Optimizing intermodal commuting by way of detours and breaks



Evidence of micromobility users in France

Dylan MOINSE









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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 circuity, 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].

[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

^[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., & Teijl, 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

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Research aim

A better understanding of intermodal passenger **route choices**, particularly regarding **detours** and **breaks** as **optimization-based strategies**.

		Objectives:
Distances	1	Measuring the kilometer- and time-savings by using feeder modes when intermodal trips involve detours; Does taking a detour result in increasing the total distance and time?
Angles	2	Determining the influence of route orientation on intermodal travel optimization; Is starting a path in the opposite direction of the destination synonymous with decreased efficiency?
Strategies	3	Classifying and clustering detour- and break-oriented optimization strategies; Are there different types of detours and breaks to optimize the intermodal journey?

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. Moinse (2022) ©

[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

217 Sample 2

[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 ٠ [11];
- Escaping Transit Voronoi Station (E-TVS). ٠

Detours

129

Breaks

110



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Fig. 1: Map of the respondents' itineraries beyond the defined Voronoi polygon Source: D. Moinse (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/gr2dgd [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/gr2dgg

Legend

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.





[12] Lee, J., Choi, K., & Leem, Y. (2016). Bicycle-Based Transit-Oriented Development as an Alternative to Overcome the Criticisms of the Conventional Transit-Oriented Development. International Journal of Sustainable Transportation, 10(10), 975-984. DOI: 10.1080/15568318.2014.923547

1. Detours and distances

b) Spatio-temporal circuity coefficient

Geographical Route Directness Index (GRDI) between [13]:

- Observed path ("effective", eff): E-TVS;
- Shortest path ("alternative", alt): inside the Voronoi polygon;
- Euclidean distance ("euclidean", eud): straight line.

Optimization ratios [14; 15]:

- Effective distance **0.5 time** longer than Euclidean distance;
- Effective access/egress distance **6 to 8 times** longer than alternative distance;
- Effective total distance = alternative total distance.

Kilometer savingsTime savings-3%-19%

Ratios	Circuity
Circuity index (C _{km}) Ratio km _{eff} /km _{eud}	1.54
Kilometer ratio (R _{km}) Ratio km _{eff} /km _{alt}	0.97
 Ratio km_{eff}/km_{alt} for access 	5.75
 Ratio km_{eff}/km_{alt} for egress 	7.73
 Ratio km_{eff}/km_{alt} in-vehicle 	0.9
Objective time ratio (R_{tO}) Ratio t_{eff}^{O}/t_{alt}^{O}	0.81
Objective time ratio (R_{tP}) Ratio t_{eff}^{P}/t_{alt}^{P}	0.82

 Table 1 Kilometer and time savings between effective, alternative and Euclidean routes
 Source: D. Moinse (2023) ©

[13] Ciscal-Terry, W., Dell'Amico, M., Hadjidimitriou, N. S., & Iori, M. (2016). An analysis of drivers route choice behaviour using GPS data and optimal alternatives. *Journal of Transport Geography*, 51, 119-129. DOI: 10/gm9sjm
 [14] Wardman, M. (2001). A review of British evidence on time and service quality valuations. *Transportation Research Part E: Logistics and Transportation Review*, 37(2), 107-128. https://doi.org/10/fcxbb3
 [15] Hörl, S., & Balac, M. (2021). Introducing the eqasim pipeline: From raw data to agent-based transport simulation. *Procedia Computer Science*, 184, 712-719. https://doi.org/10/grzkbq





pattern (76.7°),

alternative routes ($\alpha_{alt})$ with low detours

The linear regression model demonstrates

a **positive relation** between an angle

approaching **space inversion** and the

objective time savings of an effective

to the destination (110.5°).

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n=170



0%

-20%



Legend

Type of effective segment:

Angle of effective segments with detours $\alpha_{_{eff}}$ (degrees)

90° 80°

100°

Fig. 4 Linear regression model crossing angle patterns and time savings Source: D. Moinse (2023) ©

[16] Tobler, W. R. (1961). Map transformations of geographic space [Thesis, University of Washington]. https://digital.lib.washington.edu:443/researchworks/handle/1773/5629

unlike

Û

inversion

route (R_t^O).

3. Optimization strategies

a) Classification of E-TVS strategies

Main forms of detours [17]:

- **1. Transfer avoidance**: The willingness to bypass a transit line by connecting to a more distant station (n=152);
- **2. Attractiveness of further stations**: Benefits from better frequency and express trains (n=12);
- **3.** Reduced time on board public transport: A more distant but with an equivalent level of service (LOS) to reduce transit time (n=7).

Preference for an extra cycling access or egress of + 9 minutes to avoid a transfer [18].

The main reason for the analyzed detours corresponds to the search for transfer optimization.

Optimization detour-based strategy 1 Avoiding transfers

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Source: D. Moinse (2023) ©

[17] 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 [18] van Mil, J. F. P., Leferink, T. S., Annema, J. A., & van Oort, N. (2020). Insights into Factors Affecting the Combined Bicycle-Transit Mode. *Public Transport*, 13(3), 649-673. DOI: 10.1007/s12469-020-00240-2



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**^P (time saving); ٠
- Z values: km_{alt} km_{eff} •

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Four types of E-TVS route profiles emerge.

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

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



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Fig. 6 Clustering of intermodal journeys comprising detours Source: D. Moinse (2023) ©

n=129

10/13

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. Moinse (2023) ©



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

Main insights

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	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 Hautsde-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

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17 July, 2023 in Montréal



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Questionnaire protocol

2. Geocoding

1. Travel chain

Α

G1Q01*: Public transport [closed-ended] G1Q02*: Departure and stations arrival [openended1 G1003*: Access mode(s) [closed-ended] G1Q04* : Access route comfort [evaluation] G1Q05*: Egress mode(s) [closed-ended] G1Q06*: Earess route comfort [evaluation] G1Q07*: Type(s) of micromobility [closed-ended] G1Q08*: Type of vehicle propulsion [closed-ended] G1Q09*: Vehicle ownership [closed-ended] G1O10*: Intermodal

Origin G2Q01: place [open-ended] G2Q02: Origin place [mapping] G2Q03: Destination place [textual] G2Q04: Destination place [mapping] G2O05*: Shortest route [closed-ended] G2Q05a*: Reason(s) for detour [closed-ended] G2Q06*: Intermediate breaks [closed-ended] G2Q06a*: Reason(s) for intermediate breaks [closed-ended]

3. Trip patterns

G3Q01*: Boarding [closed-ended] G3Q01a*: Collective mode(s) [closed-ended] G3Q01b*: Reason(s) for boarding [closed-ended] G3Q01c*: Parking facilities/ Boarding comfort [closed-ended] G3Q01d*: Obstacles [closed-ended] G3Q01e*: Parking facilities [closedended] G3Q01f*: Parking location [closedended] G3Q02*: Frequency [closed-ended] G3Q03*: Reason(s) for trip [closedended] G3Q06*: Reason(s) for intermodality [ranked] G3Q07a;b;c*: Access mode(s) of substitution [closed-ended] G3Q08a;b;c*: Egress mode(s) of substitution [closed-ended] G3Q09*: Solution(s) [open-ended]

4. Mobility habits

G4O01*: Use of travel modes [closed-ended] G4Q02a;b;c*: Passes for PT, bikesharing and carsharing [closed-ended] G4Q03*: Driving license [closed-ended] G4Q04a;b*: Motorization [closed-ended] G4Q05*: Bike ownership [closed-ended] G4Q06*: Impacts on mode frequency [closedended] G4Q07*: Ideal cities [evaluation] G4Q08*: Housing criteria

[evaluation]

5. User profile

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G5Q01: Gender [closed-ended] G5Q02: Age [closed-ended] G5Q03: Household composition [closed-ended] G5Q04: Professional activity [closed-ended] G5Q05: Type of occupation [closed-ended] G5Q06: Last diploma [closedended] G5Q07: House income [closedended]



experience [closed-ended]



Classification of E-TVS journeys

Optimization detour-based strategy
1: Avoiding transfersOptimization detour-based strategy
2: Attractive stationOptimization detour-based strategy
3: Reduced time on board the train



Legend

Main train station (frequent et express trains)

+++++ Train line

Stop

Voronoï diagram

→ Access leg by

micromobility

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Spatio-temporal circuity coefficient

Kilometer distance (km) $\mathbf{km}_{eff/alt} = km_{access(eff/alt)} + km_{onboard(eff/alt)} + km_{egress(eff/alt)}$ **Objective time** (t^O) $\mathbf{t}^{o}_{eff/alt} = t^{O}_{access(eff/alt)} + t^{O}_{waiting(eff/alt)} + t^{O}_{onboard(eff/alt)} + t^{O}_{egress(eff/alt)}$ **Perceived time** (t^P) [7; 8] $\mathbf{t}^{P}_{eff/alt} = 1.8^{*}t^{P}_{access(eff/alt)} + 2.8^{*}t^{P}_{waiting(eff/alt)} + 1^{*}t^{P}_{onboard(eff/alt)} + 1.8^{*}t^{P}_{egress(eff/alt)}$

Spatial optimization ratio



Temporal optimization ratio

$$\mathbf{R}_{t}^{O} = \frac{\mathbf{t}^{O}_{alt}}{\mathbf{t}^{O}_{eff}} \qquad \qquad \mathbf{R}_{t}^{P} = \frac{\mathbf{t}^{P}_{alt}}{\mathbf{t}^{P}_{eff}}$$



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(latitude) * cos(longitude)
- y = cos(latitude) * sin(longitude)
- z = sin(latitude)

2. Calculation of vectors (AB, BC):

- AB = (xB xA, yB yA, zB zA)
- BC = (xC xB, yC yB, zC zB)

- 3. Calculation of the dot product of AB and BC:
- $AB \cdot BC = (xAB * xBC) + (yAB * yBC) + (zAB * zBC)$

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

- $|| AB || = \sqrt{(xAB^2 + yAB^2 + zAB^2)}$
- $|| BC || = \sqrt{(xBC^2 + yBC^2 + zBC^2)}$

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

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

Transit catchment areas

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)

* 13

* 129

Ε

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

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



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Transit catchment areas





Ride-along interviews (PCTE1)

Characteristics	Participant 1 (PCTE1)
Modal combination	E-scooter + regional train + e-scooter
Optimization strategy	Avoiding metro network + break time
Ride-along date	11 April 2022 (7:00)
Country (region)	France (Hauts-de-France)
Transit line	Regional train (K50)
Origin station	Lille Flandres
Destination station	Maubeuge
Kilometers	97.3 (1.4 + 94.4 + 1.5)
Minutes	84 (6 + 72 + 6)
Trip frequency	1 time per week
Trip purpose	Commuting (working)
Intermodal experience	6 months
Age	23
Gender	Female

Source: D. Moinse (2022)



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Ride-along interviews (PCTE1)





Legend



Ride-along interviews (PCTE2)

Characteristics	Participant 2 (PCTE2)
Modal combination	E-scooter + metro + e-scooter
Optimization strategy	Metro station choice
Ride-along date	25 March 2022 (à8:30)
Country (region)	France (Hauts-de-France)
Transit line	Metro (Line 1)
Origin station	République - Beaux-Arts
Destination station	Cité Scientifique Pr. Gabillard
Kilometers	11.4 (1.3 + 7.9 + 0.5 + 1.7)
Minutes	30 (4 + 15 + 2 + 9)
Trip frequency	2 times per week
Trip purpose	Commuting (education)
Intermodal experience	1 year
Age	26
Gender	Male

Source: D. Moinse (2022)

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Ride-along interviews (PCTE1)





Legend



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

Alternative access trip

Subway station

Walking egress trip

Egress trip by subway