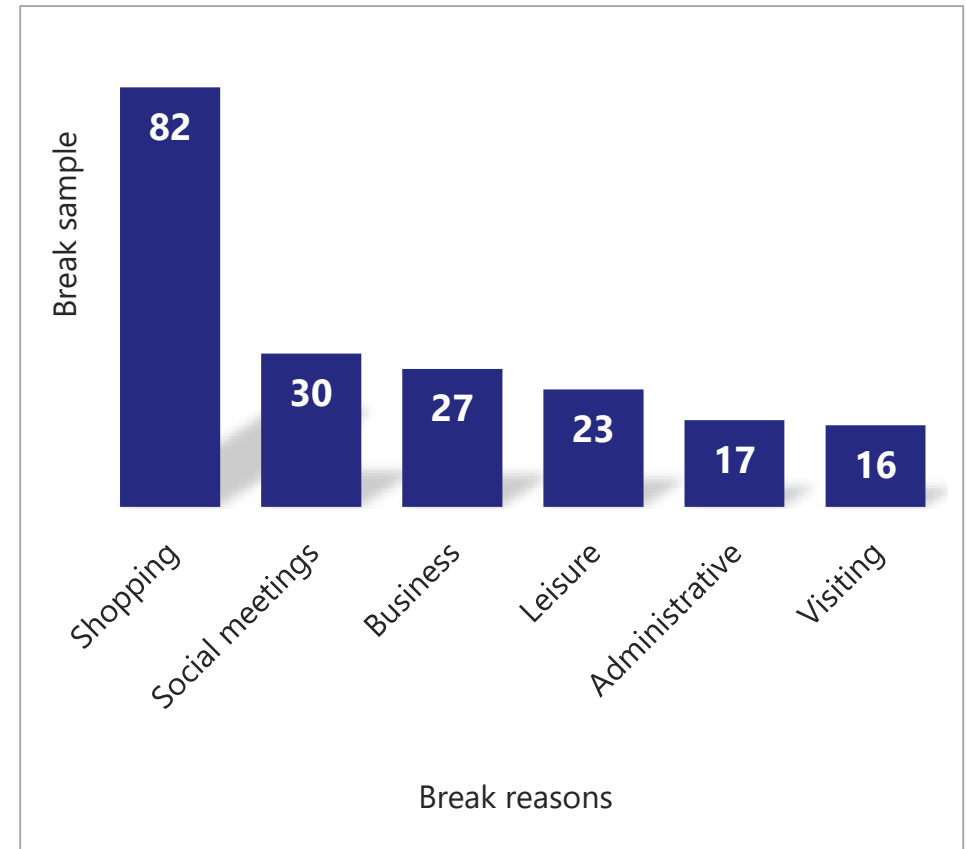


Fig. 8: Reasons given for the 110 reported breaks (multi-choice)

Main insights

| | Research question | Results | Hypothesis |
|---|--|---|------------|
| 1 | What is the size of station areas? Does it evolve taking into account the strategies developed by the surveyed riders? | The acceptable transit catchment area by micromobility is 4 km, but it extends to 6 km for travelers who take detours. This difference results in 2 km or 10 min (+125%) longer access/egress trips to make a detour. | |
| 2 | Does making E-TVS during an intermodal journey result in increased travel time and kilometer? | The detour-based optimization strategy allows for time savings of 19% and kilometer savings of 3% . By categorizing intermodal travel profiles, the majority of strategies enable both time and kilometer reduction. | |
| 3 | Similarly, does the direction (angle) have an impact on the performance of intermodal journeys? | On the contrary, space inversion (extreme form of detour) is associated with time savings: 25% compared to 12% for detours without spatial inversion. | |
| 4 | What are the main motivations for making E-TVS or a break in intermodal journeys? | The primary motivation behind making E-TVS is often to avoid transfers . Breaks are typically taken to carry out daily shopping tasks . | |

Conclusions and limitations

The examination of detours and breaks in intermodal journeys incorporating the use of micromobility alternatives provides a better understanding of transit-based mobility and opens up new avenues for the **design of public transportation networks**:

- Regarding the lack of “transit culture” by authorities [20], the aim to inform **design and urban development policies**;
- Leads to rethinking the reorganization of mobility systems, considering the dual approach between the efficiency of the mass transit network and territorial connectivity [21]. The intermodal use of micromobility seems to overcome the **dilemma of performance versus adherence of transit**, by promoting the coexistence of direct and fast transit systems with local accessibility.

Further research avenues:

- Integrating the influence of the **built environment** in route choice (urban density, diversity, design of public spaces, *etc.*);
- Exploring the **competitiveness** side of intermodal journeys involving detours compared to automobile travel;
- Developing **research methods** to supplement the implementation of this questionnaire (survey specifically focused on this subject, Big Data or GPS tracking, *etc.*) in other countries;
- Continuing **ride-along interviews** to obtain more details on route choice;
- Investigating in-depth the role of **breaks** in optimization strategies.

[20] Tan, W., Bertolini, L., & Janssen-Jansen, L. (2014). Identifying and conceptualising context-specific barriers to transit-oriented development strategies: The case of the Netherlands. *The Town Planning Review*, 85(5), 639-663. DOI: 10/gh3pd7

[21] Conesa, A. (2010). *Modélisation des réseaux de transports collectifs métropolitains pour une structuration des territoires par les réseaux: Applications aux régions Nord-Pas-de-Calais et Provence-Alpes-Côte d'Azur* [Thesis, Lille 1]. <https://www.theses.fr/2010LIL10083>

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Publications:

Scientific article on intermodal use of personal e-scooters in the Provence-Alpes-Côte d'Azur region:

Moinse, D., Goudeau, M., L'Hostis, A., & Leysens, T. (2022). Intermodal use of (e-)scooters with train in the Provence-Alpes-Côte d'Azur region: Towards extended train stations areas? *Environmental Economics and Policy Studies*, 34. DOI:10/gqpz86

Book chapter on a quantitative observation of intermodal passengers in nine train stations:

Moinse, D. (2022). *L'émergence de pratiques intermodales en trottinette électrique : une approche par l'observation quantitative dans la région Hauts-de-France*. <https://hal.archives-ouvertes.fr/hal-03857489v1>

Book chapter on a systematic literature review on a "Micromobility-based TOD":

Moinse, D. (2022). *A Systematic Literature Review on Station Area Integrating Micromobility in Europe: A 21 st Century Transit-Oriented Development*. <https://hal.archives-ouvertes.fr/halshs-03857389v1>

**Optimizing intermodal commuting by way of detours and breaks:
Evidence of micromobility users in France**

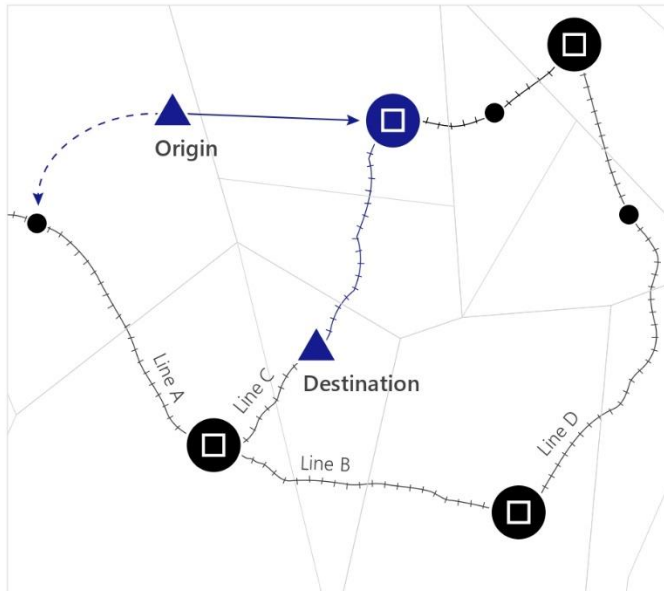
17 July, 2023 in Montréal

Source: D. Moinse (Lille, France, 2023)



Classification of E-TVS journeys

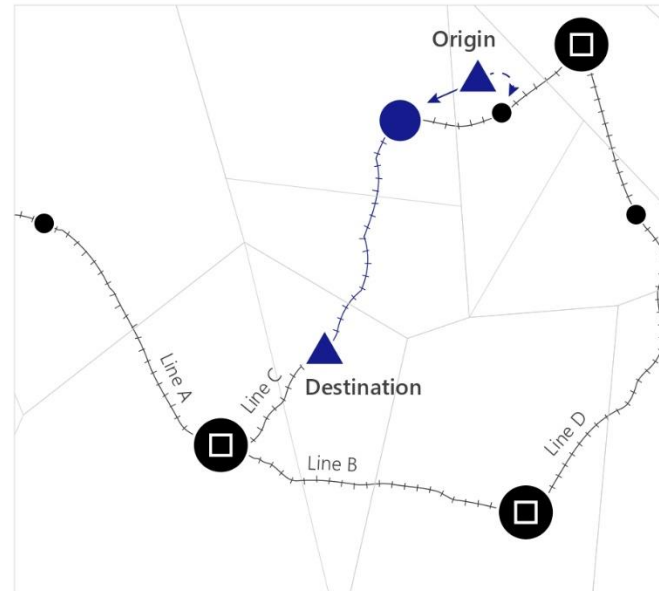
Optimization detour-based strategy
1: Avoiding transfers



258 analyzed commuting legs (129 answers): 171 access or egress including detours by micromobility

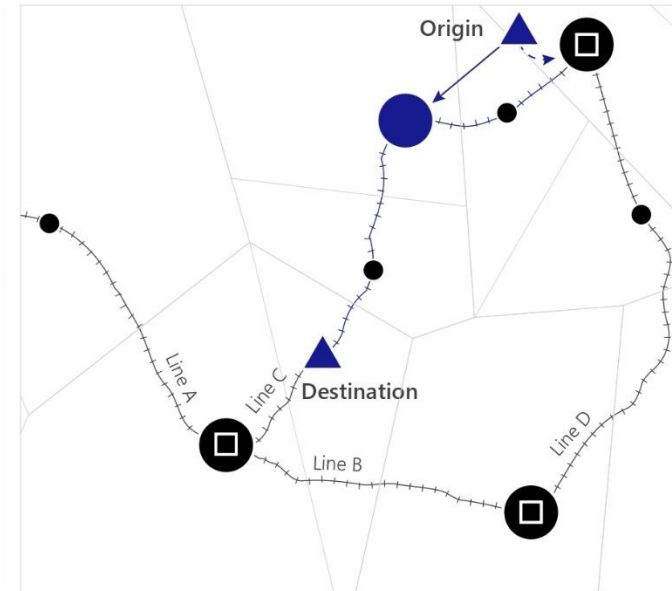
1 Transfer saving
n=152

Optimization detour-based strategy
2: Attractive station



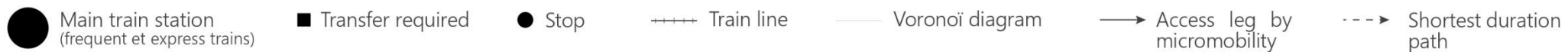
2 Favoring a more attractive station
n=12

Optimization detour-based strategy
3: Reduced time on board the train



3 Favoring a further station to save transit time
n=7

Legend



Calculation of the angles

Angle of **B** between **A** and **C** using the geographical coordinates (WGS84): concepts of **spherical trigonometry**.

1. Conversion of geographical coordinates into Cartesian coordinates (x, y, z) :

- $x = \cos(\text{latitude}) * \cos(\text{longitude})$
- $y = \cos(\text{latitude}) * \sin(\text{longitude})$
- $z = \sin(\text{latitude})$

2. Calculation of vectors (AB, BC) :

- $AB = (x_B - x_A, y_B - y_A, z_B - z_A)$
- $BC = (x_C - x_B, y_C - y_B, z_C - z_B)$

3. Calculation of the dot product of **AB** and **BC**:

- $AB \cdot BC = (x_{AB} * x_{BC}) + (y_{AB} * y_{BC}) + (z_{AB} * z_{BC})$

4. Calculation of the norm of vectors **AB** and **BC**:

- $\|AB\| = \sqrt{(x_{AB}^2 + y_{AB}^2 + z_{AB}^2)}$
- $\|BC\| = \sqrt{(x_{BC}^2 + y_{BC}^2 + z_{BC}^2)}$

5. Calculation of the angle: radians β and degrees α

- $\beta = \arccos((AB \cdot BC) / (\|AB\| * \|BC\|))$
- $\alpha = \beta * (180 / \pi)$

Transit catchment areas

$$\text{Station area} = \pi * r^2$$

Pedestrian conventional station area:
 0.79 km² (r = 500 meters)

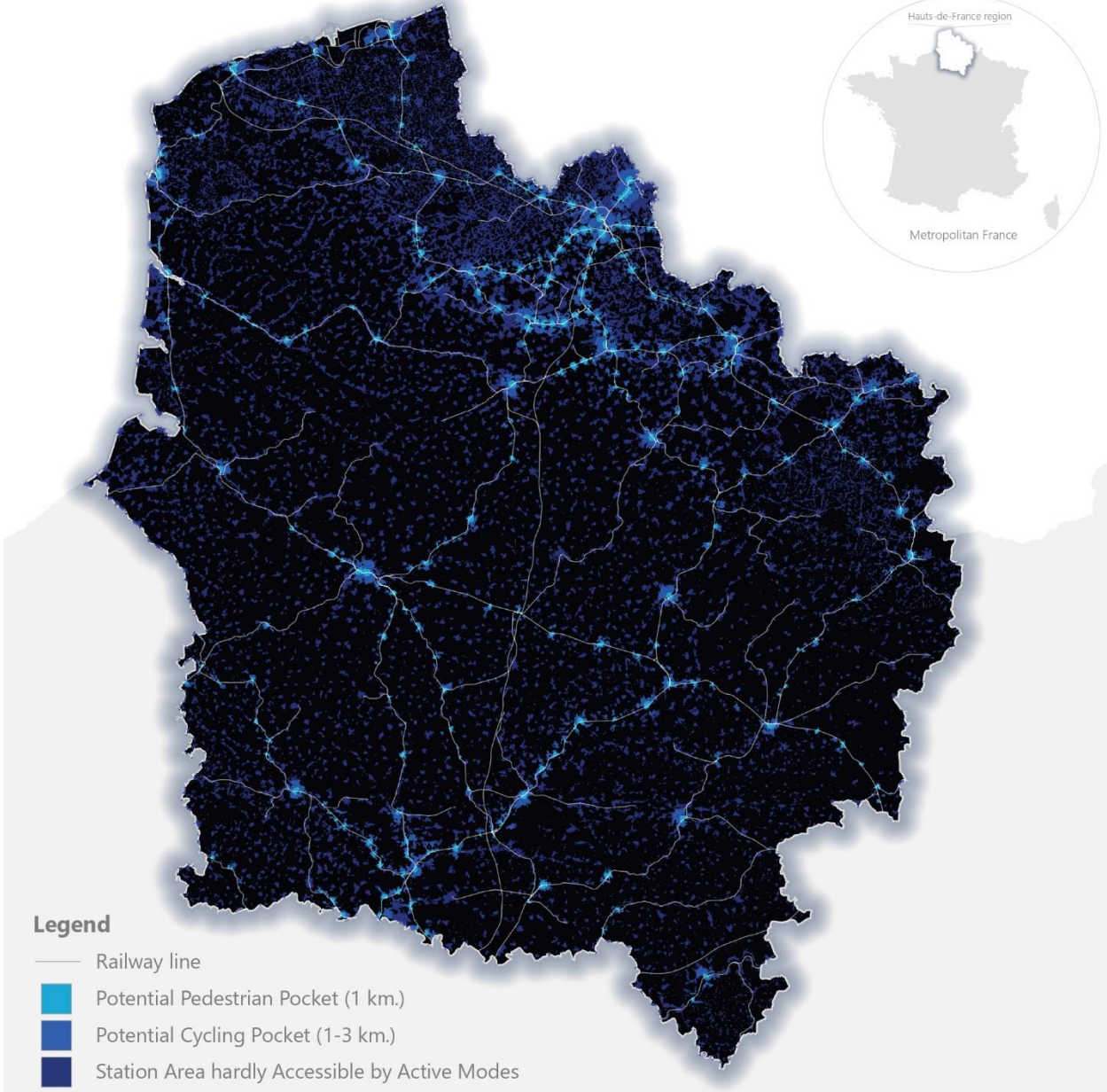
Extended pedestrian station area:
 3.14 km² (r = 1 kilometer)

Cycling station area:
 45.36 km² (r = 3.8 kilometers)

Cycling station area (E-TVS):
 102.07 km² (r = 5.7 kilometers)

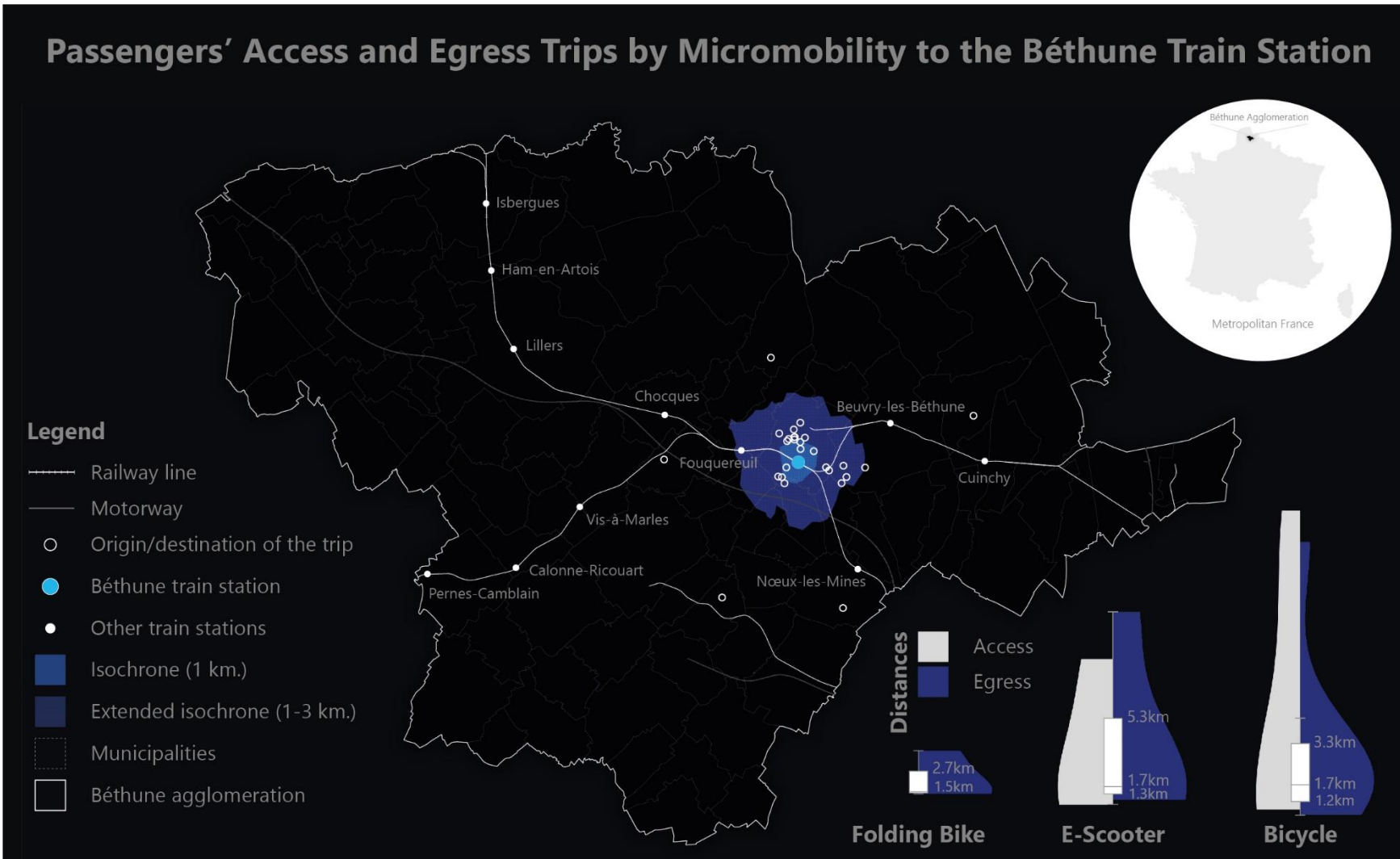
* 129

* 13

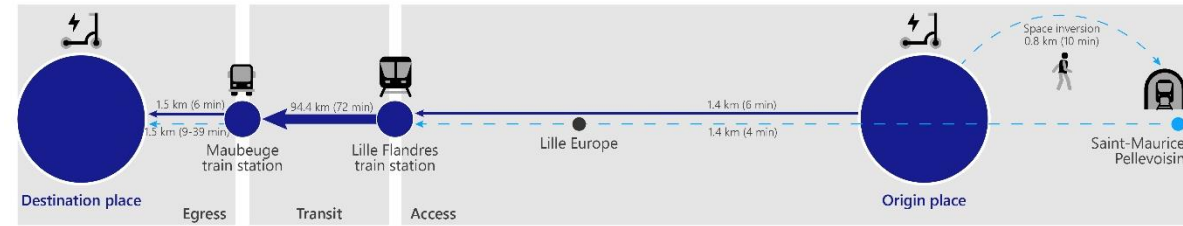
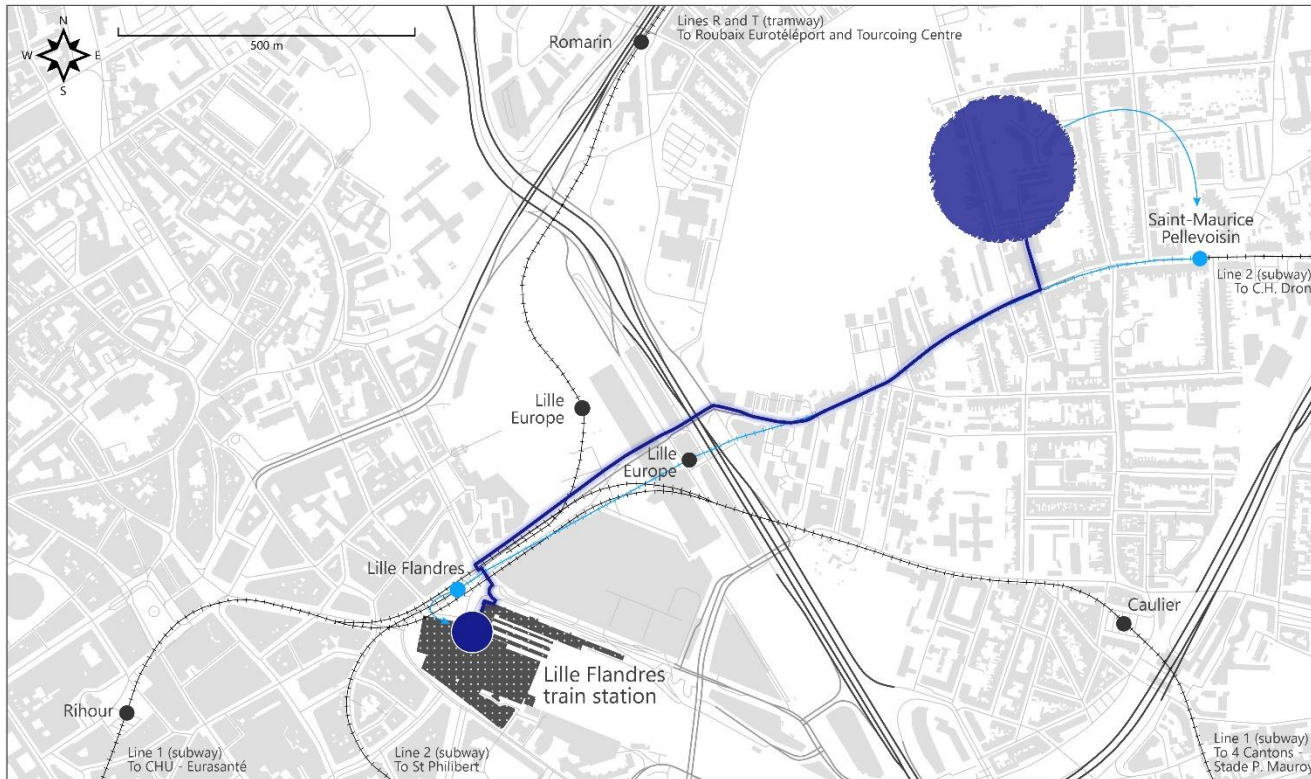


Transit catchment areas

Passengers' Access and Egress Trips by Micromobility to the Béthune Train Station



Ride-along interviews (PCTE1)



| Segment | Access E-scooter | Walk-and-ride | Transit Regional train | Egress E-scooter | Bus (waiting time) + ride + walk |
|---------------|------------------|---------------|------------------------|------------------|----------------------------------|
| Modal choice | | | | | |
| Distance (km) | 1.4 | 2.2 | 94.4 | 1.5 | 1.1 + 0.4 |
| Time (min) | 6 | 10 + 4 | 72 | 6 | (0 to 30) + 5 + 4 |

Legend

Ride-along interview (access trip)

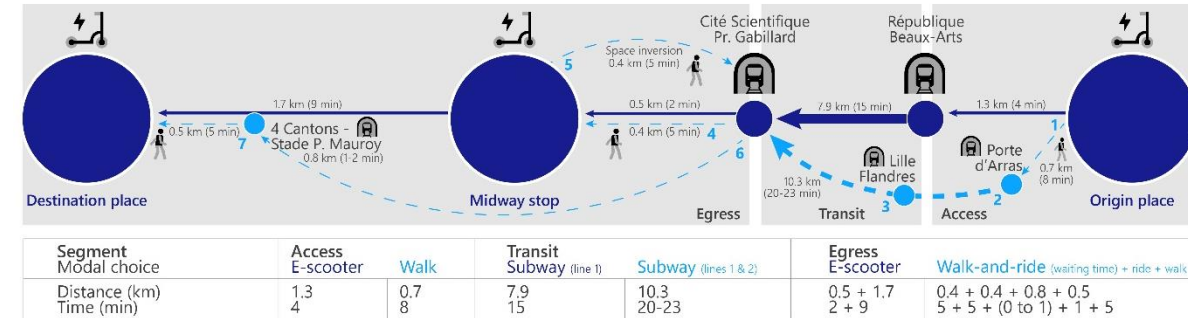
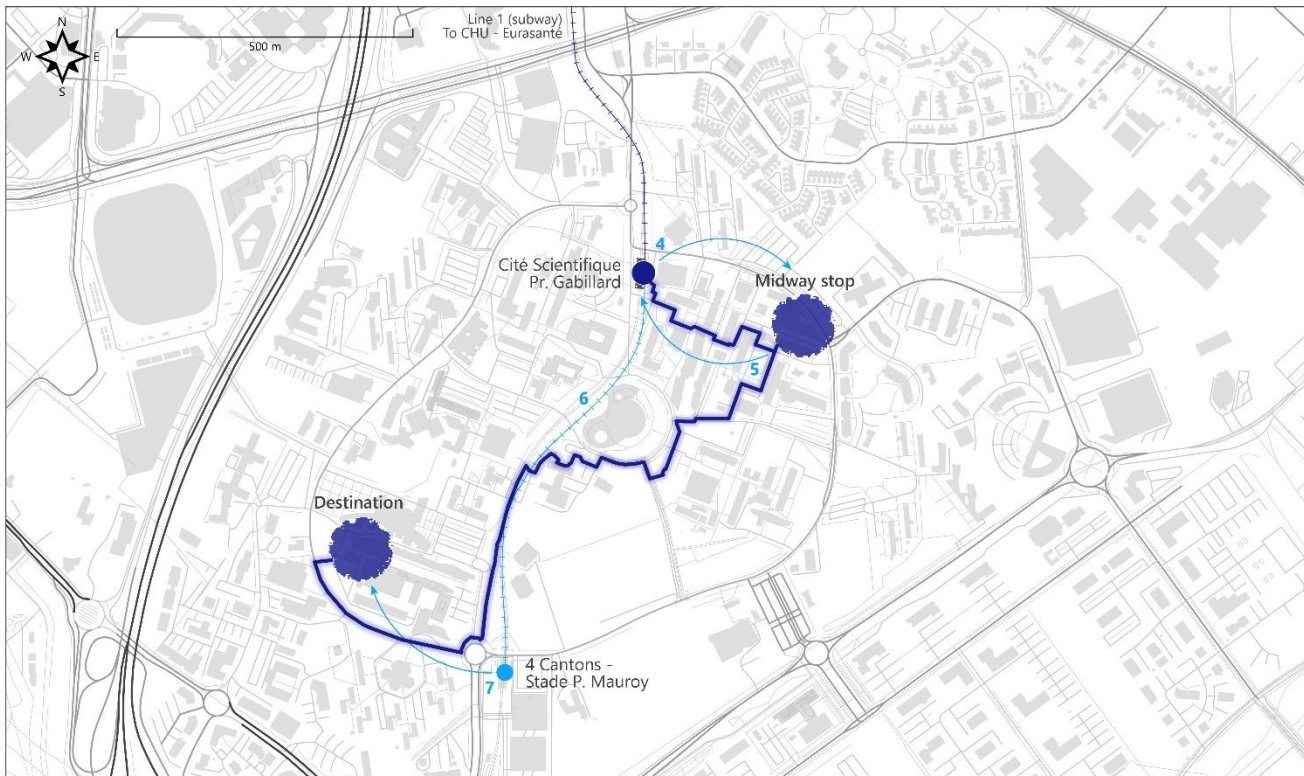
- Origin place
- Departure train station
- Access trip by e-scooter

Alternative access trip

- Subway station
- Access trip by subway
- Walking access trip

| Intermodal trip | Distance (km) | Time (min) |
|-----------------------------|---------------|------------|
| Micromobility + Train | 97.3 | 84 |
| Walk + Subway + Train + Bus | 98.1 | 95 to 125 |

Ride-along interviews (PCTE1)



Legend

Ride-along interview (egress trip)

- Destination place
- Destination subway station
- Egress trip by e-scooter

Alternative access trip

- Subway station
- Egress trip by subway
- Walking egress trip

| Intermodal trip | Distance (km) | Time (min) |
|------------------------|---------------|------------|
| Micromobility + Subway | 11,4 | 30 |
| Walk + Subway | 13,1 | 44-48 |