



Photography: Moïnse, 2023

Keywords: Transit-Oriented Development (TOD); Data Science; Predictive Modeling; Urban Planning; Machine Learning (ML); Classification; Adaptive Algorithms

Enhancing Transit-Oriented Development with Micro-mobility:

A Renewed Node-Place Index Approach in the Hauts-de-France Region

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Transport and Geography: Sustainable transit-oriented development (STOD): new perspectives and advances

28th August 2024



Overview

1. Introduction

- a. *Node Place Model*
- b. *A Growing Model*
- c. *Research Aim*

2. Methodology

- a. *Case Study*
- b. *Station Areas*
- c. *Methodological Framework*

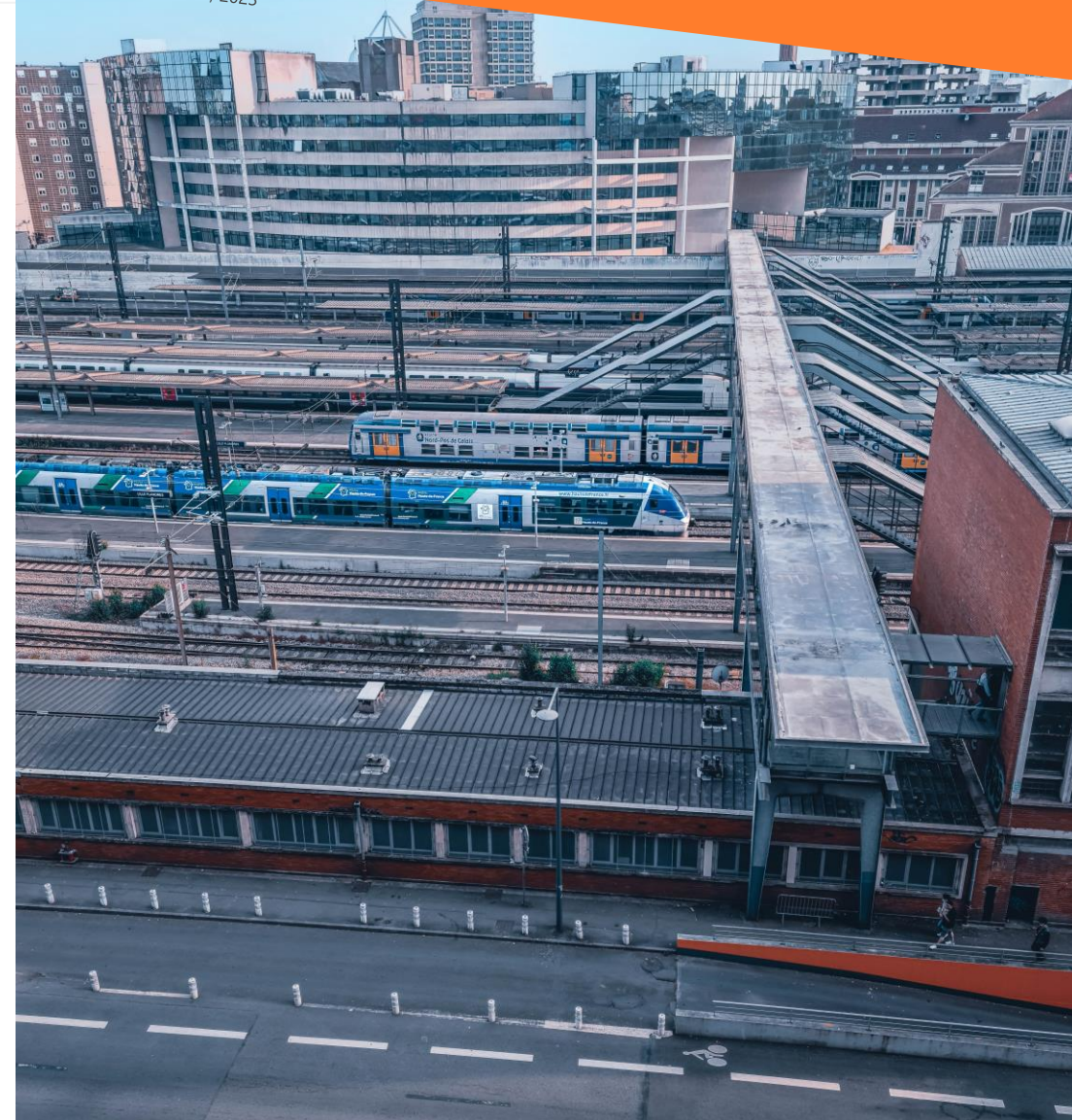
3. Findings

- a. *Influence on Ridership*
- b. *Cube Diagrams of the NPART Model*
- c. *Classification*

4. Conclusion

- a. *Model Reproducibility*
- b. *Discussion*

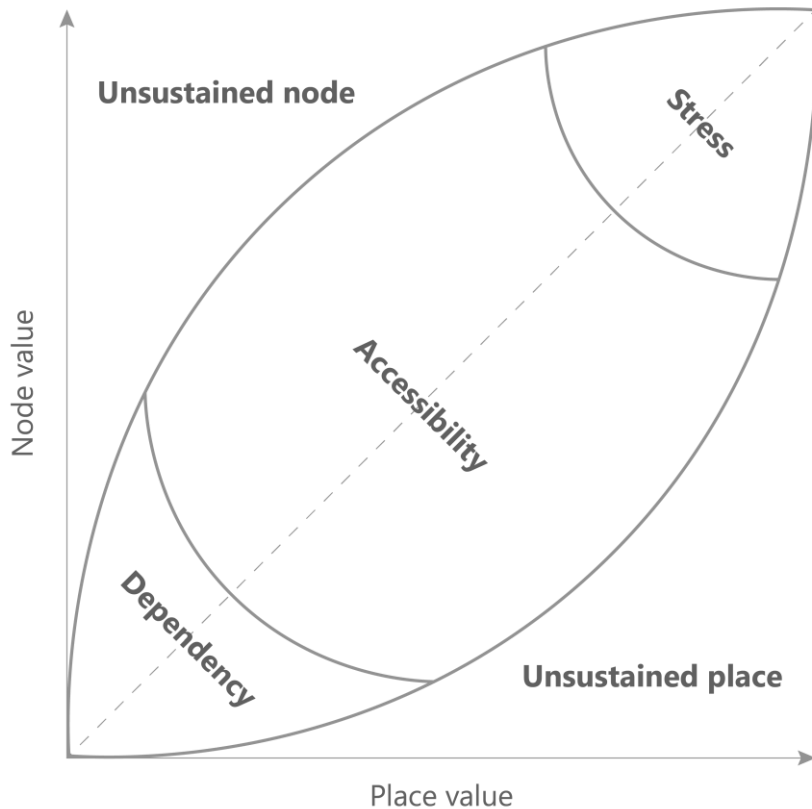
Photography: Moinse, 2023



Node Place Model

Evaluating the quality of transit services and the intensity of activities within a specific area to determine **the potential for transit-oriented development** [1; 2]:

- Shift from planning for mobility to **planning for sustainable accessibility**, by achieving integration between transport and land-use planning [3; 4];
- **Multi-criteria** analysis tool and **normative typology** of station areas [5].



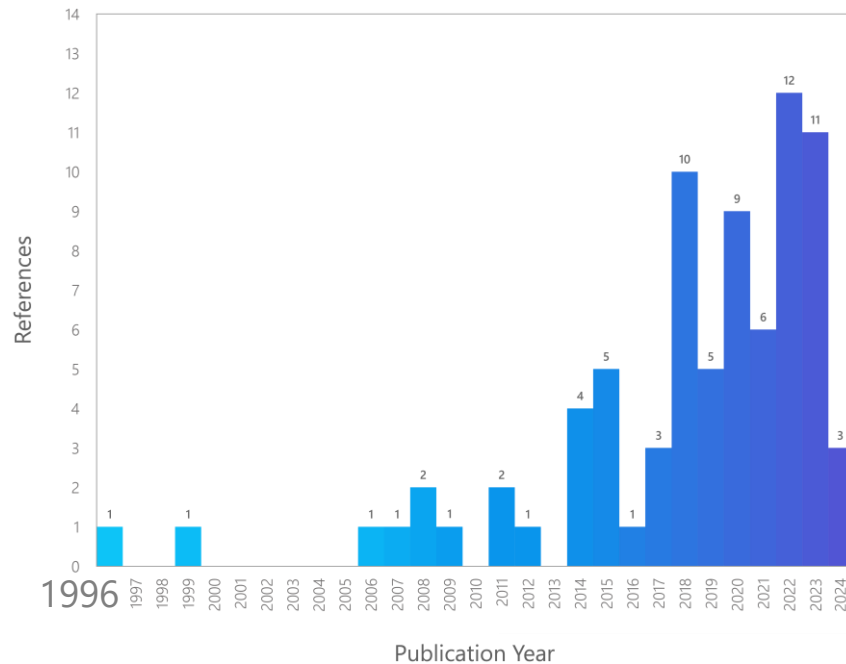
Source: Diagram conceptualized by Bertolini (1999, p. 202) and reinterpreted by Yang et Song (2021, p. 3)
Redesign: Authors, 2024

- [1] Bertolini, L. (1996). Nodes and Places: Complexities of Railway Station Redevelopment. *European Planning Studies*, 4(3), 331-345. <https://doi.org/10/fr4z3r>
- [2] Bertolini, L. (1999). Spatial Development Patterns and Public Transport: The Application of an Analytical Model in the Netherlands. *Planning Practice and Research*. <https://doi.org/10/fckj75>
- [3] Banister, D. (2008). The Sustainable Mobility Paradigm. *Transport Policy*, 15(2), 73-80. <https://doi.org/10/csng4v>
- [4] Caset, F., Vale, D. S., & Viana, C. M. (2018). Measuring the Accessibility of Railway Stations in the Brussels Regional Express Network: A Node-Place Modeling Approach. *Networks and Spatial Economics*, 18(3), 495-530. <https://doi.org/10/gjt5w3>
- [5] Higgins, C. D., & Kanaroglou, P. S. (2016). Forty Years of Modelling Rapid Transit's Land Value Uplift in North America: Moving Beyond the Tip of the Iceberg. *Transport Reviews*, 36(5), 610-634. <https://doi.org/10/ggw575>

A Growing Model

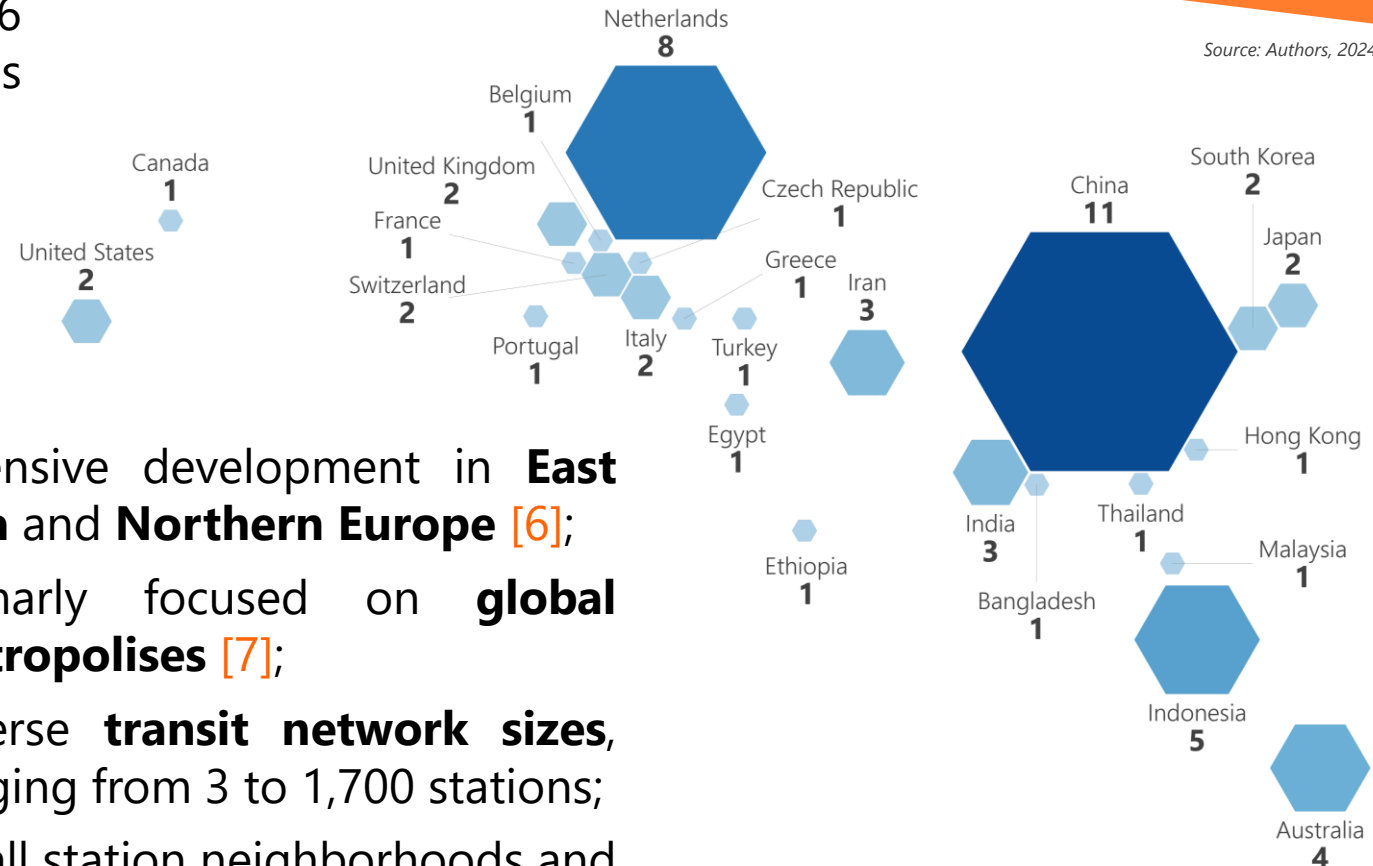
Since the conceptualization of the tool between 1996 and 1999, the number of studies dedicated to this approach has continued **to grow significantly** [6]:

- **79 bibliographic references** listed.



Source: Authors, 2024

- Extensive development in **East Asia** and **Northern Europe** [6];
- Primarily focused on **global metropolises** [7];
- Diverse **transit network sizes**, ranging from 3 to 1,700 stations;
- Small station neighborhoods and limited consideration for **cycling**.



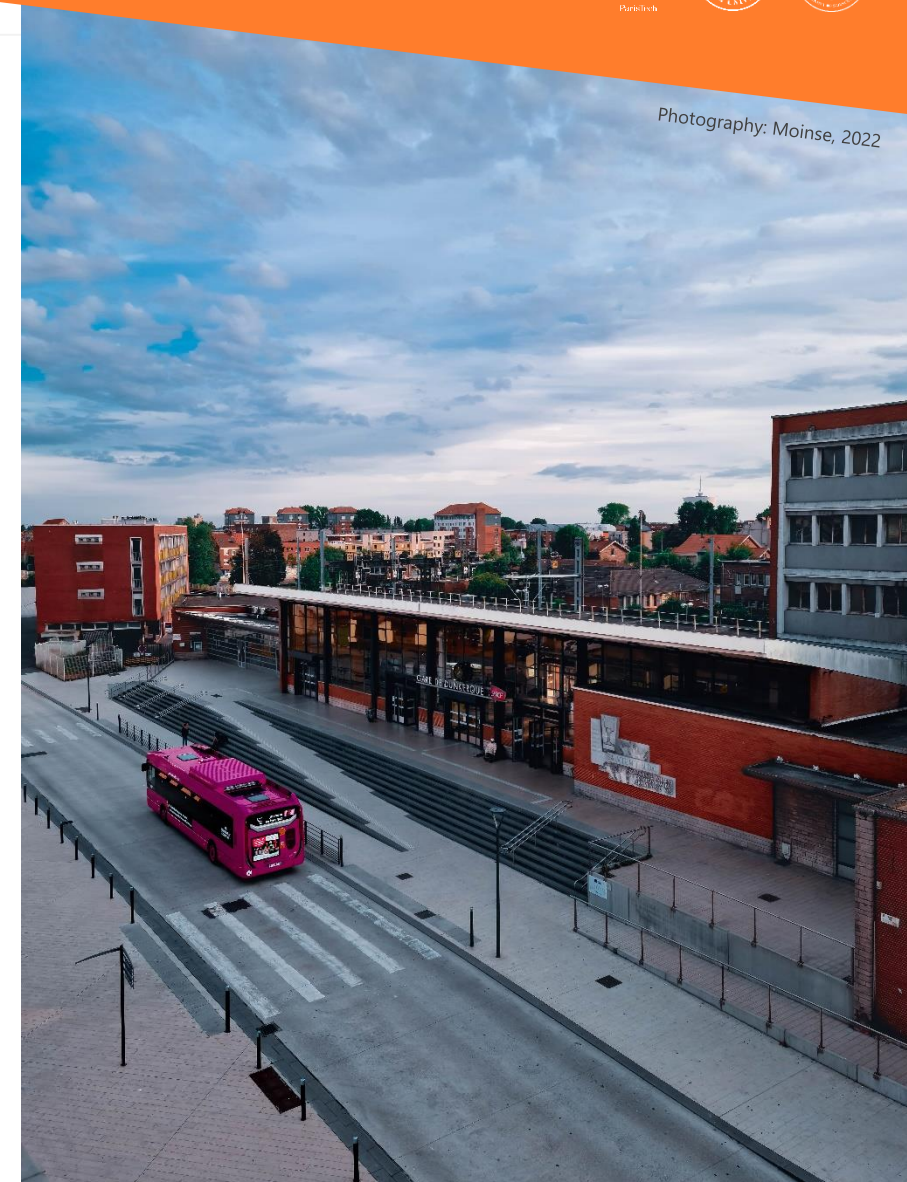
Source: Authors, 2024

[6] Ibrahim, S., Ayad, H., & Saadallah, D. (2022). Planning Transit-Oriented Development (TOD): A Systematic Literature Review of Measuring the Transit-Oriented Development Levels. *International Journal of Transport Development and Integration*, 6, 378-398. <https://doi.org/10/gr9c72>

[7] Nigro, A., Bertolini, L., & Moccia, F. D. (2019). Land Use and Public Transport Integration in Small Cities and Towns: Assessment Methodology and Application. *Journal of Transport Geography*, 74, 110-124. <https://doi.org/10/gf8zgr>

Research Aims

1. **Spatial Temporal Contextualization:** Adopting an intermodal perspective by considering the contributions of cycling, while analyzing temporal dynamics;
2. **Calibration:** Enhancing the model by incorporating new relevant dimensions to improve the Transit-Oriented Development concept;
3. **Geographic Scale:** Applying the revised model to the Hauts-de-France Region, characterized by both urban and rural areas;
4. **Descriptive Statistics:** Assessing the influence of various variables on station attractiveness;
5. **Classification:** Contextualizing nodes and their surroundings to develop a typology of stations;
6. **Automation:** Developing automated techniques for data collection and analysis to ensure the model's reproducibility.



HAUTS-DE-FRANCE REGION



Legend

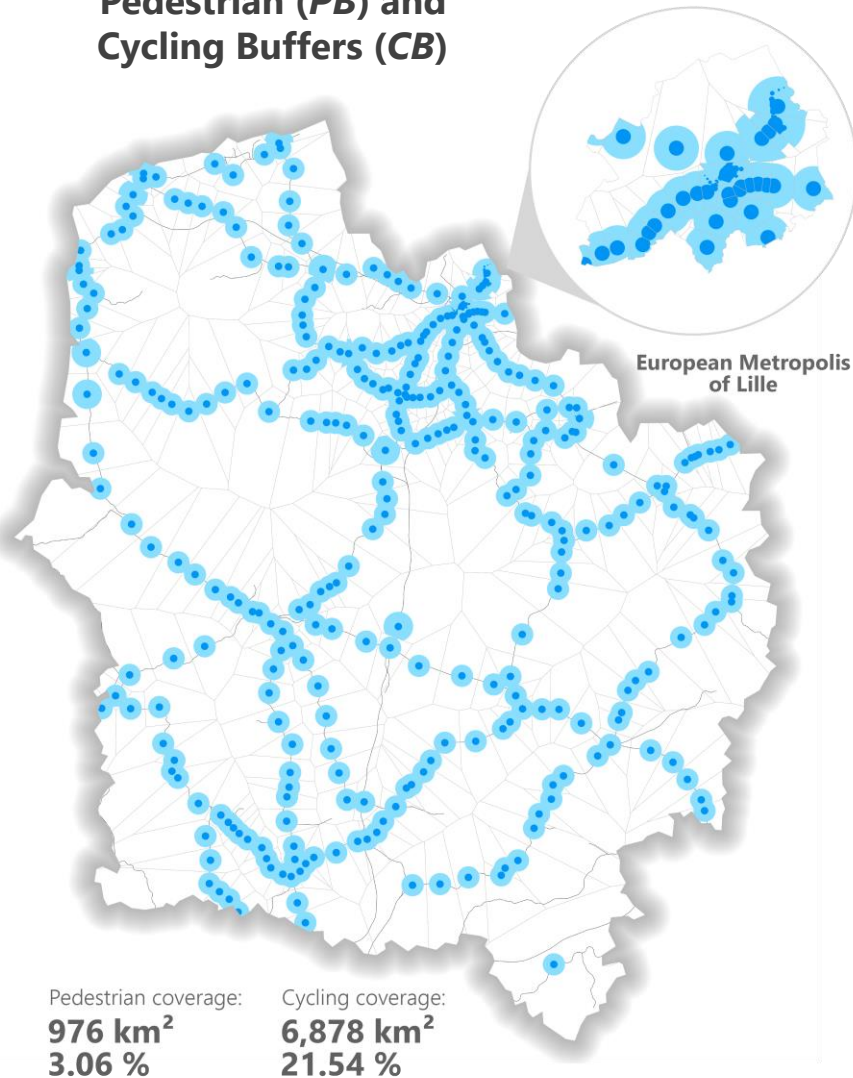
- Railway Stations
- Railway Network
- Segregated Cycle Lane
- Cycling Path

Case Study

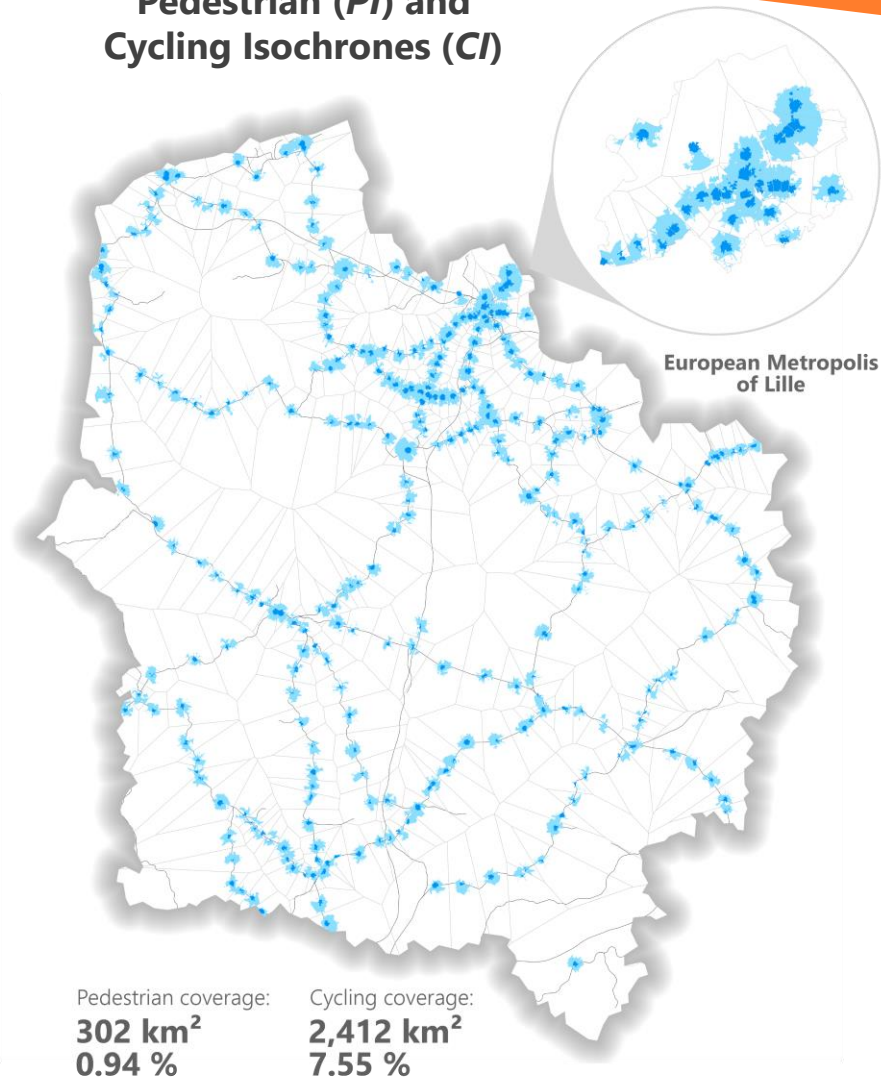
Focus on **the Hauts-de-France** administrative region:

- Formed in 2015 from the merger of the Nord-Pas-de-Calais and Picardie Regions;
- Well-developed transport network, including **rail connections**;
- Densely interconnected with a **polycentric** railway network, organized around the European Metropolis of Lille, the conurbation of the Mining Basin, medium-sized towns, and 'rurban' areas;
- **12.5 % rail modal share** in the region, compared to 11% on average in France;
- **2.2 % bicycle** modal share, against 3.5 % average nationwide [8].

Pedestrian (PB) and Cycling Buffers (CB)



Pedestrian (PI) and Cycling Isochrones (CI)



Legend

- 1-km pedestrian area
- 3- and 4-km cycling area
- Voronoi Diagram

Station Areas

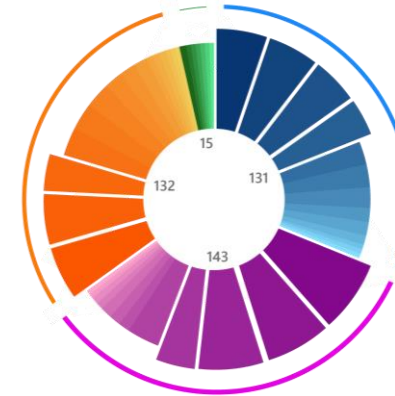
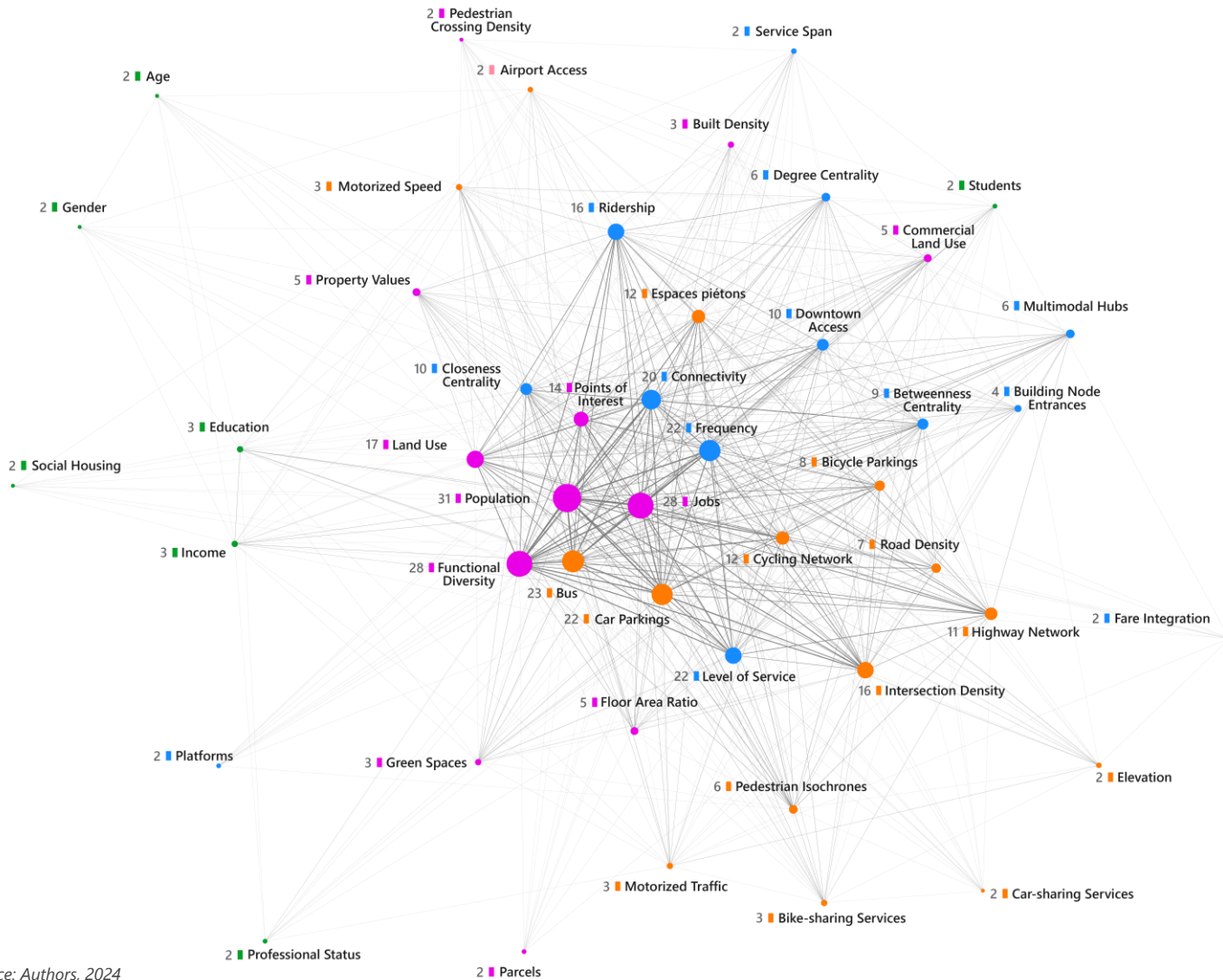
Pedestrian and **Cycling** zones (**buffers** and **isochrones**) for high-speed and regional rail stations, completed by metro and tramway stops (Multimodal Hubs).

Size of station areas based on acceptable distances [9]:

- **1 km** for walking;
- **3 to 4 km** for cycling.

[9] Moïnse, D., & L'Hostis, A. (2024). Optimizing Intermodal Commuting by way of Detours and Breaks: Evidence of Micromobility Users in France. *Journal of Transport Geography*, 116(103821), 1-16. <https://doi.org/10/gtkvs9>

Main Indicators from the Literature



Legend

- Node and Ridership dimensions
- Place dimension
- Accessibility dimension
- Demographics dimension

4 dimensions

NPART Model:

- *Node* (Transit);
- *Place* (Development);
- *Accessibility* (Oriented);
- *Ridership* (Demand).

Node Place Accessibility Ridership per Time (NPART)

Node (N)

Place (P)

Accessibility (A)

Ridership per time (RT)

Transit Facilities

- N1 N2 High-speed train frequency
- N3 N4 Regional train frequency
- N5 N6 Service span

Transit Performance

- N7 Rail speed
- N8 Number of directions
- N9 Degree centrality

Network Metrics

- N10 Closeness centrality
- N11 Betweenness centrality

Destination Accessibility

- N12 Reachable stations within 1 hour
- N13 N14 Access to the regional core (Lille)
- N15 N16 Access to the national core (Paris)

Density

- P1 Population density
- P2 Employment density
- P3 Residential land use
- P4 Commercial land use
- P5 Industrial and office land use
- P6 Green space land use

Diversity

PoIs

Land Value

Demographics

- P7 P8 P9 Local, urban and regional POIs
- P10 P11 Residential and office real estate
- P12 Public housing
- P13 Household income

Walkability

Bikeability

Connectivity

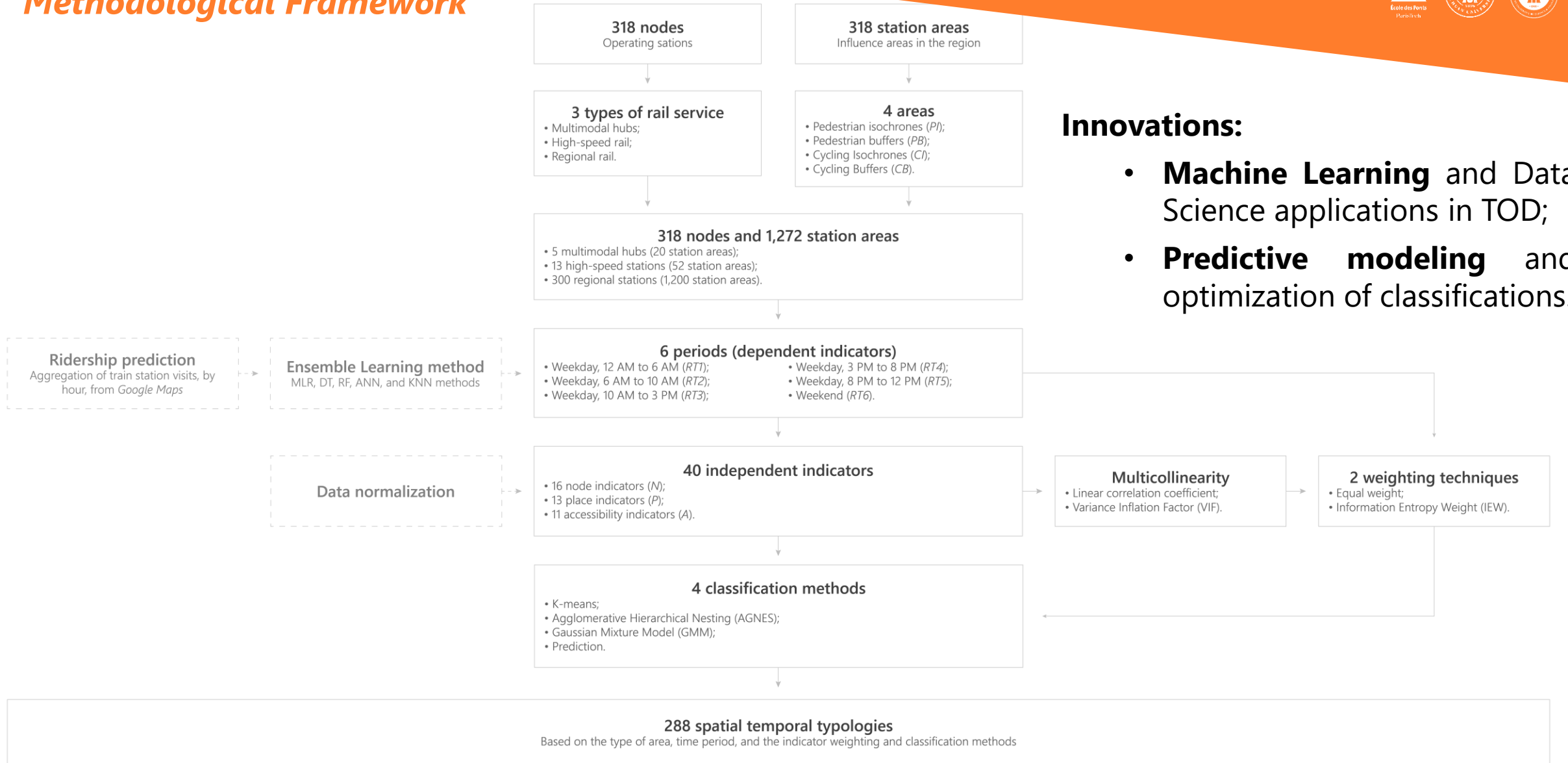
Demand Management

- A1 Pedestrian network
- A2 Intersection density
- A3 Pedshed and bikeshed ratio
- A4 Cycling network
- A5 Bicycle parking capacity
- A6 Shared bicycles
- A7 Metro and tramway stops
- A8 BRT and bus stops
- A9 Motorized speed limit
- A10 Car parking area
- A11 Household motorization rate

- RT1 Weekday (12 AM to 6 AM)
- RT2 Weekday (6 AM to 10 AM)
- RT3 Weekday (10 AM to 3 PM)
- RT4 Weeday (3 PM to 8 PM)
- RT5 Weekday (8 PM to 12 AM)
- RT6 Weekend

46 indicators

Methodological Framework

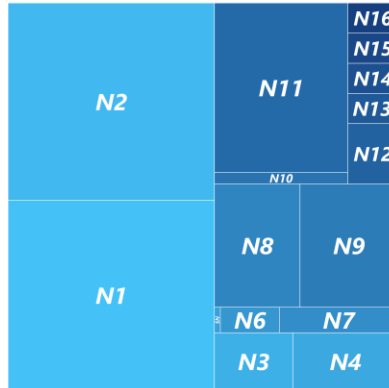
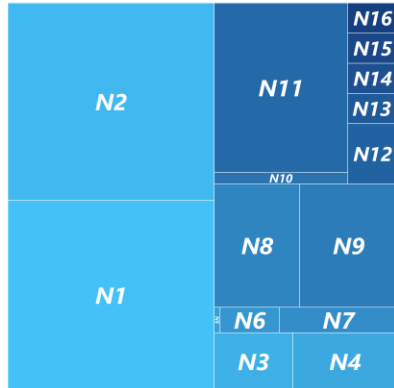


Innovations:

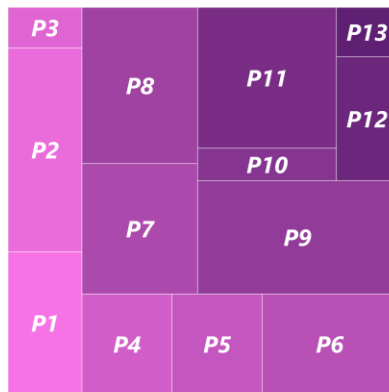
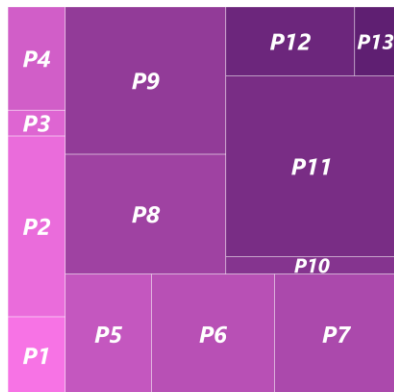
- **Machine Learning** and Data Science applications in TOD;
- **Predictive modeling** and optimization of classifications.

Pedestrian Isochrones (PI)

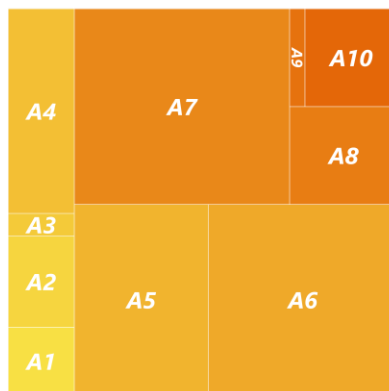
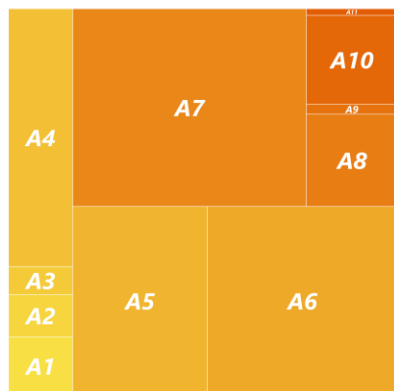
Cycling Isochrones (CI)



Node (N)



Place (P)



Accessibility (A)

Influence on Ridership

Each indicator has been assigned a weight for both pedestrian and cycling isochrones, reflecting **its relative influence on ridership**.

ID	Indicators	PI	CI
Node			
N2	Daily frequency of high-speed service (weekend)	0.27	0.27
N1	Daily frequency of high-speed service (weekday)	0.26	0.26
N11	Betweenness centrality (shortest paths)	0.15	0.15
Place			
P11	Industrial, commercial and office real estate	0.21	0.13
P9	Superior POIs	0.16	0.15
P8	Intermediate POIs	0.13	0.12
Accessibility			
A7	Number of metro and tramway stops	0.31	0.28
A6	Sharing bicycle station capacity	0.24	0.24
A5	Bicycle parking capacity	0.17	0.17

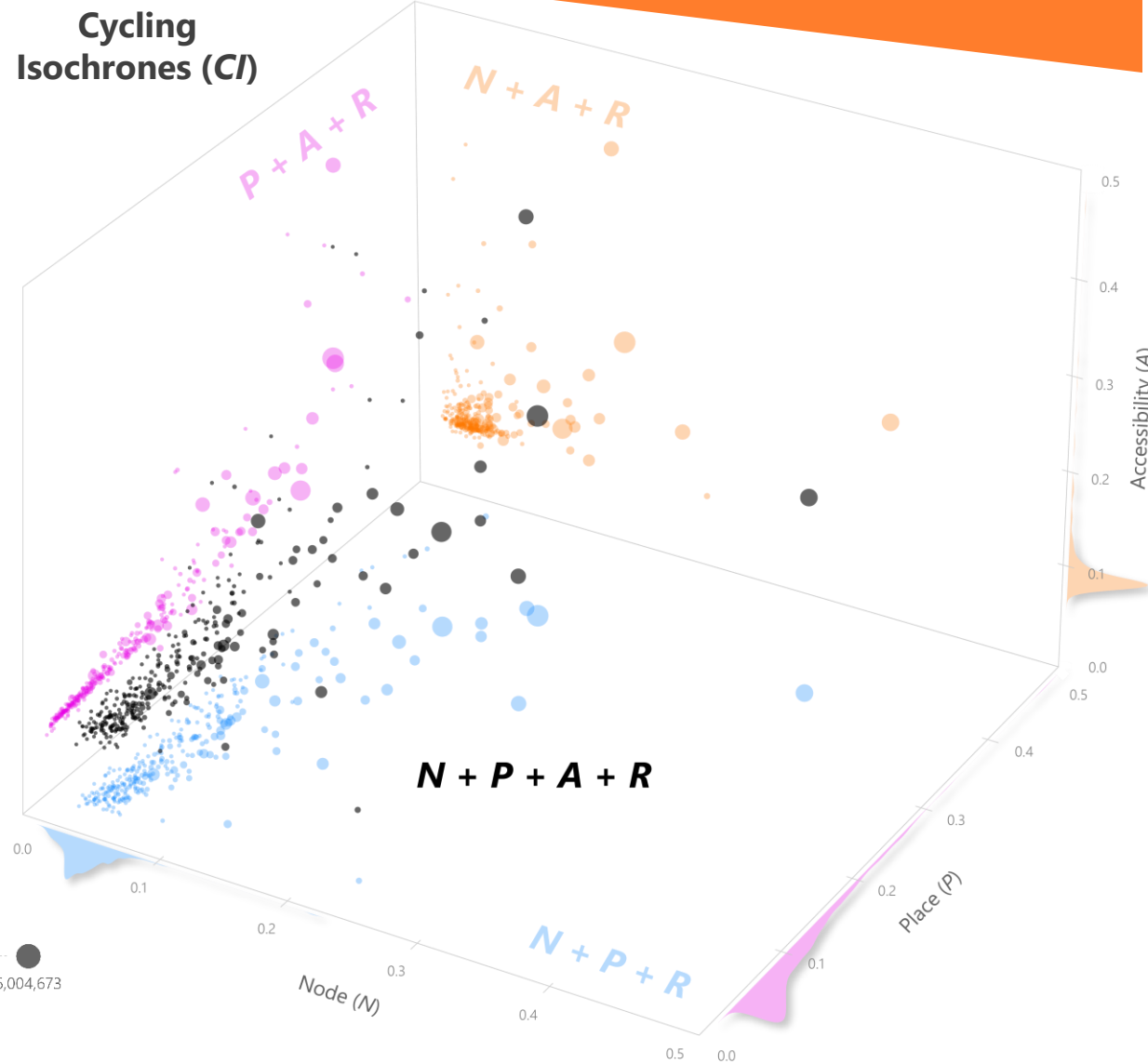
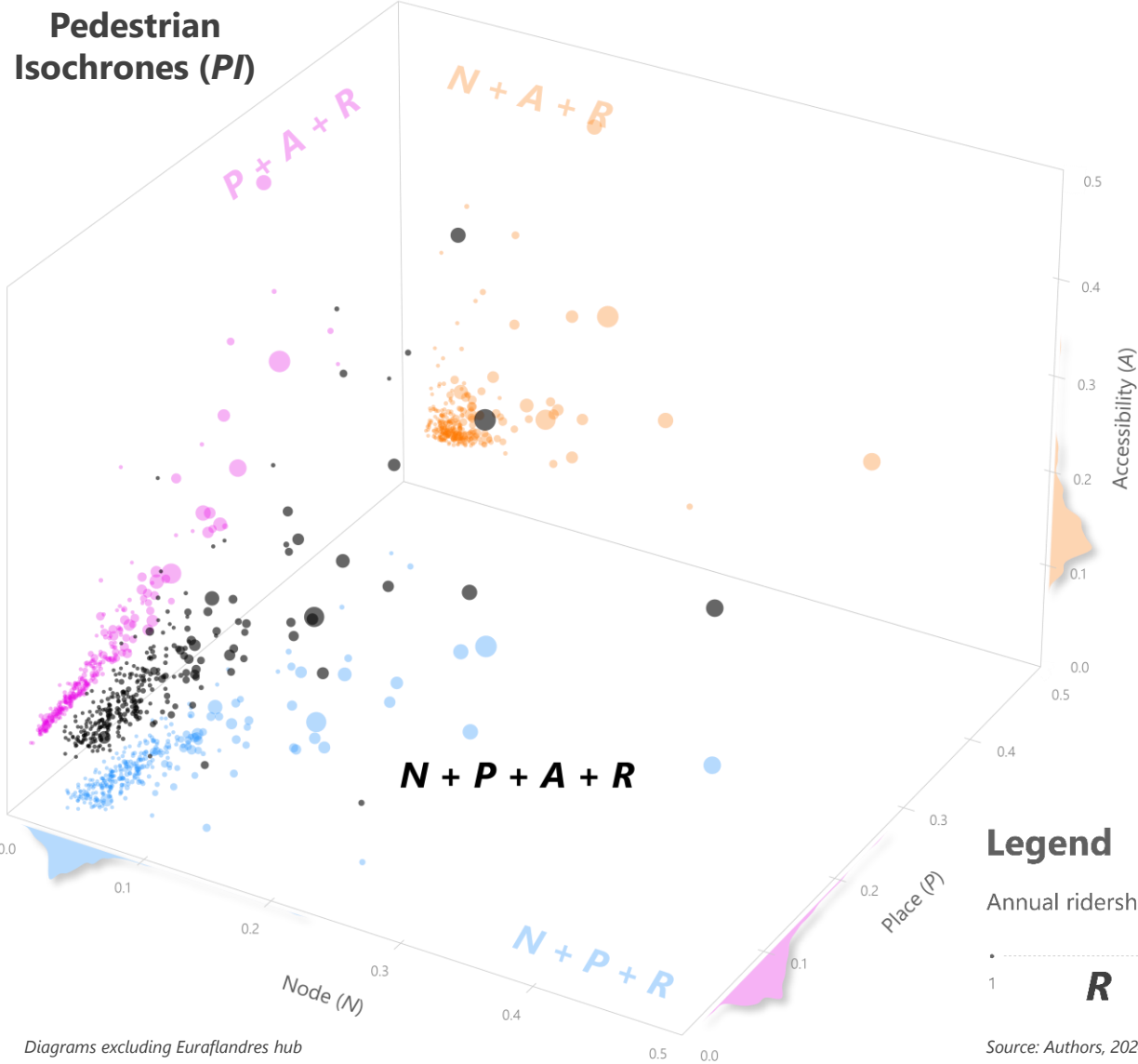
Cube Diagrams of the NPART Model

Information entropy weight (IEW)

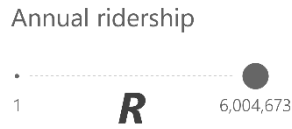


Pedestrian Isochrones (PI)

Cycling Isochrones (CI)



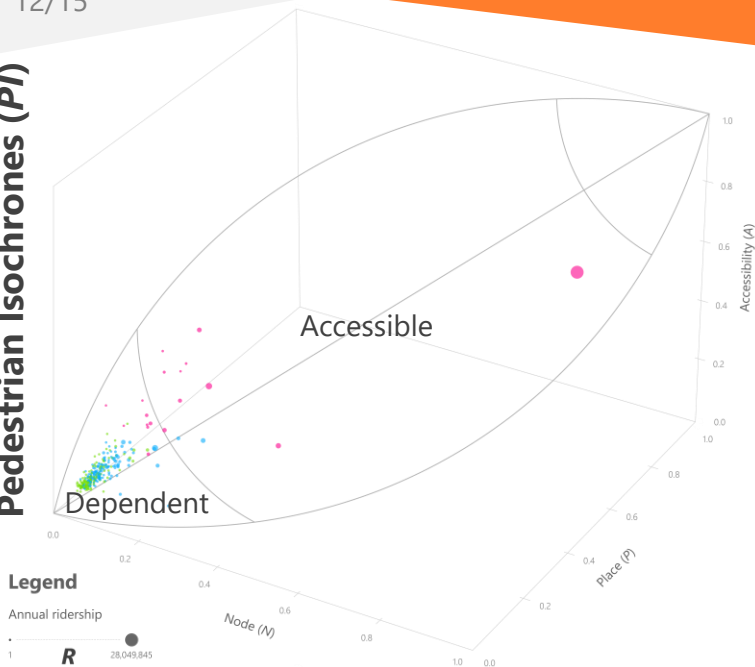
Legend



Source: Authors, 2024

Diagrams excluding Euraflandres hub

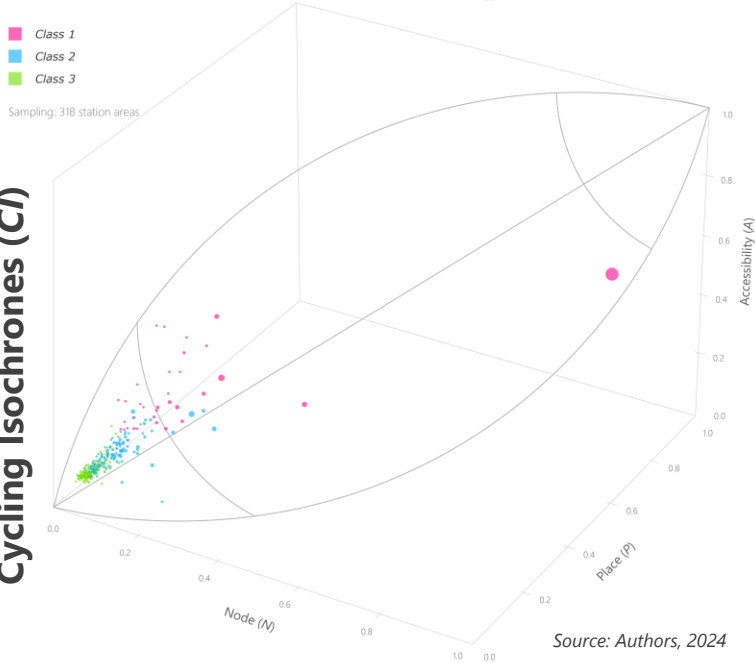
Pedestrian Isochrones (PI)



Pedestrian Isochrones (PI)

	TOTAL	Accessibility	Dependency
Class 1	18	10	8
Class 2	151	2	149
Class 3	149	0	149
TOTAL	318	12	306

Cycling Isochrones (CI)



Cycling Isochrones (CI)

	TOTAL	Accessibility	Dependency
Class 1	34	19	15
Class 2	133	4	129
Class 3	151	0	151
TOTAL	318	23	295

Classification

3 classes of stations:

- High values across all dimensions (**Class 1**);
- Qualitative service and surroundings, but links poorly connected (**Class 2**);
- Car-centric (**Class 3**).

Extending station areas to a **cycling scale** doubles the number of nodes and their surrounding places considered 'accessible,' thereby upgrading them to **Class 1**.

Characterization

K-means clustering
 Information entropy weight (IEW)
 Tuesday, from 6 AM to 9 AM (RT2)

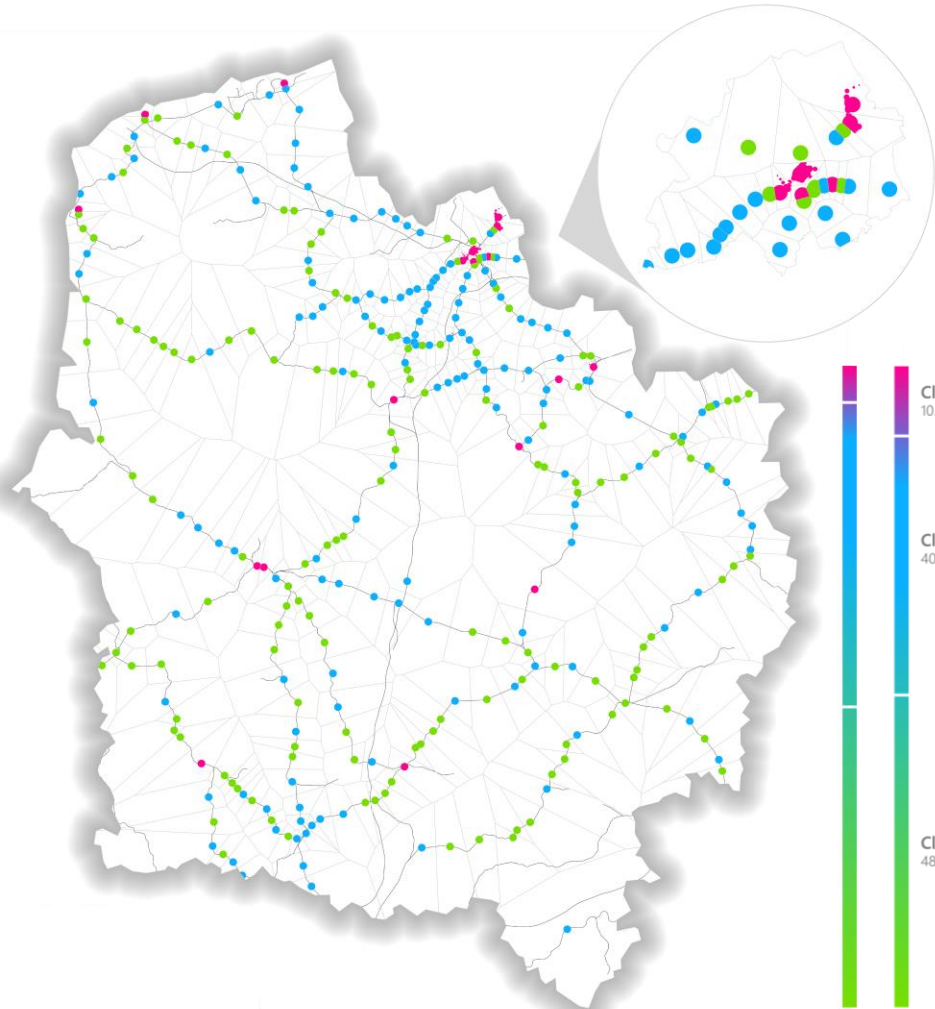


HAUTS-DE-FRANCE REGION

European Metropolis of Lille

HAUTS-DE-FRANCE REGION

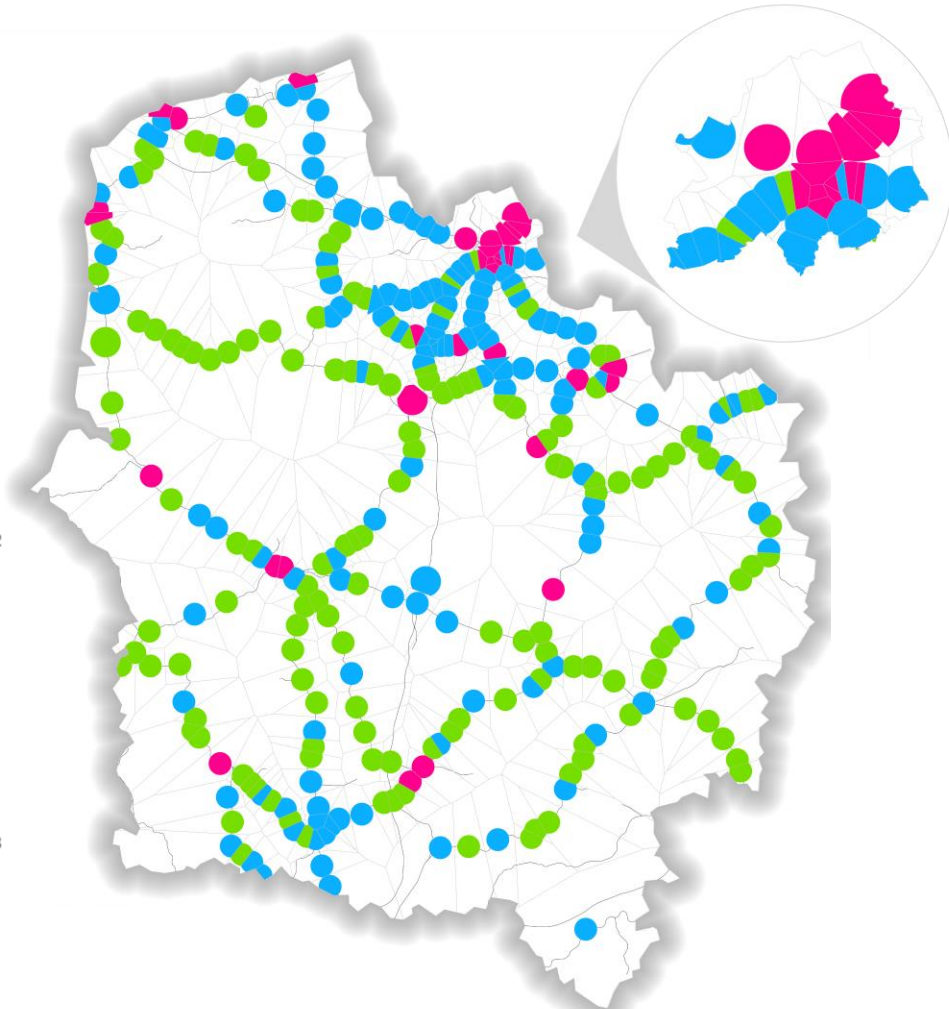
European Metropolis of Lille



Pedestrian Isochrones (PI)



Source: Authors, 2024



Cycling Isochrones (CI)

- ✓ Ridership
- ✓ Frequency
- ✓ Population and job density
- ✓ Commercial land use
- ✓ Green spaces
- ✓ POIs (all types)
- ✓ Real estate values
- ✓ Affordable housing
- ✓ Pedestrian network
- ✓ Cycling facilities
- ✓ Metro and tramway network
- ✗ Road speed limit
- ✗ Vehicle ownership
- ✗ Average income
- ✓ Residential land use
- ✓ Industrial and office land use
- ✗ Sharing bicycles
- ✓ Car parking area
- ✗ Car parking area
- ✓ Average income

1. Codes for Generating Railway Station Neighborhoods

- [Pedestrian and Cycling Buffers](#) ✓
- [Pedestrian and Cycling Isochrones](#) ✓

2. Codes for Spatial and Statistical Data Collection

Node (N) <i>Transit</i> 🚆	Place (P) <i>Development</i> 🏢	Accessibility (A) <i>Oriented</i> 🗺️	Ridership per Time (RT) <i>Demand</i> 🚶
N1: Frequency (Weekdays, High-speed Rail) ✓	P1: Population Density ✓	A1: Length of Walking Paths ✓	RT1: Peak-Hour Ridership (Weekdays) ✓
N2: Frequency (Weekends, High-speed Rail) ✓	P2: Employment Density ✓	A2: Intersection Density ✓	RT2: Off-Peak Hour Ridership (Weekdays) ✓
N3: Frequency (Weekdays, Regional Rail) ✓	P3: Residential Land Use ✓	A3: Pedshed and Bikeshed Ratios ✓	RT3: Peak-Hour Ridership (Weekends) ✓
N4: Frequency (Weekends, Regional Rail) ✓	P4: Commercial and Public Service Land Use ✓	A4: Length of Cycling Paths ✓	RT4: Off-Peak Hour Ridership (Weekends) ✓
N5: Service Span (Weekdays) ✓	P5: Office and Industry Land Use ✓	A5: Cycling Parking Capacity ✓	
N6: Service Span (Weekends) ✓	P6: Green Space Land Use ✓	A6: Public Sharing Bicycles ✓	
N7: Commercial Rail Speed ✓	P7: Proximity Points of Interest ✓	A7: Metro and Tramway Stops ✓	
N8: Number of Directions	P8: Intermediate Points of Interest	A8: BRT and Bus	

Model Reproducibility

Automation of data collection and analysis process.

Exclusively relied on **coding**, avoiding the use of tools such as GIS.

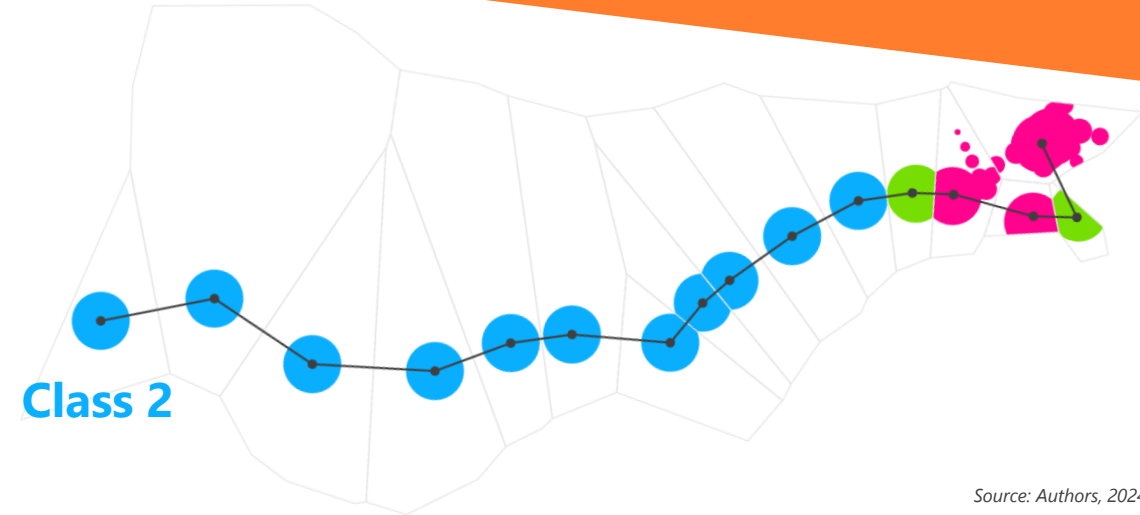
Coding publicly shared in a **GitHub** repository:

- Tutorial for generating geographical areas;
- Collecting and measuring Node, Place, Accessibility, and Ridership per Time data;
- Analyzing data.

Combining Geography and Statistics

Main Findings:

- **Positive association** between **Node** (Transit), **Place** (Development), **Accessibility** (Oriented), and **Ridership** (Demand);
- Integration of micro-mobility aligns with similar urban planning principles as **Bicycle-based TOD** [10];
- **Statistical innovations;**
- Intrinsic link between TOD and **proximity** on a multi-scalar level;
- **Recommendations** to urban planners and policymakers: Optimizing urban development strategies and improving connectivity and accessibility by identifying **high-potential areas** (**Class 2**).



Source: Authors, 2024

Perspectives:

- **Territorial diagnosis** to qualify the typology of stations and provide a more nuance and micro-geographic perspective, based on a case study of a **railway corridor** encompassing the 3 types of stations and station areas.

[10] 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. <https://doi.org/10.1080/15568318.2014.923547>

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Related publications by authors:

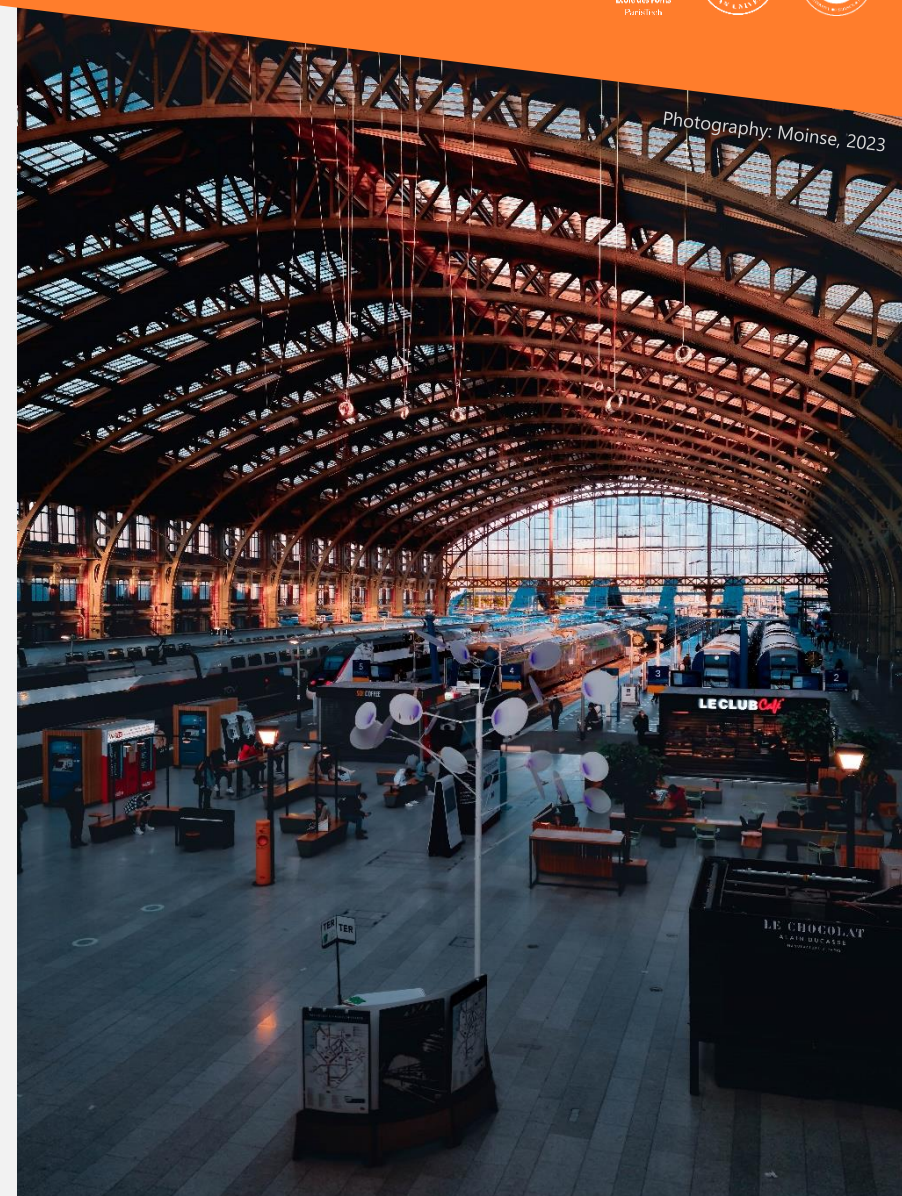
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Amini Pishro, A., L'Hostis, A., Chen, D., Chen, M., Amini Pishro, M., Zhang, Z., Li, J., Zhao, Y., & Zhang, L. (2023). The Integrated ANN-NPRT-HUB Algorithm for Rail-Transit Networks of Smart Cities: A TOD Case Study in Chengdu. *Structure*, 13, 24. <https://doi.org/10/gsmfmx>

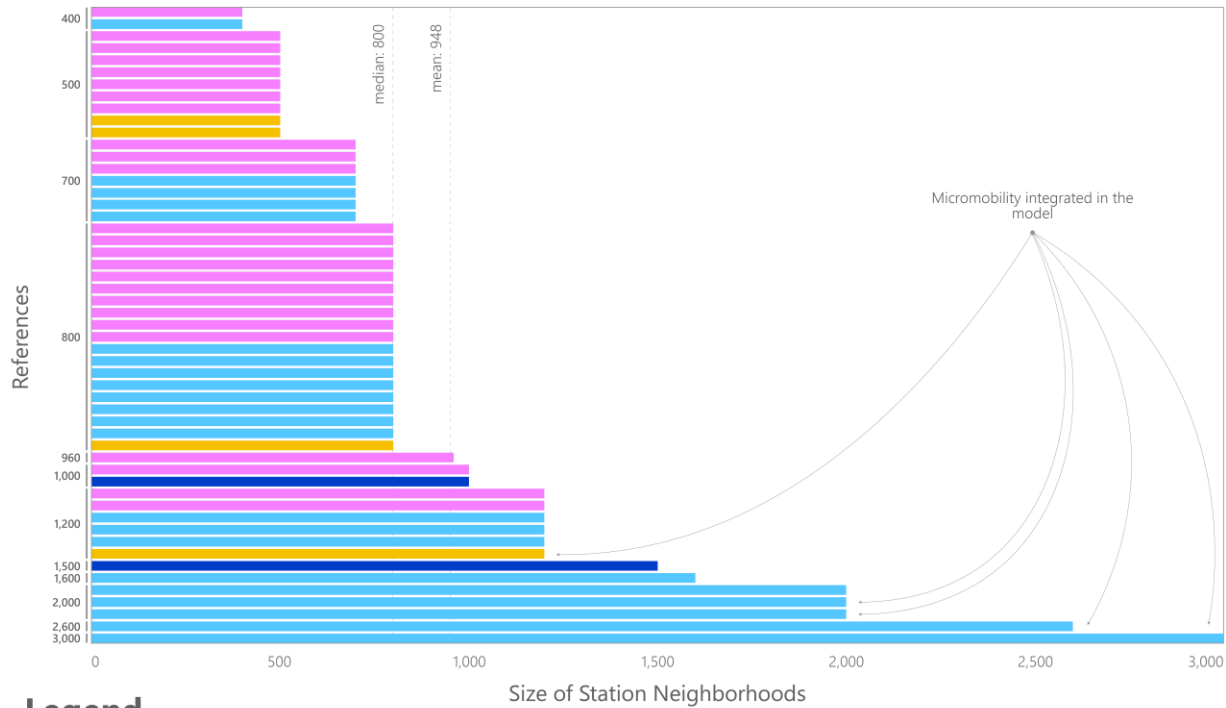
Amini Pishro, A., Yang, Q., Zhang, S., Amini Pishro, M., Zhang, Z., Zhao, Y., Postel, V., Huang, D., & Li, W. (2022). Node, Place, Ridership, and Time Model for Rail-Transit Stations: A Case Study. *Scientific Reports*, 12(1), Article 1. <https://doi.org/10/gtg7fd>

Moïnse, 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. <https://doi.org/10/gqz86>

Many thanks for
your attention!

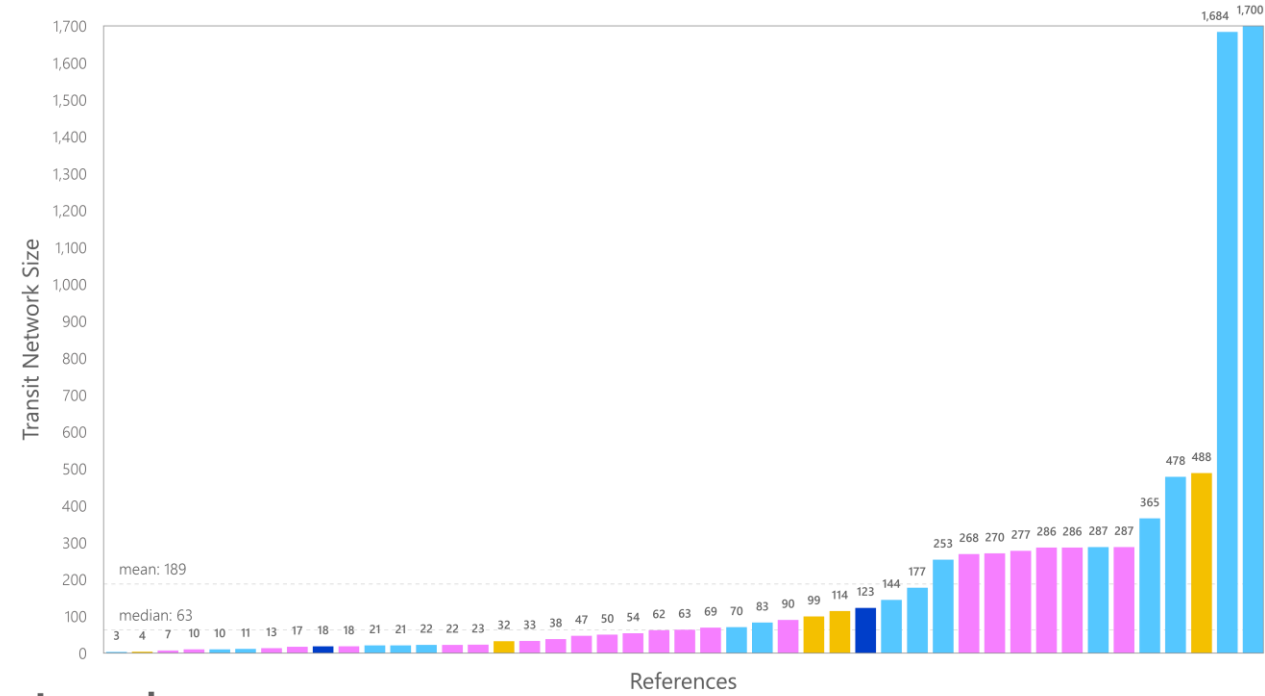


Literature Review



Legend

- High-speed network
- Urban transit network
- Regional train network
- Multimodal hubs

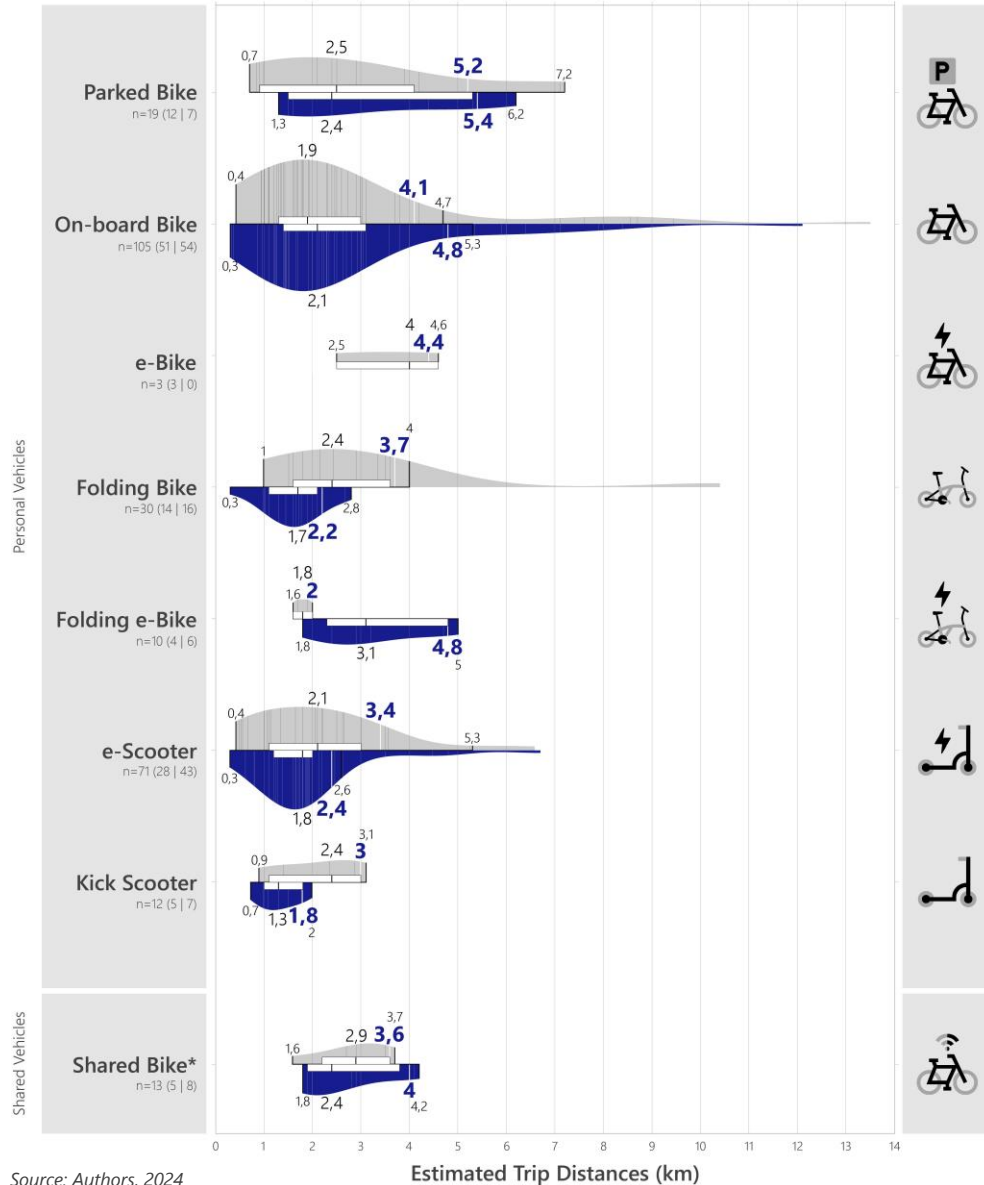


Legend

- High-speed network
- Urban transit network
- Regional train network
- Multimodal hubs

Estimated Trip Distances (km)

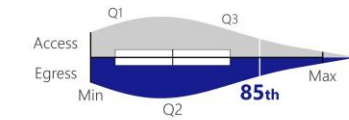
Micromobility Perimeter



Legend

- Access ("first mile")
- Egress ("last mile")

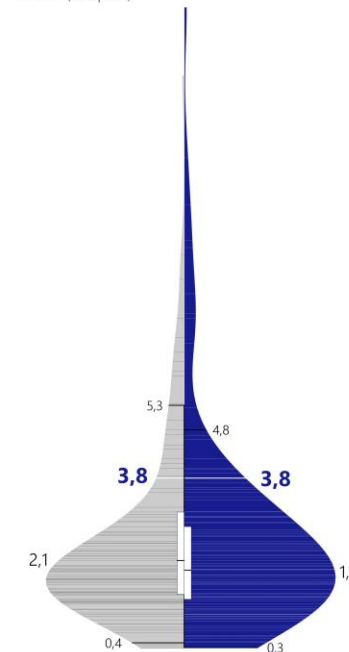
*Station-based (docked) or free-floating micromobility schemes



Min	Lowest value	Q3	Third quartile
Q1	First quartile	85th	85th percentile
Q2	Median	Max	Highest value

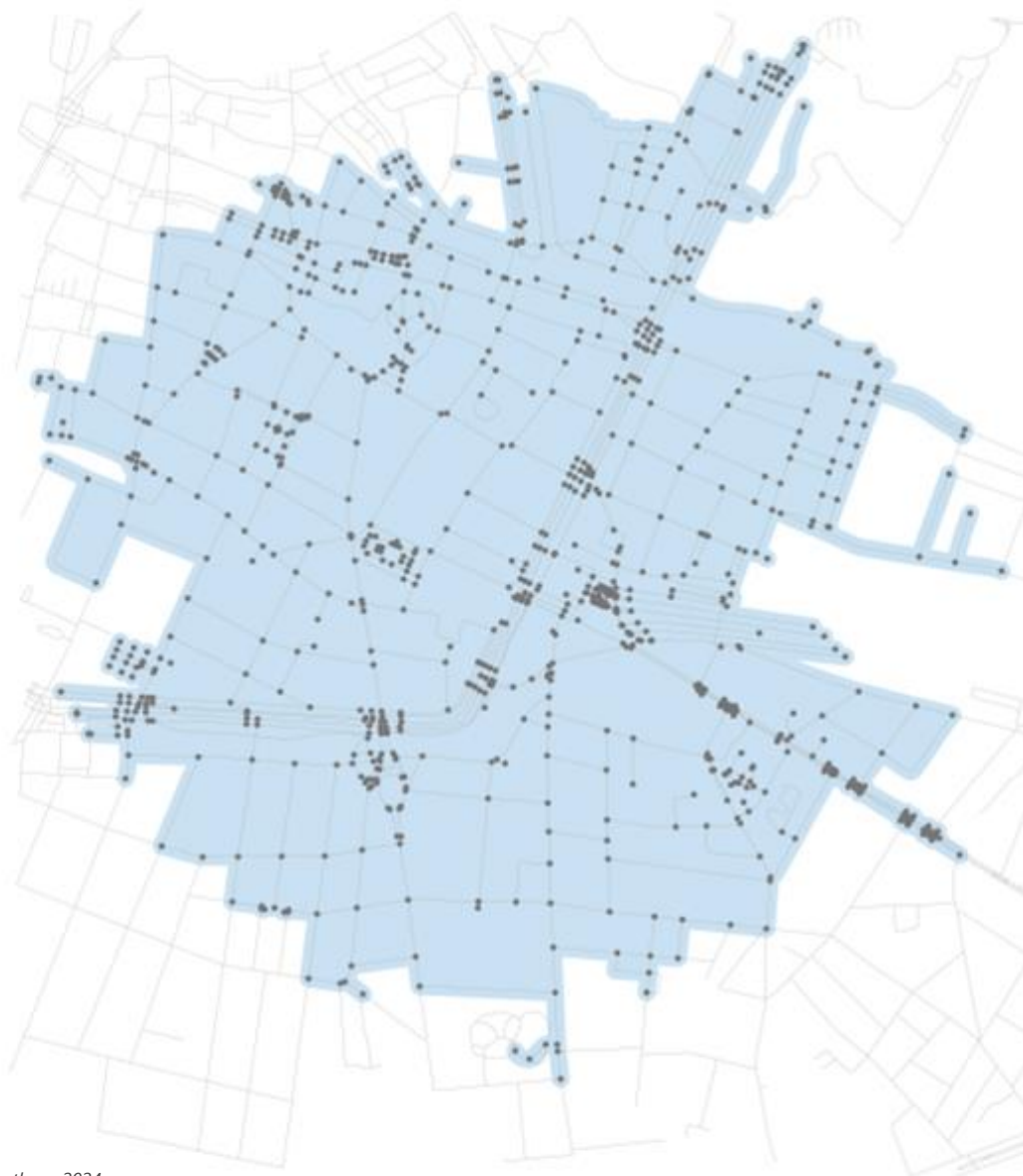
Micromobility Options

All types of light vehicles
n=262 (126 | 136)

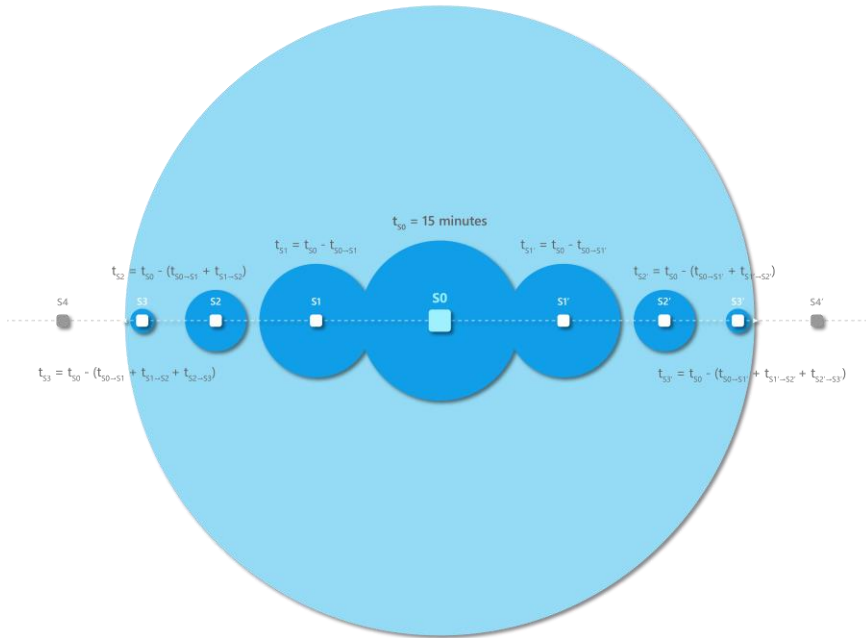


Distances

Isochrones



Size of Station Areas



Legend

Stations:

- Train Station
- Urban Rail Transit Stations

Network:

- Metro or Tramway Line

Studied Areas:

- Pedestrian Buffer or Isochrone
- Cycling Buffer of Isochrone



Legend

Stations:

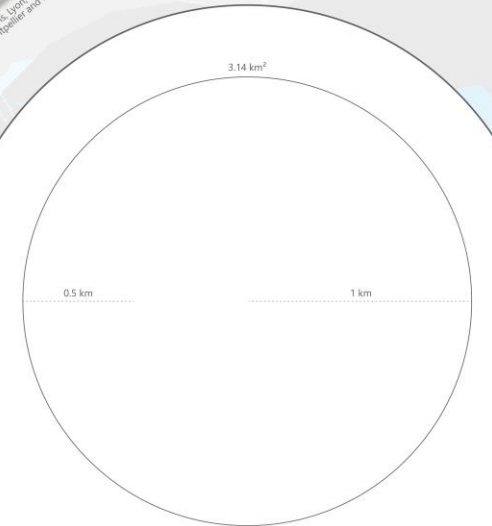
- Lille Flandres and Lille Europe
- Urban Rail Transit Stations

Networks:

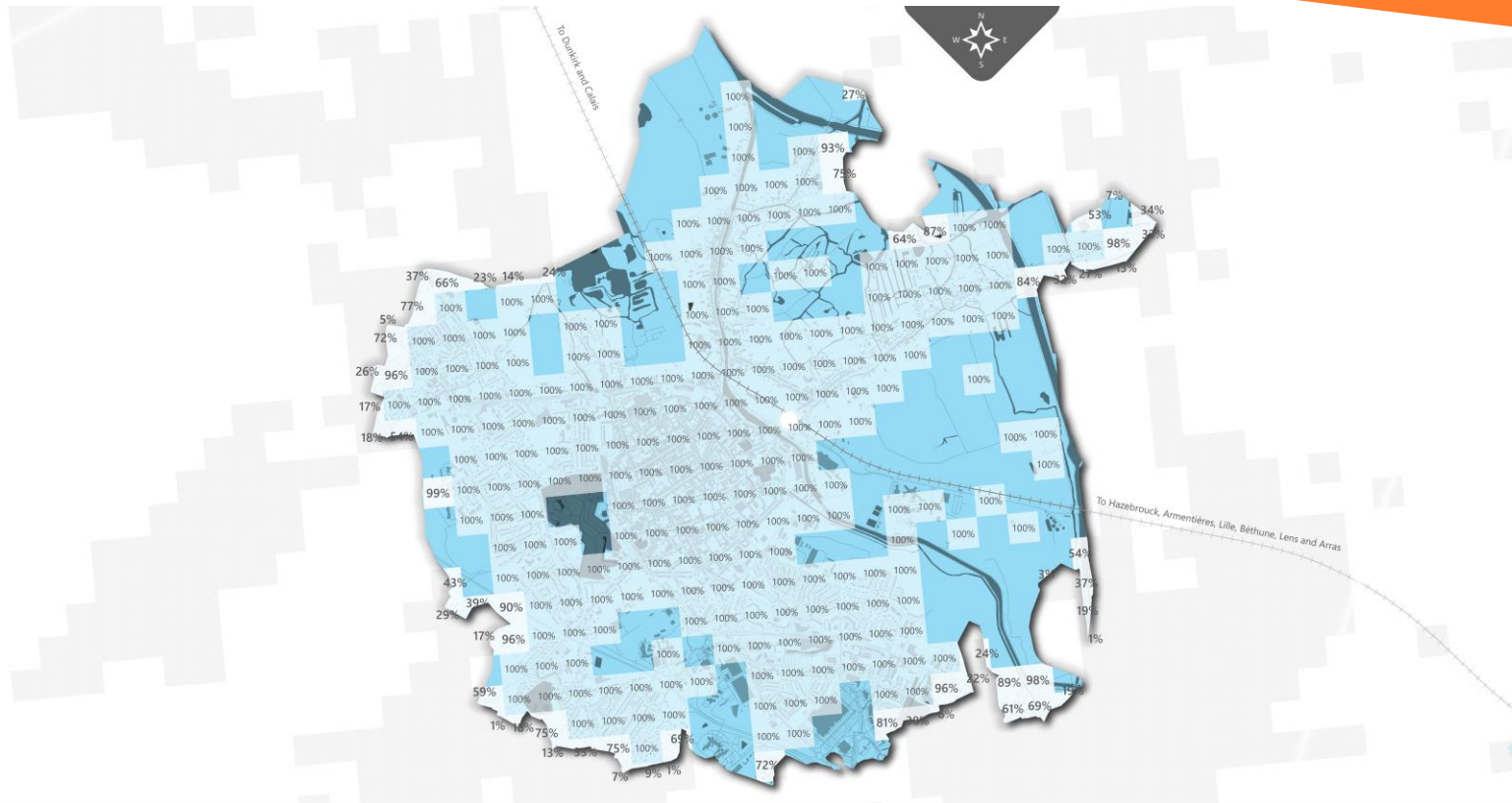
- Railway Line
- Metro or Tramway Line
- Voronoi Diagram

Studied Areas:

- Pedestrian Isochrone
- Cycling Isochrone
- Pedestrian Buffer
- Cycling Buffer



Data Collection



Legend

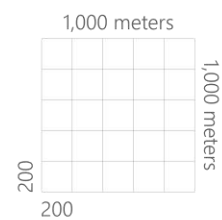
Transit Network:

- Saint-Omer Railway Station
- +—+—+—+ Railway Line

Studied Area:

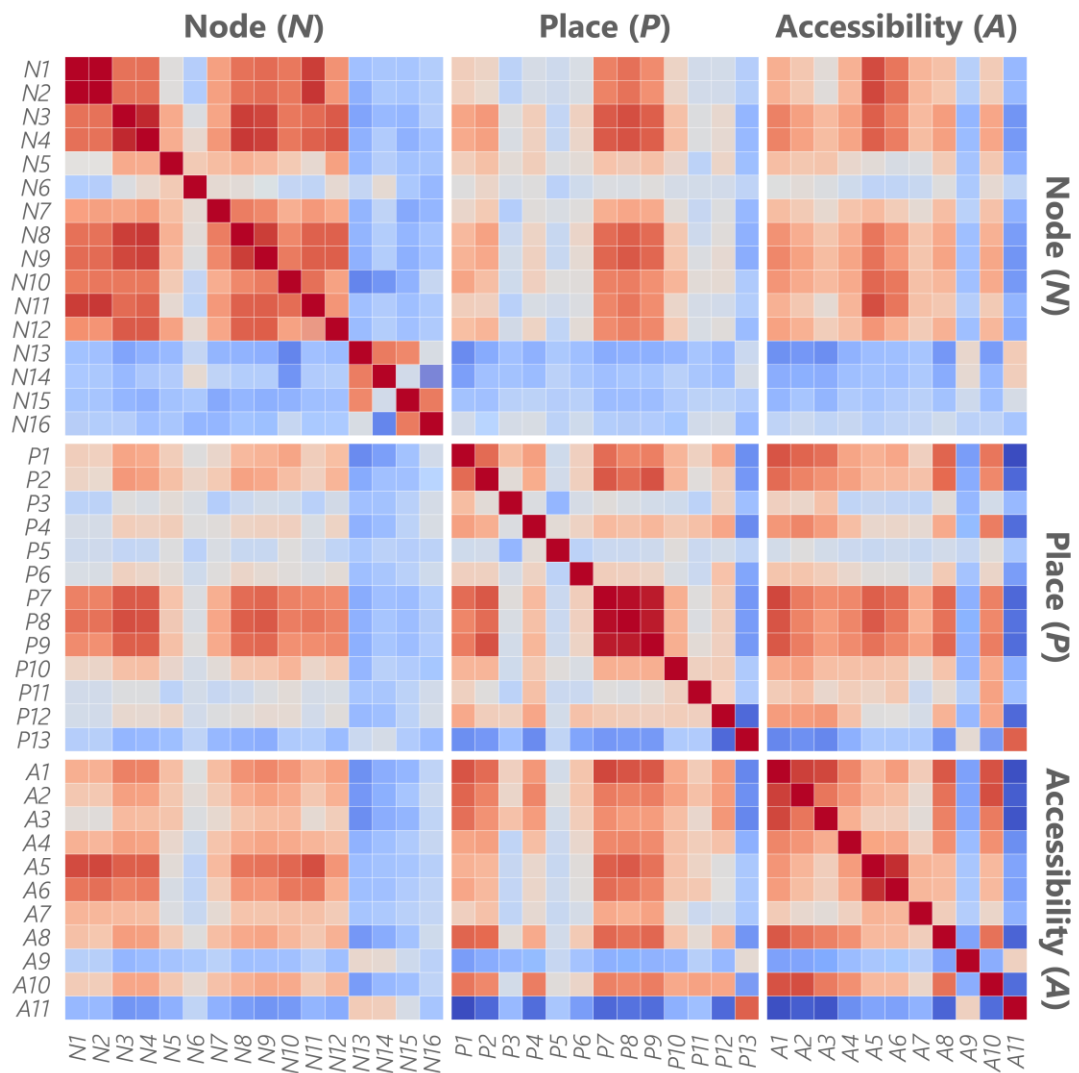
- Cycling Isochrone

Census Grid:

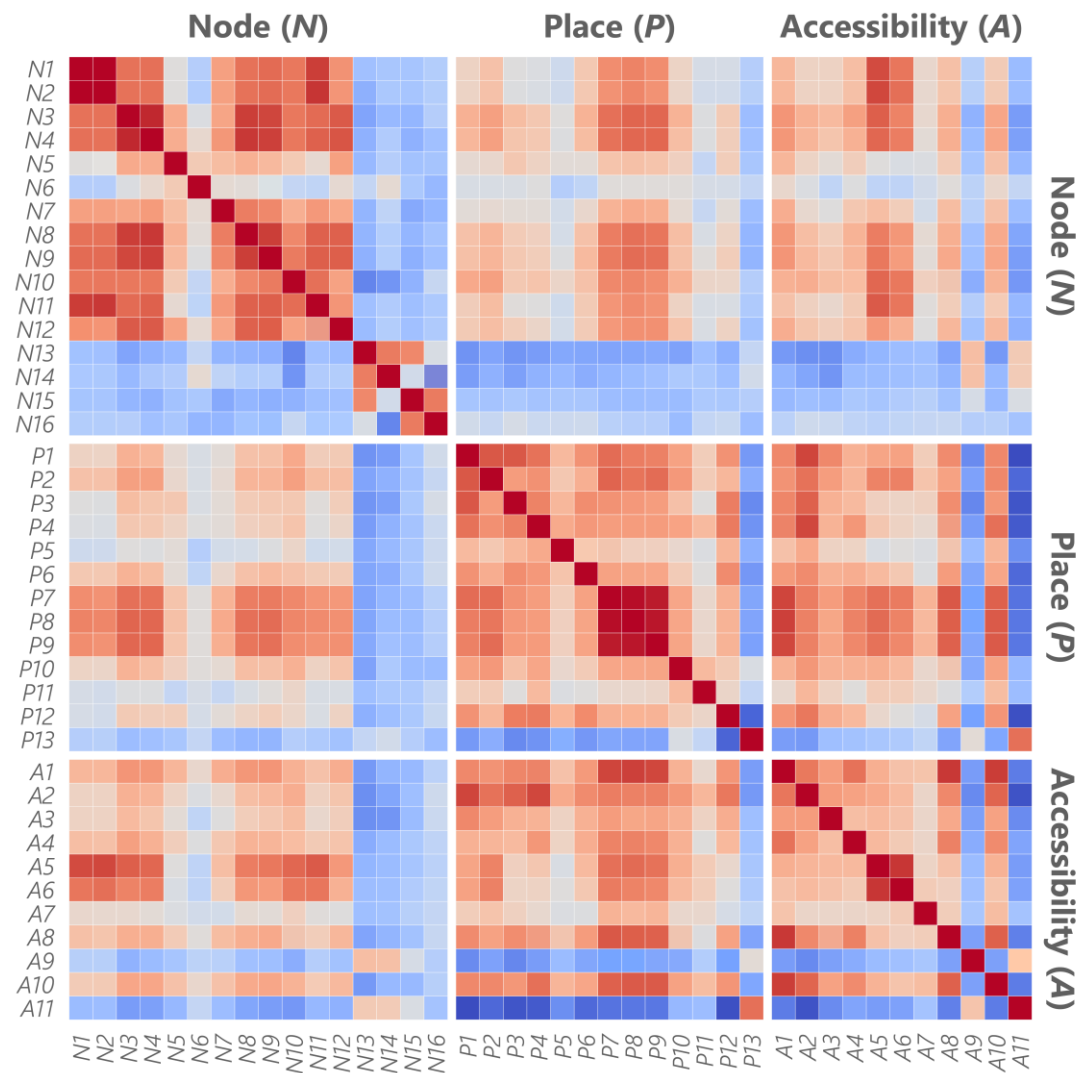


Correlation Matrices

Pedestrian isochrones (PI)

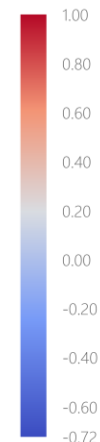


Cycling isochrones (CI)

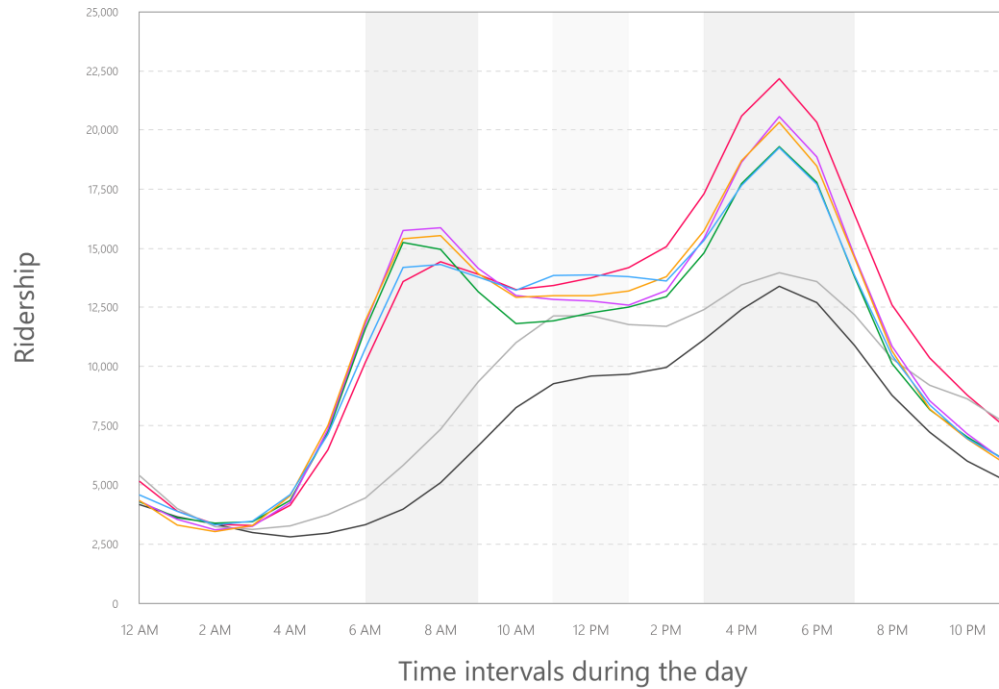


Legend

Coefficient R^2

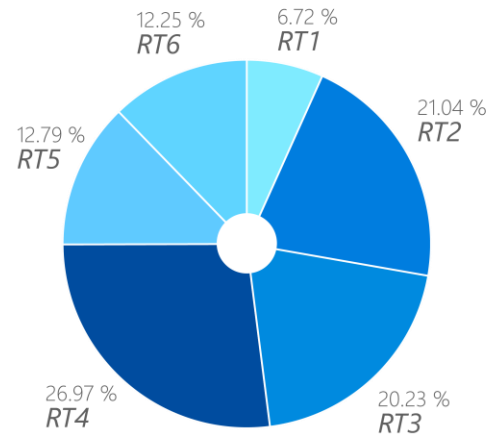


Ridership



Legend

- Monday
- Wednesday
- Friday
- Sunday
- Tuesday
- Tuesday
- Saturday

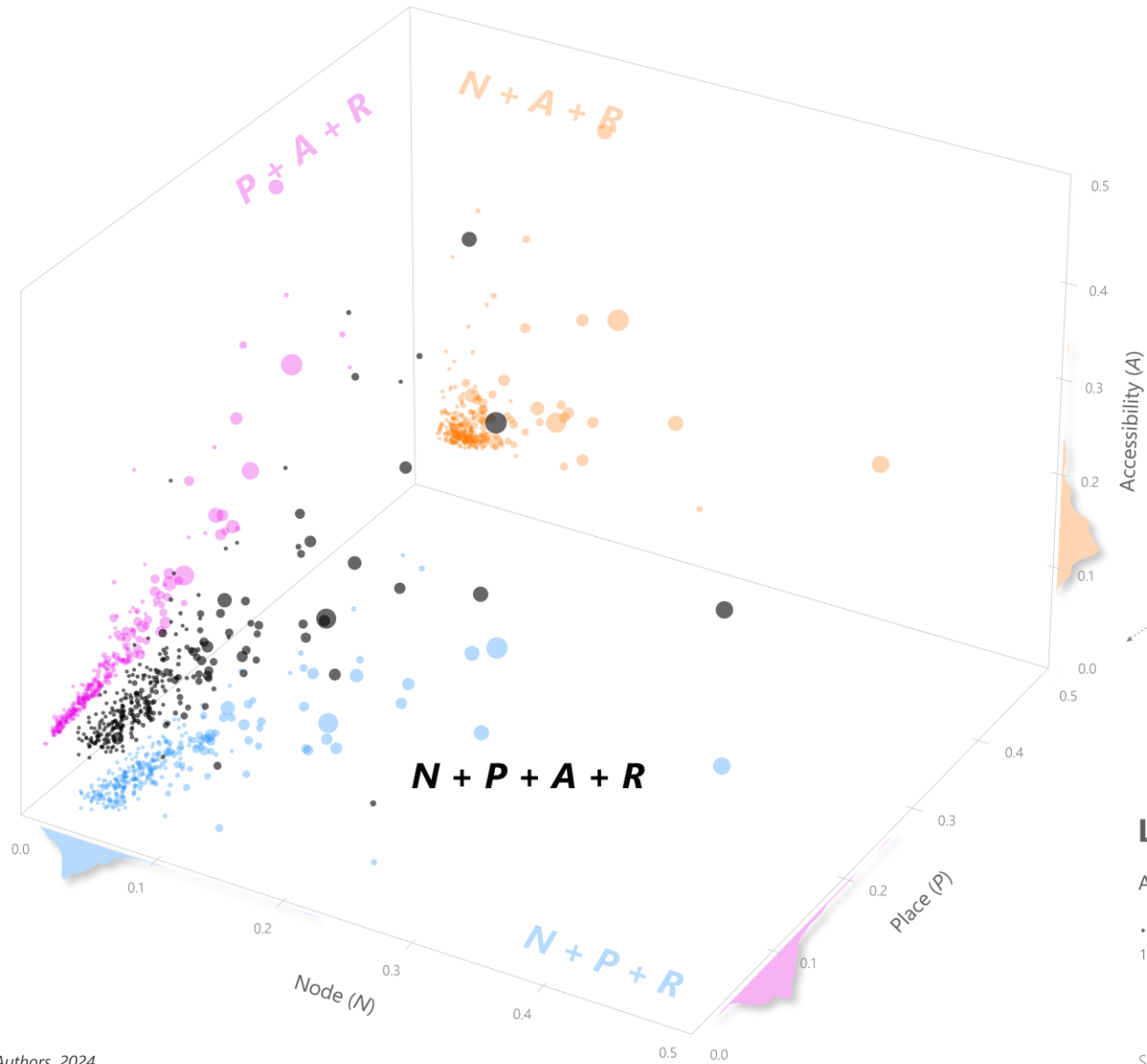


Source: Authors, 2024

Ridership per Time (RT)

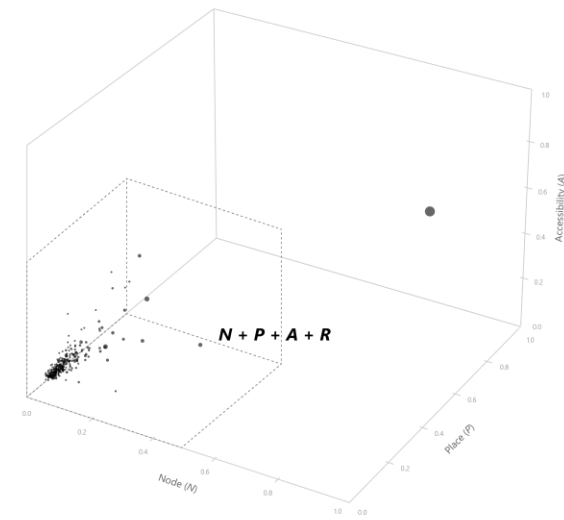
Dimension	ID	Indicators
	RT1	Weekday (12 AM to 6 AM)
	RT2	Weekday (6 AM to 10 AM)
	RT3	Weekday (10 AM to 3 PM)
	RT4	Weekday (3 PM to 8 PM)
	RT5	Weekday (8 PM to 12 AM)
	RT6	Weekend

Diagram with Euraflandres

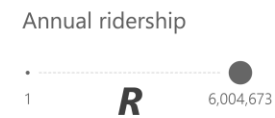


Pedestrian Isochrones Information entropy weight (IEW)

Diagram including *Euraflandres* hub

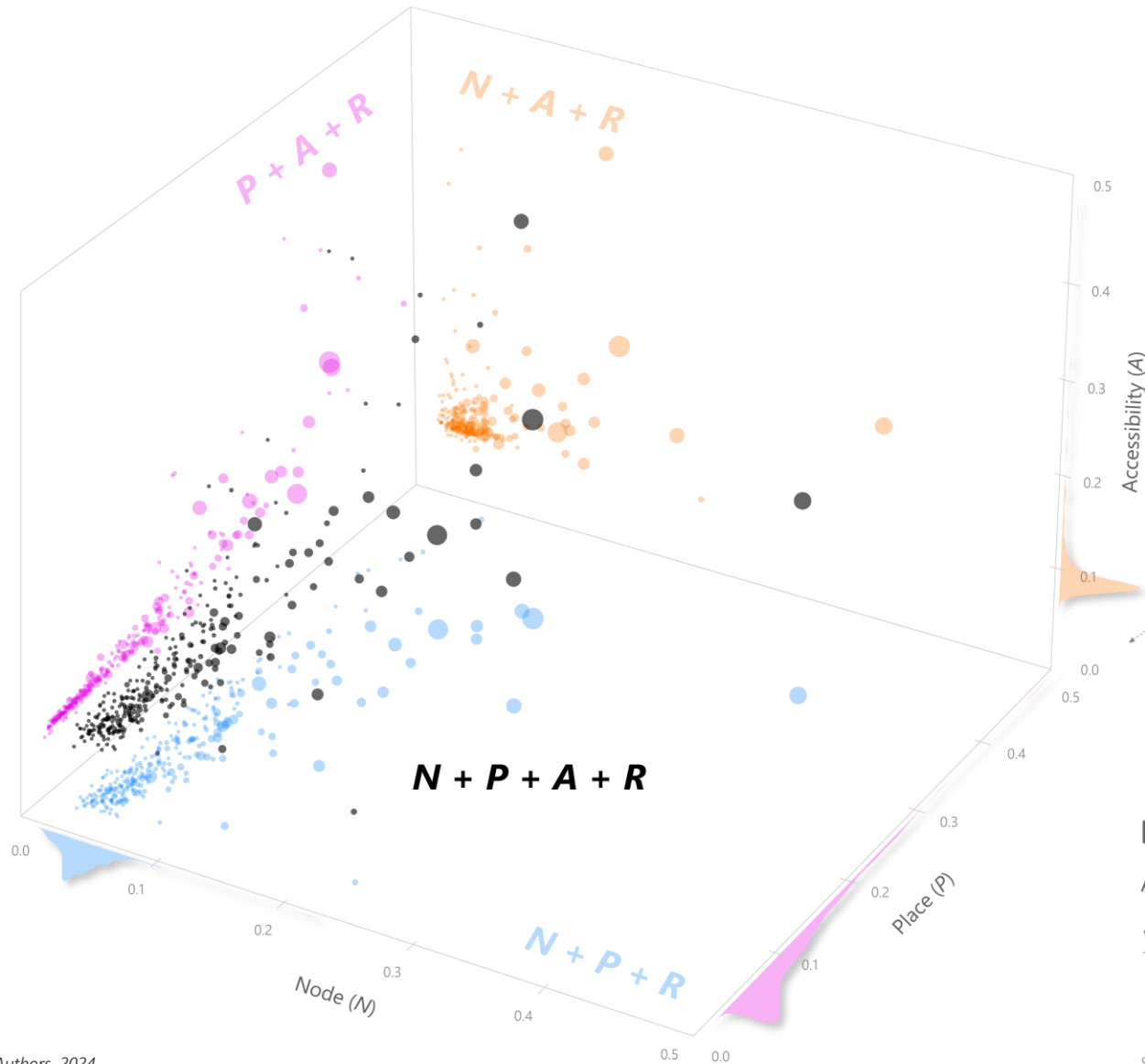


Legend



Sampling: 318 station areas

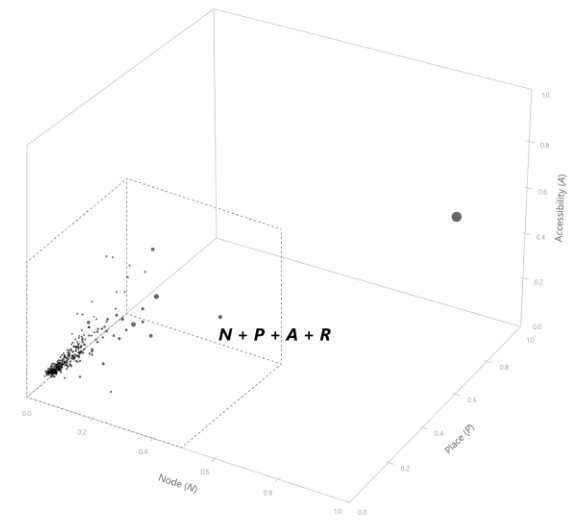
Diagram with Euraflandres



Cycling Isochrones

Information entropy weight (IEW)

Diagram including *Euraflandres* hub



Legend

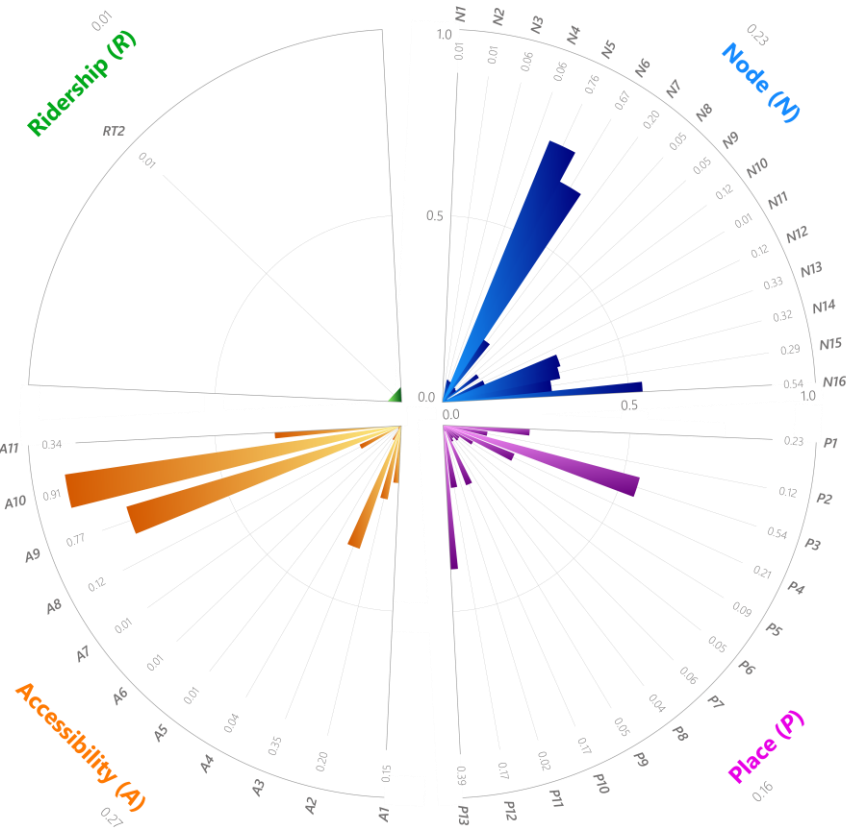
Annual ridership



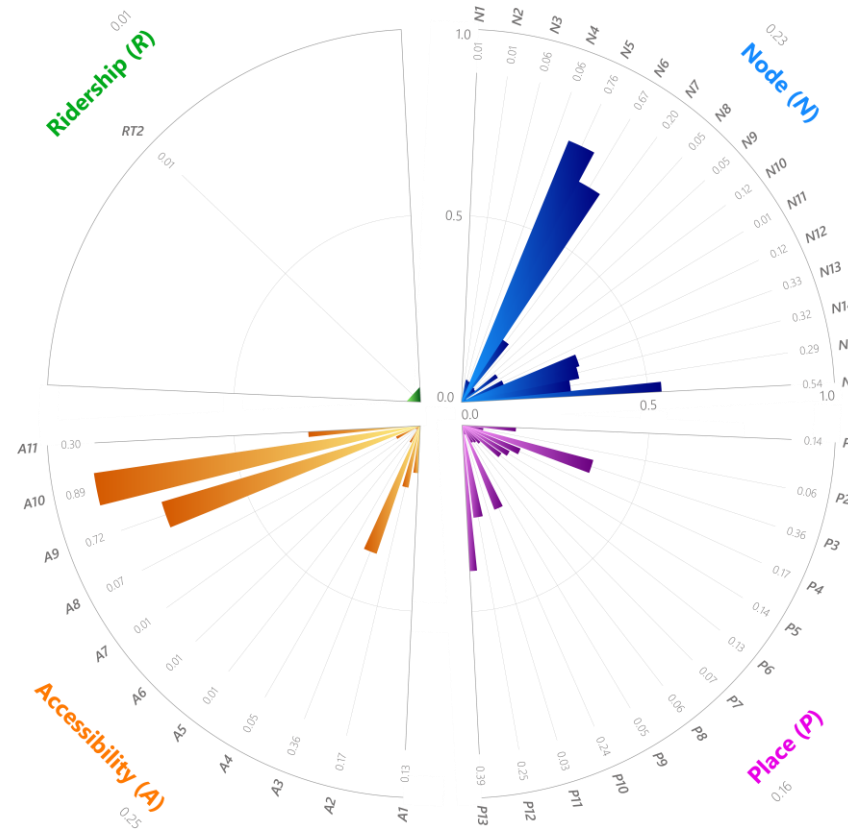
Sampling: 318 station areas

Profile of Stations

Pedestrian Isochrones (PI)



Cycling Isochrones (CI)



Discrepancies between walking and cycling scales

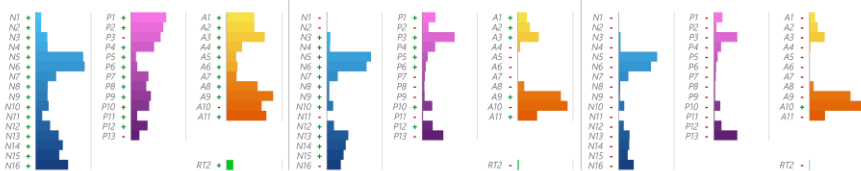
PI +

- Classes **1 2 3** Population density (P1)
- Classes **1 2** Bus stops (A8)
- Class **1** Employment density (P2)
- Class **1** Pedestrian network (A1)
- Class **1** Cycling network (A4)
- Class **1** Bicycle parking capacity (A5)
- Class **1** Shared bicycles (A6)
- Class **1** Motorization rate (A11)

CI +

- Classes **1 3** Residential land use (P3)
- Classes **1 2** Office and industry land use (P5)
- Classes **1 2** Green spaces (P6)
- Classes **1 2** Public housing (P12)
- Class **1** Average income (P13)
- Class **1** Superior POIs (P9)
- Class **2** Cycling network (A4)

Class 1 (18 stations) **Class 2** (151 stations) **Class 3** (149 stations)



Class 1 (34 stations) **Class 2** (133 stations) **Class 3** (151 stations)

