Shared Micro-Mobility City Performance Index

Development of a Shared Micromobility
City Performance Index (SMM-CPI) for the
Standardized Evaluation of Traffic Impacts of
Shared Micromobility Services in Cities

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Summary – Executive Summary

The Shared Micromobility City Performance Index (SMM-CPI) was developed to provide a consistent, comparable, and methodologically enhanced tool for the standardized evaluation of shared micromobility services (bicycles, e-bikes, e-scooters). The aim is to overcome the limitations of existing benchmarking approaches (such as a focus on a single mode of transport or inconsistent data sources).

1. Methodology: Suitability as a Standard Evaluation Tool

The SMM-CPI is suitable as a standard evaluation tool because it introduces the following methodological innovations and refinements:

- **Multimodal and validated approach:** It integrates all relevant micromobility services (bicycles, e-bikes and e-scooters) into the calculation of Node indicators (trips per 1,000 residents/day, trips per active vehicle/day, active vehicles per 1,000 residents).
- **Data quality through MDS:** Unlike inaccurate GBFS feeds, the index is primarily based on direct provider data, automatable via the Mobility Data Specification (MDS) interface, enabling a valid capture of actual trips and operational states.
- **Standardized reference area (FUA):** Instead of administrative city boundaries, the analysis is based on the standardized Functional Urban Area (FUA) and urban areas according to satellite-based land use data, to ensure reliable comparability between heterogeneous cities and regions.
- **Population-weighted service coverage:** The Population Coverage Index (PCI) is integrated as an independent performance dimension. It measures the share of the population in urban areas that is actually reached by shared micromobility services, thus complementing the classical provider-oriented KPI logic.
- **Transferability:** The methodological concept is transport-mode-neutral and suitable for extension to other new mobility services (e.g. car-sharing, ride-hailing).
- **Compatibility with TEN-T Regulation 2024/1679:** Spatial and technical compatibility with European Union requirements regarding monitoring obligations of Urban Nodes (Urban Modes) and their FUAs for their Sustainable Urban Mobility Plans (SUMPs).

2. Key Findings

The central question is not what the service looks like, but how well it is used. The benchmarking of the studied Urban regions highlights key factors influencing strong usage.

- **Fleet Density Adoption Threshold:** Substantial demand (a functioning market) empirically emerges only from a fleet density of approximately 4–6 active vehicles per 1,000 residents. Below this threshold, usage is very low.
- **Network Effects:** A higher density of active vehicles per resident correlates significantly with higher usage intensity and greater transport benefit.
- **Multimodal Vehicle Mix:** A multimodal offering integrating e-scooters and bicycles is necessary to achieve high performance values and significant transport impact - including in small and medium-sized towns in commuter zones.
- **Spatially flexible system logics:** Hybrid systems of station-based and free-floating modes are necessary for high performance and system coverage - especially in small and medium-sized towns.

3. Key Recommendations for Municipal Decision-Makers:

- **Regional governance:** Integrated governance with clear KPIs for the entire Functional Urban Area (FUA) including its commuter zone, to reduce the structural mobility deficit there and scale services into the broader area.
- **Strategic planning:** Use of SMM-CPI indicators as metrics for monitoring and progress tracking within Sustainable Urban Mobility Plans (SUMPs).
- **Data governance:** Mandatory integration of the MDS specification in service and concession contracts to enable valid, fact-based management and planning.
- **Spatial Coverage: Establishing an appropriate density** of supply through sufficient parking spaces or free-floating zones, wherever compatible with the urban environment.
- **Fleet management:** Avoidance of artificial fleet caps below the empirically determined adoption threshold of 4–6 vehicles per 1,000 residents to enable network effects.

Glossary

Active Vehicles: Based on the MDS (see below) definition, the average of the total number of vehicles available for rental each day (minus deactivated vehicles or vehicles with empty batteries).

Functional Urban Area (FUA): According to OECD / Eurostat defined as "a statistically delimited functional urban area, consisting of a densely populated Urban Node and a functional hinterland (commuter zone), defined by commuting flows (min. 15% in-commuters)."[1]

Urban Node: An Urban Node consists of contiguous grid cells that:

- have a population density of at least 1,500 residents per km²
- reach a total population of at least 50,000 residents.

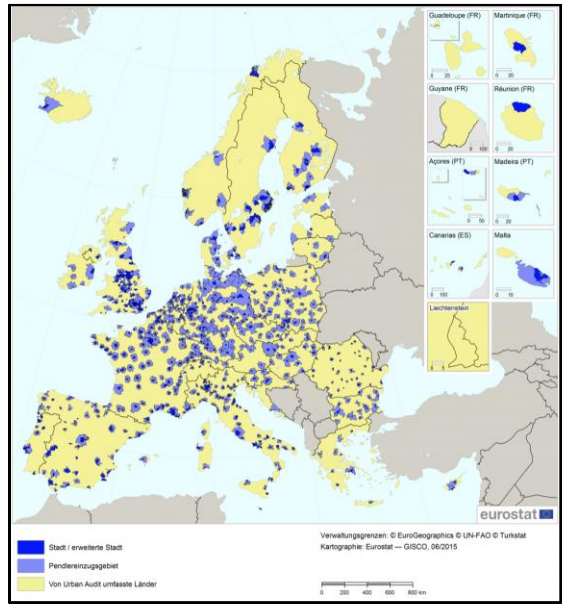

Figure 1: Overview of EU FUAs

Commuter Zone: The commuter zone comprises the surrounding municipalities functionally linked to the Urban Node. A municipality belongs to the commuter zone if at least 15% of its employed residents commute to work in the Urban Node.

General Bike Sharing Feed Specification (GBFS): GBFS is an open data standard for mobility services that provides information about the current status of vehicles such as bicycles or e-scooters. It is a real-time API in JSON format used to transmit locations, availability, and fares to apps and urban platforms.

Micromobility: Travel by small, light vehicles powered by muscle or (partially) electric means for individual passenger transport, usually over short distances. These include primarily bicycles, e-bikes ((speed) pedelecs), e-scooters, and cargo bikes, often serving as flexible solutions for urban journeys. According to the OECD definition, vehicles are limited to a maximum weight of 350 kg and a maximum speed of 20–45 km/h.[2]

Mobility Data Specification (MDS): MDS is a technical standard and set of interfaces (APIs) that standardizes the digital data exchange between cities/municipalities and private mobility service providers (e.g. e-scooter, bike sharing, or ride-hailing companies). It was originally developed by the Los Angeles Department of Transportation (LADOT) and is today managed by the Open Mobility Foundation (OMF).[3]

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[1] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Territorial_typologies_for_European_cities_and_metropolitan_regions

[2] https://www.oecd.org/content/dam/oecd/en/publications/reports/2024/03/safer-micromobility_f7dee627/0d2e0dd5-en.pdf

[3] https://www.openmobilityfoundation.org/about-mds/

Local Administrative Units (LAU): Local Administrative Units are the building blocks of NUTS (Nomenclature of Territorial Units for Statistics) and the statistical regions encompassing municipalities of the European Statistical System (ESS). In Germany, these correspond to cities and municipalities (NUTS3, LAU2 level).

Urban Area: Urban areas in the context of this work are areas containing urban uses, particularly residential, industrial and commercial uses. They are represented by the Copernicus Corine Land Cover Codes 111 (Continuous Urban Fabric), 112 (Discontinuous Urban Fabric), 121 (Industrial Or Commercial Units).[4]

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[4] For an overview of land use codes, see European Environmental Agency, Copernicus (2017): Technical guidelines – CORINE Land Cover 2018 and Corine Land Cover Change 2012-2018, page 68, (Annex I). https://land.copernicus.eu/en/technical-library/clc-product-user-manual/

1. Introduction

Shared micromobility (bicycles, e-bikes and e-scooters) has long been an integral component of urban mobility systems in many German cities – yet a consistent, methodologically sound benchmarking approach has so far barely existed. The currently available approaches, such as the Cycling Industries Europe (CIE) Benchmarking Study[5], the derived Cycling Counts Project approach[6], or Fluctuo's European Shared Mobility Index[7] provide valuable insights, but their analytical power remains limited due to restricted data availability, differing methodologies, or a deliberate focus on a single mode of transport. At the same time, the need from actors in administration, politics, and mobility providers – for example in the context of developing and monitoring Sustainable Urban Mobility Plans (SUMPs) – is growing for reliable and above all comparable metrics that reflect the actual usage, quality, and spatial accessibility of shared micromobility services.

As part of the mFUND-funded project Scoop2City, a Shared Micromobility City Performance Index (SMM-CPI) is therefore being developed to close this gap and which is methodologically suitable for extension to other new mobility services (car-sharing, moped sharing, ride-hailing, autonomous taxis, etc.). The CPI combines validated industry metrics with precise MDS (Mobility Data Specification) data, considers both bicycles and e-scooters, and integrates detailed urban context information such as population density and service areas. The goal is to develop a consistent, comparable, and municipally applicable evaluation instrument that for the first time enables a holistic picture of the performance of shared micromobility services in German (and European) cities and functional urban areas.

[5] https://cyclingindustries.com/news/details/the-2024-edition-of-cies-bike-sharing-in-148-cities-report

[6] Not yet published; project info at https://www.linkedin.com/company/cyclingcounts/

[7] https://european-index.fluctuo.com/

2. Status Quo: State of Benchmarking Methods

The following presents the three currently most significant benchmarking approaches for shared micromobility, according to their objectives, data basis, and indicators. On this basis, the methodological requirements that the SMM-CPI addresses are then derived.

2.1 Cycling Industries Europe (CIE) Bike Share Benchmarking

The CIE Bike Share Benchmarking Study currently constitutes the central European reference framework for the evaluation of bike sharing systems, particularly as an instrument for the development of Sustainable Urban Mobility Plans (SUMPs)[8], which will be mandatory from 2027 for all 431 TEN-T Urban Nodes[9] and 100+ Climate Neutral Mission Cities[10] and which should strategically focus on scaling and optimizing bike sharing systems. In Germany, this affects 79 cities with approximately 40 million residents.

Category	Cities
Mission City	Aachen, Dortmund, Dresden, Heidelberg, Münster
TEN-T Urban Node (Urban Node)	Aachen, Augsburg, Berlin, Bielefeld, Bochum, Bonn, Bottrop, Braunschweig, Bremen, Bremerhaven, Chemnitz, Darmstadt, Dortmund, Dresden, Duisburg, Düsseldorf, Erfurt, Erlangen, Essen, Frankfurt am Main, Freiburg im Breisgau, Fürth, Gelsenkirchen, Gießen, Göttingen, Gütersloh, Hagen, Halle (Saale), Hamburg, Hamm, Hannover, Heidelberg, Heilbronn, Herne, Hildesheim, Ingolstadt, Jena, Kaiserslautern, Karlsruhe, Kassel, Kiel, Koblenz, Köln, Krefeld, Landshut, Leipzig, Leverkusen, Lübeck, Ludwigshafen am Rhein, Magdeburg, Mainz, Mannheim, Mönchengladbach, Mülheim an der Ruhr, München, Münster, Neuss, Nürnberg, Oberhausen, Offenbach am Main, Oldenburg, Osnabrück, Paderborn, Pforzheim, Potsdam, Recklinghausen, Regensburg, Rostock, Saarbrücken, Siegen, Solingen, Stuttgart, Trier, Ulm, Wiesbaden, Wolfsburg, Wuppertal, Würzburg
Mission City & TEN-T Urban Node	Frankfurt am Main, Leipzig(-Halle), Mannheim, München

Table 1: German Mission Cities and TEN-T Urban Nodes

The study covers station-based and free-floating / dockless systems, as well as publicly and privately funded and operated services, but deliberately excludes other vehicle types such as e-scooters. Data comes primarily from Fluctuo (see below), which in turn is partly based on direct provider data and partly on GBFS scraping (see below).

[8] https://transport.ec.europa.eu/transport-themes/Urban-transport/sustainable-Urban-mobility-planning-and-monitoring_en

[9] https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

[10] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en

The study's methodology is based on 3 indicators:

- **Primary indicator:** Trips per 1,000 residents per day as an indicator of market penetration of sharing services and acceptance by the urban population
- **Secondary indicator #1:** Vehicles per 1,000 residents as an indicator of service density and availability
- **Secondary indicator #2:** Trips per active vehicle per day as an indicator of fleet utilization and efficiency

2.2 Fluctuo European Shared Mobility Index (ESMI)

The European Shared Mobility Index takes a multimodal approach and integrates (e-)bikes, e-scooters, mopeds, and car-sharing. The data basis is primarily based on GBFS real-time data ("scraping"), partially supplemented by direct provider data on the number of trips and average active vehicles on a monthly basis.

> **Definition: GBFS Scraping**
>
> In GBFS scraping, providers' real-time feeds on vehicle locations and availability are automatically retrieved at defined intervals. The raw data is aggregated, e.g. to calculate daily trips or active vehicles. This method enables timely data collection but has key limitations: (1) GBFS feeds only reflect real-time availability and do not provide direct trip data, (2) not all providers supply consistent data, and some have explicitly prohibited scraping, (3) location changes can also result from operational processes (redistribution). Comparisons between GBFS-scraped datasets and the actual number of trips directly from providers show a discrepancy of +/-10%. Additional calibration based on reliable reference data using appropriate statistical methods would therefore be necessary.

Box 1: Definition GBFS Scraping

Fluctuo's dataset reportedly now covers 180 European cities, with the Shared Mobility Index aggregating data into 5 major regions (Northern Europe, DACH, France+Benelux, Southern Europe, Eastern Europe) and highlighting the Top 5 cities with the most trips ("Top Ridership") per mode of transport. It remains unclear whether the GBFS scraped data is calibrated.

The ESMI shows the development of the industry over the timeline since 2020 and examines all segments of the shared mobility industry separately.

2.3 Cycling Counts Project (Rupprecht Consult, Kevin Mayne, Fluctuo)

The Cycling Counts Project transfers the CIE methodology to the national level and covers all cities with more than 150,000 residents using Fluctuo datasets. It combines provider and other context data such as cycling modal share at the national level and evaluates the share of bike sharing trips in total cycling. The goal is to make bike sharing comparable at national level to identify strategic fields of action for national ministries and improve this mobility offering at scale.

2.4 Requirements for an Enhanced Benchmarking Approach

Despite their demonstrated analytical value and sound recommendations for cities, both the CIE benchmarking methodology and the European Shared Mobility Index have several limitations.

CIE Benchmarking Study / Cycling Counts	Fluctuo European Shared Mobility Index
The primary indicator "trips per 1,000 residents per day" is based on incomplete datasets, as complete usage data is not available for all cities, limiting comparability.	It only provides a rough overview of the industry at the European level.
The study focuses exclusively on bicycles and neglects other micromobility services such as e-scooters, creating an incomplete picture of shared micromobility systems.	The index focuses on absolute numbers ("Top Ridership"), which inevitably prioritizes large capital cities.
Urban heterogeneities - such as service area size, commuting patterns, or spatial density - are not considered, allowing for structural distortions.	
There are inconsistencies in data sources regarding population figures (Urban Node vs. metropolitan area), fleet sizes (official vs. average active), and usage (GBFS scraping vs. direct provider data).	
Reference to GBFS datasets due to availability is pragmatic but inconsistent and inaccurate. This reduces the comparability and methodological robustness of results.	

These limitations mean that these studies have indicative value but do not allow for precise comparability between cities. This gives rise to the following requirements for the SMM-CPI:

- Inclusion of all major vehicle types (bicycles, e-bikes, e-scooters).
- A precise definition of input parameters (average fleet sizes, trips, service areas)
- The adoption of established European regionalizations, in particular Urban Nodes and Functional Urban Areas (FUAs).
- The explicit inclusion of smaller and medium-sized cities within FUAs
- The refinement of spatial reference levels (Urban area vs. administrative city boundaries)

Furthermore, considering the increased political focus on overcoming mobility poverty, the inclusion of population distribution is meaningful.

3. Vision: Why a City Performance Index for Shared Micromobility?

The aim of the Shared Micromobility City Performance Index (SMM-CPI) is the development of a robust, comparable evaluation instrument for the performance of shared micromobility in cities. The SMM-CPI addresses the limitations of existing benchmarking approaches by integrating bicycles, e-bikes, and e-scooters, considering precise urban context data (through intersection of spatial population distributions with micromobility provider service areas, commuting patterns, etc.), and drawing on high-quality MDS data instead of inaccurate and methodologically flawed GBFS feeds. Building on validated metrics such as trips per 1,000 residents per day, the SMM-CPI enables a differentiated assessment of availability, utilization, and spatial and demographic coverage. It thereby provides a sound basis for municipal planning, strategic optimization of bike and scooter sharing services, and evidence-based policy communication.

4. Methodology of the Shared Micromobility City Performance Index

4.1 Selection and Rationale for Performance Indicators

The SMM-CPI pursues a multidimensional approach to evaluating shared micromobility. The goal is to reflect both the usage intensity and efficiency of services as well as their spatial accessibility for the population at the Urban Node level as well as the Functional Urban Area (FUA) level. The selection of indicators is based on established European benchmarking approaches (especially CIE / Cycling Counts) but is methodologically extended and refined.

4.1.1 Usage and Supply Indicators

The following are used as performance-related Node indicators:

- Trips per 1,000 residents / day (Primary indicator for assessing market penetration and acceptance)
- Trips per active vehicle / day (Secondary indicator for fleet utilization and operational efficiency)
- Active vehicles per 1,000 residents (Secondary indicator for service density and availability)

These indicators are adopted in content from existing benchmarking approaches and transferred to all vehicle types. They thus enable direct comparability with existing bike share benchmarking analyses. In the SMM-CPI, they are calculated across all modes of transport (bicycles, e-bikes, and e-scooters) and can also be applied to other vehicle and service categories such as car sharing, ride hailing, autonomous taxis, etc.

4.1.2 Spatial Coverage as an Independent Performance Indicator

The key methodological innovation of the SMM-CPI compared to existing approaches is the introduction of spatial service coverage as an independent performance dimension. High usage or efficiency values alone do not guarantee comprehensive or socially balanced provision. To represent this dimension, the Population Coverage Index (PCI) is introduced. It measures the share of the population living in mobility-relevant urban areas that is reached within the defined service areas. This extends the classical provider KPI logic of the SMM-CPI with an explicitly spatial-demographic perspective and enables a differentiated assessment of service impact. Only the PCI makes the aspect of spatial coverage systematically measurable and comparable for the first time.

4.2 Data Sources and Processing Steps

4.2.1 Data Sources

The data basis of the SMM-CPI is primarily based on reliable trip, fleet, and coverage data from shared micromobility providers. A suitable and partially utilized data source is the Mobility Data Specification (MDS)[11]. Unlike GBFS feeds, which only reflect real-time availability, MDS enables - through its historical data - a reliable capture of actual trips and active vehicles, even if data quality can vary between providers. For the present validation, aggregated trip and fleet data were obtained both directly from operators and via municipal data platforms with MDS interfaces.

> **Definition: Mobility Data Specification (MDS)**
>
> MDS is an open technical data and API framework developed by the Open Mobility Foundation (OMF). It serves as an interface between cities/authorities and mobility providers (e.g. e-scooter sharing, bike sharing, car sharing). MDS establishes uniform data formats and communication protocols with which cities can:
>
> - Receive real-time data on vehicles (e.g. location, status)
> - Actively manage fleets (e.g. geofencing, parking restrictions)
> - Retrieve usage statistics and reports
> - Digitally communicate rules and requirements to providers
>
> MDS consists of various modules/APIs:
>
> - **Provider API** – delivers real-time and historical information to the city
> - **Policy API** – defines digital mobility rules (e.g. no-parking zones)
> - **Agency API** – enables cities to send rules and requirements to providers
> - **Geography API** – manages spatially referenced geometric data
> - **Metrics API** – for aggregated statistics and analysis

[11] Ideally, MDS would be used via a central data agreement with providers to geolocate all trips and intersect them with municipal boundaries. For the SMM-CPI methodology validation, aggregated data from municipal data platforms and direct provider submissions were used.

MDS was developed to improve interoperability between cities and providers, standardize data quality, enable governance of digital Urban mobility, and ensure transparency and control over shared mobility forms. Unlike the open data standard GBFS, MDS is not an open data standard but rather a regulatory data format for the protected exchange between cities and mobility providers. Its use therefore requires a written data agreement between the municipal administration and the operator, along with appropriate authentication. Increasingly, cities worldwide are making MDS data provision a condition of licensing or concession agreements or a prerequisite for operating shared mobility fleets in public space.

Box 2: Definition Mobility Data Specification

In addition, specific spatial and demographic datasets are used that are technically relevant, sufficiently precise, and available and comparable at EU level (as well as EEA38).

4.2.2 Definition of the Functional Reference Area

No administrative city boundaries are used as the spatial reference, as these typically contain areas without relevant mobility demand, such as water bodies, forests, etc. Instead, a functional reference area is defined that reflects urban use areas. For this purpose, the Urban Fabric classes of the Copernicus Urban Atlas[12] are used, particularly continuous and discontinuous settlement structures. These represent residential, mixed, and densified uses and constitute a reliable approximation of potential demand locations for shared mobility services. The Europe-wide harmonization of the Urban Atlas supports comparability between cities.

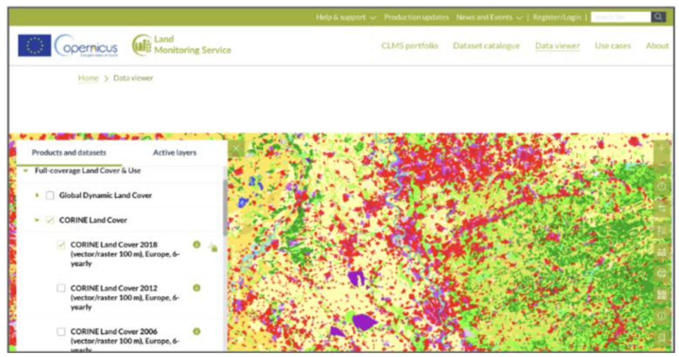


Figure 2: Copernicus Land Cover Data Viewer

For the delineation of urban areas, vectorized Corine Land Cover data (CLC, classes 111, 112, and 121) are used. This approach was deliberately chosen because CLC data is standardized and freely available across Europe, thereby ensuring reproducibility and comparability between cities. Granular presence data (e.g. mobile phone data) could theoretically reflect demand locations more precisely, but are not available in a comprehensive, standardized, and free manner. The use of CLC classes 111, 112, and 121 as reference area follows the established approach of using residential and commercial areas as a spatial proxy for mobility demand (cf.

[12]https://land.copernicus.eu/en/products/Urban-atlas/Urban-atlas-2018

Camagni et al. 2002[13]; Gallego & Peedell 2001[14]). This approach has also already been used for the analysis of bike sharing system accessibility (Mahajan & Sanchez-Vaquerizo 2024[15]).

4.2.3 Definition of Service Areas

Spatial service area data for shared micromobility is generally available as GBFS Open Data format, distinguishing between "Geofencing Zones" (service areas, no-parking zones for free-floating systems) and "Stations" for station-based systems. The available GeoJSONs from all providers are merged, after which the no-parking zones are cut out and the point layers of sharing stations and station-based systems are added with 250m catchment area buffers. The 250m buffer corresponds to the empirically determined Node zone of the catchment area of station-based systems. Kabra, Belavina & Girotra (2020)[16] show, based on the Paris Vélib' system, that approximately 80% of usage comes from within a radius of under 300m around stations, with a particularly strong decline in usage beyond this boundary. While Askardzadeh et al. (2021)[17] shows that station-based bike sharing planning for Node catchment areas outside large metropolises typically uses 300m as a basis, Berg Wincent et al. (2023) show that for e-scooters in urban areas the recommended catchment area in the 75th percentile is 128-203m[18]. Klingen (2019)[19] confirms for Paris an increased bike sharing departure during metro disruptions at stations within 200m. From this empirical data, a 250m buffer was taken as the basis for the SMM-CPI, applicable equally to dense urban areas and suburban stations.

For free-floating services without fixed stations, the buffer logic does not apply. There, the entire service area corresponds to the service range.

Parameter	Defined as	Data format	Data source
Geographic data (GIS-compatible)			
Functional Urban Area (FUA)	FUA = statistically delimited functional Urban area, consisting of a densely populated Urban Node and a functional hinterland defined by commuting flows (at least 15% in-commuters) (Eurostat / OECD)	*.shp vector file*	European Environment Agency
Cities and Municipalities (Local Administrative Units (LAU))	Municipalities belonging to the FUA, corresponds to NUTS3 / LAU2 level	*.shp vector file*	Eurostat

13 https://www.sciencedirect.com/science/article/abs/pii/S0921800101002543?via%3Dihub

14 Gallego, J., & Peedell, S. (2001). Using CORINE Land Cover to map population density, Topic report 6/2001.

15 https://www.nature.com/articles/s41598-024-70706-x

16 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2555671

17 https://onlinelibrary.wiley.com/doi/10.1155/2021/9808922

18 https://doaj.org/article/9ce348cc8b0f4aa6b2585bf31d95ae09

19 https://www.sciencedirect.com/science/article/abs/pii/S0965856417312107

Urban Area	= residential, transport, industrial and commercial areas Codes 111 (Continuous Urban Fabric), 112 (Discontinuous Urban Fabric), 121 (Industrial Or Commercial Units)	*.tiff raster file (10x10m), vectorized*	Copernicus Urban Atlas (2018)
Maximum service area	Merger of service areas of all providers; for station-based systems incl. 250m buffer around stations, minus no-parking zones	*GeoJSON*	Providers via **GBFS** Open Data

Table 2: Overview of geographic input parameters

This results in 5 different spatial categories for the SMM-CPI:

Spatial category
Urban Node (UC) (= Urban Node according to TEN-T Regulation)
Functional Urban Area (FUA)
Commuter zone (cz)
Urban Area Urban Node (UC_urb)
Urban Area FUA (FUA_urb)

Table 3: Overview of relevant spatial categories

4.2.4 Population Weighting and Spatial Intersection

The coverage assessment is population weighted. The spatial distribution of the population is modeled using the Geostat Population Grid Raster[20], while the absolute population figure per municipality is based on official registration data as of 31.12.2024. The Geostat Population Grid is available in two resolutions: a 1×1 km grid (also available by age group and other demographic categories) and a high-resolution 100×100 m grid (total population only).

First, the raster is intersected with the providers' service areas (SA_max) and the urban use areas defined by the Urban Atlas (UC_urb, FUA_urb). This approach ensures that densely populated urban areas are weighted more strongly in the evaluation than sparsely populated peripheral locations and enables a realistic representation of actual accessibility. Population coverage was calculated on a raster basis. Only raster cells whose cell center falls within the shared micromobility coverage were considered (cell-center logic) to ensure a clear and reproducible assignment.

To increase the content relevance of the population raster for the specific application of the SMM-CPI, the use of a Total Addressable Market (TAM) approach was first examined. In this context, focusing on the spatial distribution of the 15–64 age cohort - available for the Geostat population raster at 1x1km resolution - seemed technically meaningful, as it more realistically

[20] https://ec.europa.eu/eurostat/web/gisco/geodata/population-distribution/population-grids

represents the potential user base for shared micromobility services than the total population, considering only groups likely to be actual users.

However, this approach was deliberately not implemented. The decisive factor was the insufficient spatial resolution of the 1x1km raster, which is not precise enough for the fine-grained spatial intersection of service areas, Urban use areas, and population distribution in an Urban context. For the SMM-CPI, a 100×100m population raster is instead used, providing 100x higher spatial accuracy and a significantly more reliable representation of actual accessibility.

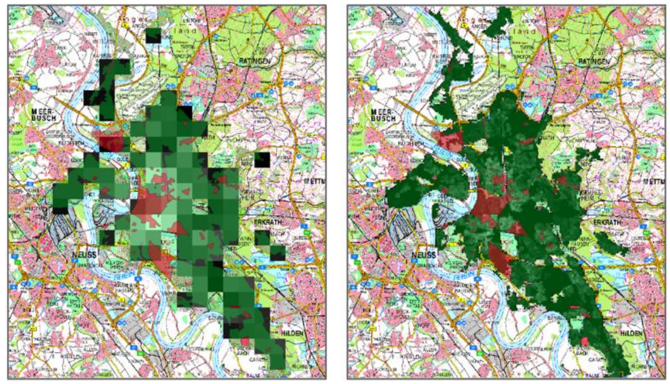


Figure 3: Geostat Population Grid Raster 1x1km vs 100x100m

1x1km grid, with significant cut-outs due to cell-centre logic	*100x100m grid, with good coverage of shared micro-mobility service areas*

This decision is not only data-methodologically justified, but also conceptually deliberate. By using the total population in a high-resolution raster, the methodological approach remains transport-mode-neutral and transferable. This is particularly relevant for future applications of the SMM-CPI to other mobility forms, such as ride-hailing services or autonomous taxis, where age- or user-group-specific restrictions play little or no role compared to e-bikes or e-scooters.

Additionally, using the daytime population as an additional reference indicator was examined, calculated from residential population plus in-commuters minus out-commuters based on commuter data from the Federal Employment Agency[21]. This approach is fundamentally relevant for the evaluation of Urban Nodes but was rejected, as it does not reflect a spatially differentiated distribution of the population within the functional urban area and its Europe-wide availability and comparability is not assured. Accordingly, the daytime population is at best suitable as a supplementary context indicator for individual Urban Nodes, but not as a robust basis for the SMM-CPI.

Parameter	Defined as	Data format	Data source
Demographic data			
Residents Urban Node	Official registered population at reference date (31.12.2024)	*.shp vector*	Eurostat (attribute table)
Residents FUA	Sum of registered population of all municipalities within the FUA	*.shp vector*	Eurostat (attribute table)
Population distribution	100x100m raster	*.tiff raster*	Geostat Population Grid (100x100m)

Table 4: Overview of demographic input parameters

[21] https://pendleratlas.de/

4.2.5 Calculation of the Population Coverage Index

The Population Coverage Index (PCI) is calculated for each local administrative unit as follows:

$$PCI = \frac{\text{Population within (Service Area} \cap \text{Reference Area)}}{\text{Total population within the Reference Area}}$$

The index takes values between 0 and 1 and can be interpreted as a percentage coverage rate. It therefore measures not where a service exists, but how many people it actually reaches. "What % of the population lives in covered areas, i.e. has access to shared micromobility services?" rather than "What % of the area is covered?"

4.2.6 Integration into the Overall Index

The usage- and supply-oriented KPIs together with the population-weighted spatial coverage indicator (PCI) form the index architecture of the SMM-CPI. Through this combination, usage, efficiency, service density, and spatial accessibility are systematically evaluated together. The SMM-CPI thus enables a comparable and planning-relevant assessment of shared micromobility.

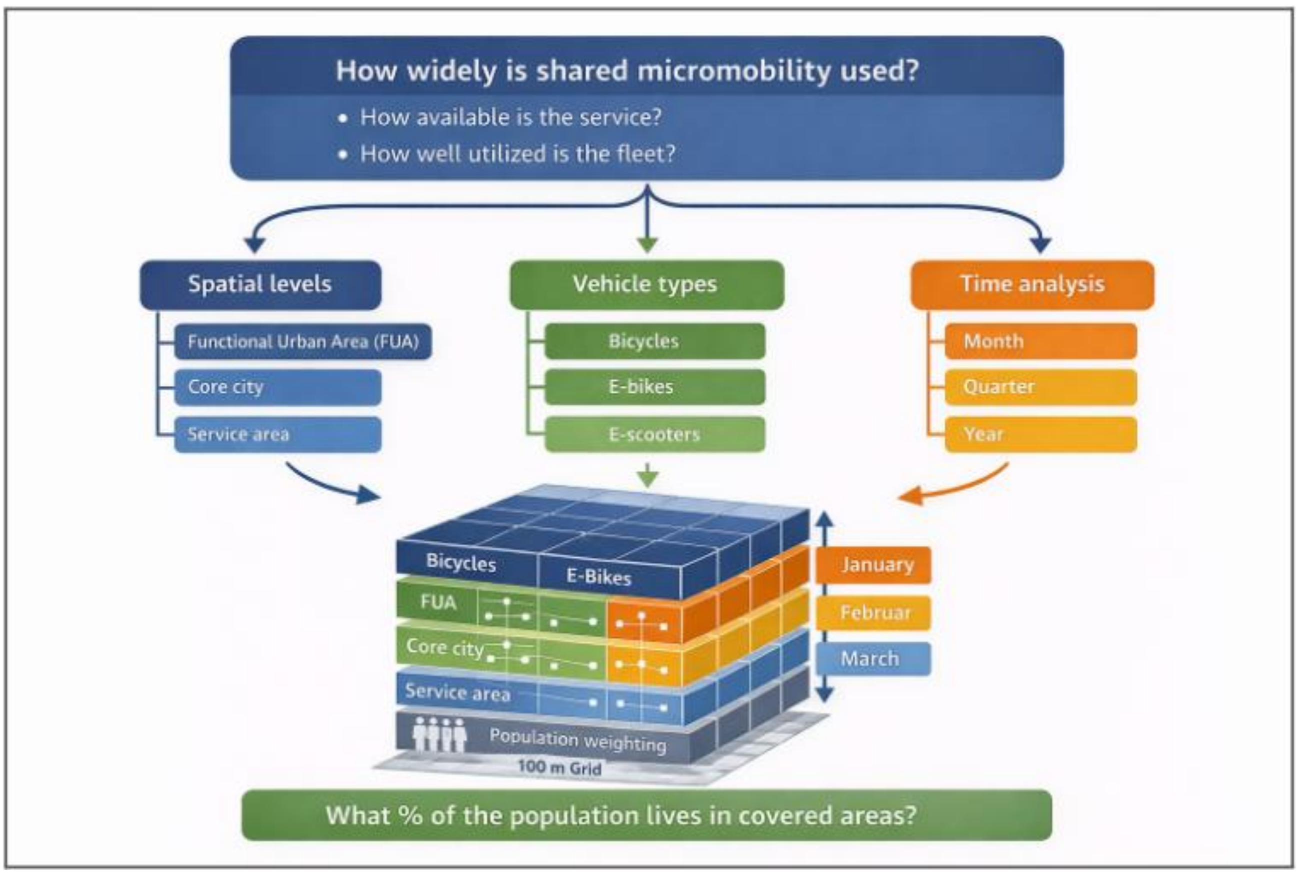


Figure 4: Visual representation of the index architecture.

The index encompasses a list of indicators that can be used depending on the spatial reference level (Urban Node or FUA).

Indicator abbreviation	Defined as	Indicator name
1. Primary indicator: Trips / Demographic category / Day		
F_UC / Res_UC	All trips (Urban Node) / 1,000 residents (Urban Node)	Trips / 1,000 res. Urban Node
F_fua / Res_fua	All trips (Urban Node) + regional catchment area (FUA) / 1,000 total residents (FUA)	Trips / 1,000 residents FUA
F_fua / Res_cz	All trips (commuter zone) / 1,000 residents outside Urban Node (commuter zone)	Trips / 1,000 residents commuter zone
2. Secondary indicator #1: Vehicles / Demographic & spatial category		
Fl_active / Res_UC	Aggregated daily average fleet in calendar year / 1,000 residents (Urban Node)	Vehicles / 1,000 res. Urban Node
Fl_active / Res_fua	Aggregated daily average fleet in calendar year / 1,000 residents (FUA)	Vehicles / 1,000 residents FUA
Fl_active / Res_cz	Aggregated daily average fleet in calendar year / 1,000 residents (commuter zone)	Vehicles / 1,000 residents commuter zone
3. Secondary indicator #2: Trips / Vehicle / Day		
F_UC / Fl_active / 365	All trips (Urban Node) / aggregated daily average fleet in calendar year / 365 days	Utilization rate Urban Node
F_FUA / Fl_active / 365	All trips (FUA) / aggregated daily average fleet in calendar year / 365 days	Utilization rate FUA
F_cz / Fl_active / 365	All trips (commuter zone) / aggregated daily average fleet in calendar year / 365 days	Utilization rate commuter zone
4. Spatial coverage indicator		
SA_max / UC_urb	Max service area / Urban area (%)	Spatial coverage
Res_UC ∩ SA_max	Residents Urban Node within max service area (%)	Population coverage (Population Coverage Index) Urban Node
Res_fua ∩ SA_max	Residents within max service area (%)	Population coverage (PCI) FUA

Res_cz ∩ SA_max	Residents within max service area (%)	Population coverage (PCI) commuter zone
Fl_active / UC_urb	Aggregated daily average fleet in calendar year / Urban area Urban Node	Fleet density Urban Node
Fl_active / FUA_urb	Aggregated daily average fleet in calendar year / Urban area FUA	Fleet density FUA
Fl_active / CZ_urb	Aggregated daily average fleet in calendar year / Urban area FUA	Fleet density commuter zone

Table 5: Overview of all indicators

5. Urban Case Studies: Application and Insights from the SMM-CPI

The empirical application of the SMM-CPI to selected urban areas serves to validate the presented methodology and demonstrate the added value gained compared to conventional benchmarking approaches. The case studies illustrate how the index evaluates the performance of shared micromobility in a differentiated manner, taking into account urban and spatial-demographic conditions.

5.1 The Case Study of Düsseldorf

The city of Düsseldorf serves as the primary case study for the detailed application of the SMM-CPI. As one of the TEN-T Urban Nodes (Table 1 in Chapter 2.1), it represents a relevant reference point for the optimization of urban mobility strategies in the context of European targets (SUMPs).

5.1.1 Spatial and Demographic Input Parameters

The state capital Düsseldorf with its 658,245 residents (as of 31.12.2024)[22] is the Urban Node of a functional urban area with a total population of 1,606,232 residents[23], extending over a total of 19 cities and municipalities. Neighboring large cities such as Duisburg or Krefeld do not belong to the FUA Düsseldorf according to the Eurostat/OECD definition, despite their spatial proximity, as less than 15% of their employed residents commute to the Urban Node of Düsseldorf.

[22] https://statistik.duesseldorf.de/

[23] https://statistik.nrw/gesellschaft-und-staat/gebiet-und-bevoelkerung/bevoelkerung/bevoelkerung-nach-gemeinden

Municipality within FUA Düsseldorf	Residents (31.12.2024)	Municipality within FUA Düsseldorf	Residents (31.12.2024)
Düsseldorf (Urban Node)	*658,245*	*Langenfeld*	*59,975*
Dormagen	*63,799*	*Meerbusch*	*57,078*
Erkrath	*43,706*	*Mettmann*	*39,542*
Grevenbroich	*65,983*	*Monheim*	*43,630*
Haan	*30,086*	*Neuss*	*154,317*
Heiligenhaus	*26,252*	*Ratingen*	*89,368*
Hilden	*55,157*	*Rommerskirchen*	*14,079*
Jüchen	*23,926*	*Velbert*	*82,463*
Kaarst	*43,295*	*Wülfrath*	*20,731*
Korschenbroich	*34,600*	**Total**	**1,606,232**

Table 6: The 19 cities and municipalities of the Functional Urban Area Düsseldorf according to Eurostat / OECD definition

After extraction of the Copernicus land use codes 111 ("Continuous Urban Fabric"), 112 ("Discontinuous Urban Fabric") and 121 ("Industrial and Commercial Units"), the urban-used functional urban area is structured as follows (see Figure 5):

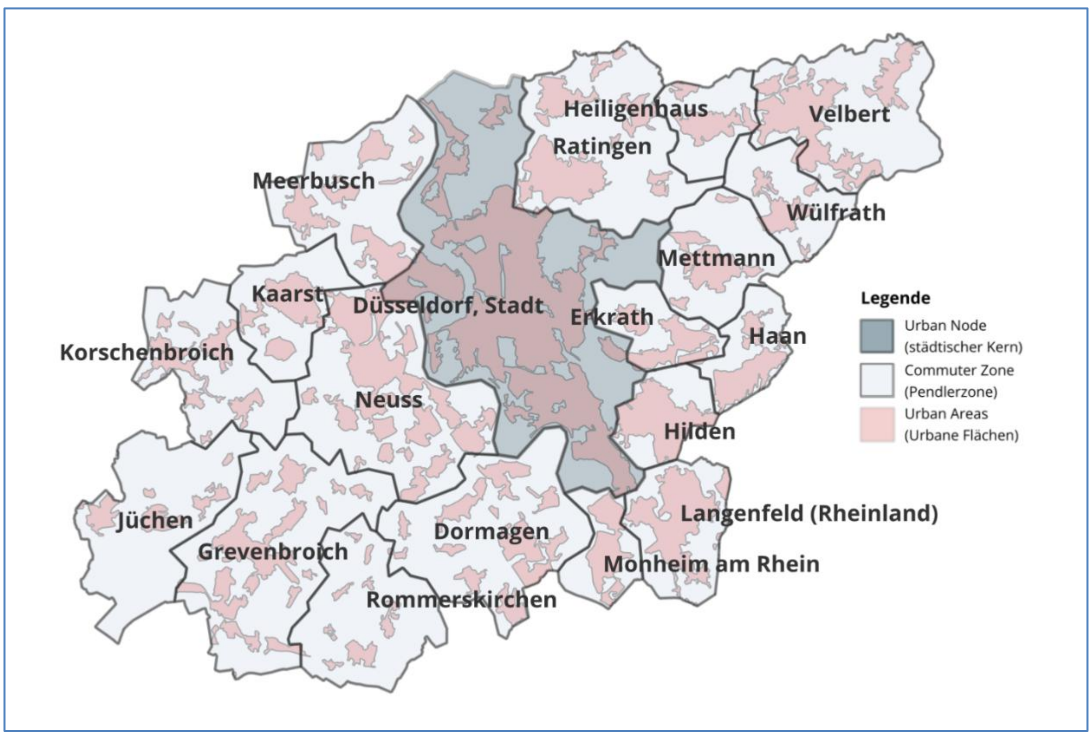


Figure 5: Graphic representation of the FUA Düsseldorf and its cities and municipalities.

5.1.2 Shared Micromobility Supply in Düsseldorf

The city of Düsseldorf regulates shared micromobility offerings via special use permits with clear requirements for fleet management, spatial use, and data provision. For e-scooters and e-bikes, the total fleet is capped at 12,000 vehicles (max. 8,400 e-scooters, max. 3,600 e-bikes) divided among the number of active providers. There are 3 zones each with individual caps to ensure urban-compatible service density. Vehicles should preferably be parked at defined sharing stations (currently 267, Fig. 6), which can be jointly used by all providers. No-parking zones are also defined, particularly in sensitive areas such as the old town, central squares, and green spaces, compliance with which is technically enforced via geofencing. Providers are required to provide operational and usage data in MDS format to enable monitoring, management, and further development of services. As of 31.12.2025, there are four shared micromobility providers for e-bikes and e-scooters in Düsseldorf, whose aggregated data flows into the analysis here.

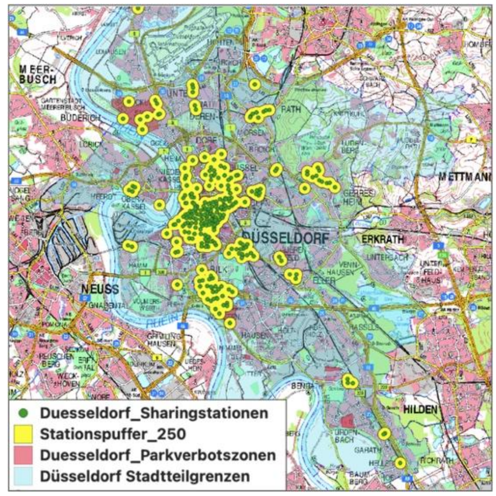


Figure 6: Spatial coverage in the Düsseldorf Urban Node

Within the commuter zone of Düsseldorf, there were shared micromobility offerings from 4 different providers in 2025 in the cities of Neuss (4 providers), Langenfeld (2 providers), Meerbusch (1 provider), Hilden (2 providers), and Monheim am Rhein (2 providers). A total of an average of 1,703 vehicles were in operation there, of which 97.2% were e-scooters.

5.1.3 Spatial and Population-Weighted Coverage for Düsseldorf

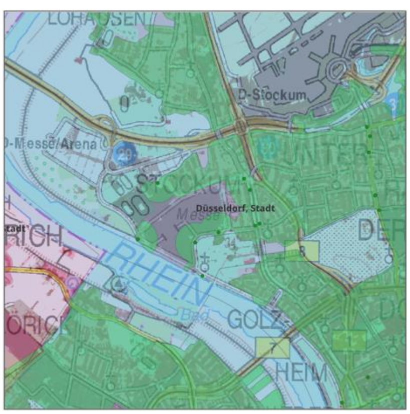


Figure 7: Example of an urban area cut-out from service area due to No-Parking-Zone (Expo Centre)

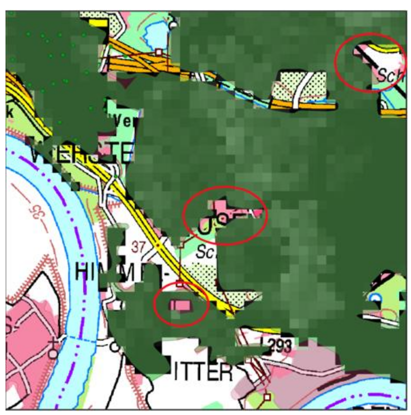


Figure 8: Example of an urban area cut-out where grid cell centres are outside of service areas

The spatial coverage rate of the shared micromobility offering in the state capital Düsseldorf is 87.3%. Gaps arise primarily due to the exclusion of no-parking zones not covered by sharing stations including their 250m radius buffers (as a proxy for walkable access, see 4.2.4), as in this example of the Düsseldorf exhibition grounds (Fig. 7).

When we look at the Population Coverage Index, i.e. population-weighted coverage, it is notable that this value at 81.7% is still quite high, but also 5.6 percentage points lower than the spatial coverage rate. This can be attributed either to some raster cells whose center lies within a no-parking zone excluded area or outside the service area (Fig. 8), or to the fact that the excluded raster cells have quite high population density.

This makes clear that it is of little use to derive qualitative differences in service availability in Urban Nodes from differences in the single-digit percentage range in city comparisons. Only with larger differences (10%+) does this distinction become more relevant. More productive here is the consideration at the functional urban area level.

The functional urban area of Düsseldorf with its 19 cities and municipalities has a spatial shared micromobility coverage rate of 43.1% overall. When looking exclusively at the commuter zone, the value is 26.5%. Population-weighted, the coverage rate is 52.6% (32.4% in the commuter zone). This means that only around one third of the population in the commuter zone can use an intermodal journey chain without falling back on private vehicles.

	Shared Micromobility Coverage Rate	Residents within Shared Micromobility Service Area	Population Coverage Index (population-weighted coverage rate)
	SA_max / UC, FUA, CZ_urb	*Res ∩ SA_max*	*Res_uc,fua,cz ∩ SA_max*
Urban Node	87.3%	537,951	81.7%
Commuter zone	26.5%	307,395	32.4%
Functional Urban Area	43.1%	845,346	52,6%

Table 7: Spatial and population-weighted coverage rate of different spatial units of Düsseldorf FUA.

5.1.4 Shared Micromobility Performance in the Urban Node vs. Commuter Zone in 2025

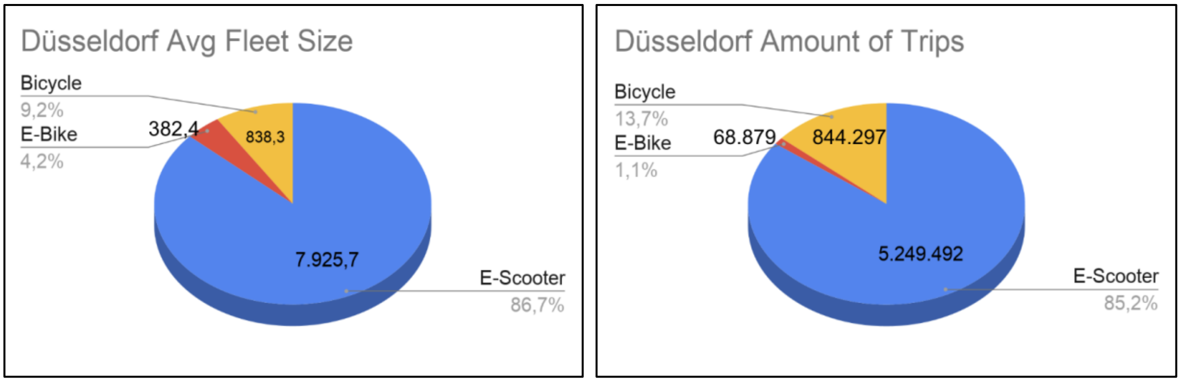
Based on the spatial and demographic input data presented above, we now examine the primary indicator and the two secondary indicators of the SMM-CPI. They result from two data points drawn from the MDS data platform of the city of Düsseldorf:

- Number of trips in calendar year 2025, aggregated across all providers and vehicle types.
- The daily average fleet of all providers and vehicle types aggregated in calendar year 2025.

In Düsseldorf, 6,183,065 trips were generated in the year by an average of 9,754.1 vehicles. In the commuter zone, there were 1,702.9 vehicles with 962,057 trips. The majority of trips were generated by e-scooters.

	städtischer Kern (Urban Node)					Pendlerzone				
	Q1 2025	Q2 2025	Q3 2025	Q4 2025	Gesamt 2025	Q1 2025	Q2 2025	Q3 2025	Q4 2025	Gesamt 2025
Durchschnittsflottengröße										
E-Scooter	7.382,7	7.933,0	8.167,7	8.321,7	7.925,7	390,0	672,7	634,8	618,8	1.611,1
E-Bike (Pedelec)	670,3	279,3	384,3	219,3	382,4	0,0	0,0	0,0	0,0	34,0
Fahrrad	842,3	850,0	827,0	834,0	838,3	0,0	0,0	0,0	0,0	0,0
Gesamt	**8.895,3**	**9.062,3**	**9.379,0**	**9.375,0**	**9.146,4**	**390,0**	**672,7**	**634,8**	**618,8**	**1.645,1**
Fahrten										
E-Scooter	954.118	1.432.794	1.611.644	1.270.326	5.249.492	104.551	109.093	124.917	102.775	643.119
E-Bike (Pedelec)	18.090	12.483	28.152	11.161	68.879	8	0	179	399	4.338
Fahrrad	0	0	0	0	844.297	0	0	0	0	0
Gesamt	**972.208**	**1.445.277**	**1.639.796**	**1.281.487**	**6.162.668**	**104.559**	**109.093**	**125.096**	**103.174**	**647.457**

Table 8: Average fleet size and number of trips per vehicle type comparing Urban Node and commuter zone



Figures 9 & 10: Average fleet size and number of trips aggregated by vehicle type.

The methodology allows, depending on the granularity of the collected data, examining these values in a differentiated manner for e-scooters, e-bikes, and bicycles, or looking at individual months or quarters. Here is an overview of the shared micromobility performance in Düsseldorf and its commuter zone for 2025, broken down by mode of transport:

	Urban Node	Commuter Zone	FUA
1. Primary indicator: Trips / 1,000 residents / day			
Total	25.7	1.9	11.6
Scooter only	21.8	1.9	11.6
Bike only	3.8	0.01	0.0
2. Secondary indicator #1: Vehicles / 1,000 residents			
Total	13.9	1.7	6.7
Scooter only	12.0	1.7	5.9
Bike only	1.9	0.0	0.8
3. Secondary indicator #2: Trips / vehicle / day			
Total	1.8	1.1	1.7
Scooter only	1.8	1.1	1.7
Bike only	2.0	0.3	2.0
4. Service density: Vehicles / km²			
Total	89.6	6.1	28.9
Scooter only	77.6	5.9	25.5
Bike only	12.0	0.1	3.4

5. Service availability / spatial coverage			
Service area ∩ Urban area	87.3%	26.5%	43.1%
6. Service availability / population-weighted coverage			
Residents ∩ Service area	81.7%	32.4%	52.6%

Table 9: Output indicators of the SMM-CPI for Düsseldorf, its commuter zone and the FUA

From this data it is obvious that Düsseldorf and its commuter zone are primarily served by e-scooters (85.2% of trips). This is primarily because in 2025 there was no public bike sharing system and the e-bike quotas under the special use permit were not fully utilized by the providers.

The data also shows that supply density and service availability in the commuter zone decreases significantly and is very unevenly distributed. With Neuss, Langenfeld, Meerbusch, Hilden, and Monheim am Rhein, 5 of the 18 cities and municipalities in the Düsseldorf commuter zone are integrated into providers' service areas, but with separate agreements or special use permits. The data shows that cities and municipalities outside the Urban Node, such as Langenfeld or Hilden, can achieve relatively good usage when they have sufficient fleet size and coverage (Table 10).

City	*FUA*	*Country*	*Population (Eurostat 2024)*	*Public Bike Sharing (PBS) System*	*Concessions for Shared Micromobility*	*Mode*	*Trips / 1,000 Pop*	*Vehicles / 1,000 Pop*	*Utilisation Rate*	*Vehicles / km2*	*Spatial Coverage (%)*	*PCI % (Pop Coverage)*
Neuss	Düsseldorf	Germany	154.317	no	yes	E-Scooter, E-Bikes	5,8	5,3	1,1	27,5	74,7%	84,6%
Monheim am Rhein	Düsseldorf	Germany	35.359	no	yes	E-Scooter, E-Bikes	6,6	5,6	1,2	27,7	97,0%	91,9%
Hilden	Düsseldorf	Germany	55.157	no	yes	E-Scooter, E-Bikes	5,7	3,3	1,7	19,1	66,2%	86,7%
Langenfeld (Rheinl,)	Düsseldorf	Germany	59.975	no	yes	E-Scooter, E-Bikes	3,9	3,2	1,2	15,6	63,5%	75,1%
Meerbusch	Düsseldorf	Germany	57.078	no	yes	E-Scooter, E-Bikes	1,5	3,8	0,4	19,7	65,4%	75,3%

Table 10: Results for the 5 municipalities of the Düsseldorf commuter zone with shared micromobility service

5.1.5 Expert Assessment and Summary

The state capital Düsseldorf has a quantitatively significant shared micromobility offering. Based on the primary indicator of 25.7 trips per 1,000 residents / day, the city would rank 4th in the CIE Bike Sharing Benchmarking 2024, just behind Ljubljana.

City	Trips/1000 inhabitants/day
Paris	36.9
Antwerp	36.1
Ljubljana	26.0
Tartu	20.4
Toulouse	19.8

Table 11: Comparable primary indicator results from the CIE Bike Sharing Benchmarking Study 2024.

It should be noted that this direct comparison is of limited significance due to the methodological limitations of the CIE approach outlined in Chapter 2.1 (e.g. lack of e-scooter consideration and inconsistent data basis). Nevertheless, the results show that Düsseldorf achieves a shared micromobility performance through the significant private investment of providers that - without substantial public investment in service operations - is comparable to the highest-performing public bike sharing systems in Europe. What independent contribution the data-driven and proactive mobility management (Connected Mobility Düsseldorf GmbH) makes to this result cannot be isolated on the basis of this analysis. Performance values in the associated commuter zone are expectedly significantly lower. A final qualitative assessment of performance strength, however, is only possible through comparative analysis with other regions (Ch. 5.2).

5.2 Comparative Analysis with Other Cities and FUAs

The comparison with other German and European major cities and FUAs within this work serves to validate the methodology and gain insights about correlations and benchmarks. Through this differentiated analysis, municipal and regional planners are enabled to optimize regulatory levers (fleet sizes, service areas) on the basis of empirical data.

5.2.1 Development of Evidence-Based Benchmarks for Shared Micromobility

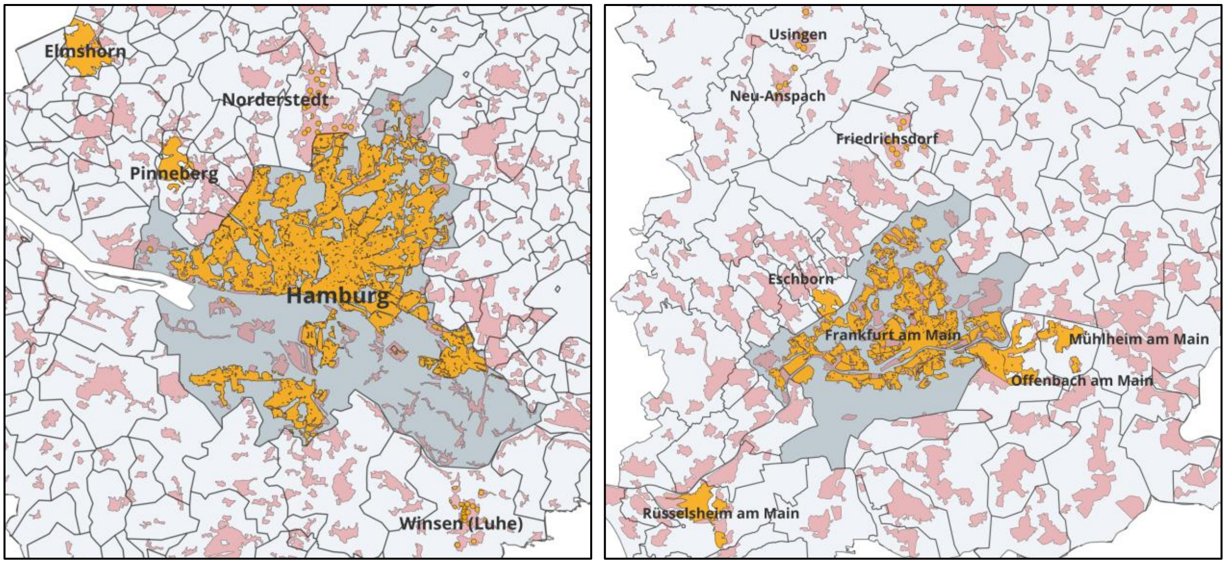
It is good to have multimodal mobility options including diverse sharing services available to reduce dependence on private motorized transport. Even better is when these services are also well used.

The following table shows a list of 35 studied cities in 3 size categories (500,000+ residents, 100–250,000 residents & 20–100,000 residents), sorted by their usage intensity measured by the primary indicator trips per 1,000 residents / day. The list includes all major cities with more than 100,000 residents that are part of the functional urban areas of the studied Urban Nodes. For the FUA Düsseldorf, this would be Neuss with its 154,000 residents. Small and medium-sized cities could be included in this list if they have a shared micromobility offering and provider-level data is unambiguous at the municipality level without estimates. Excluded are those cities where data is available, e.g. via regional systems, but has not been broken down to individual municipalities by the data providers.

	City	Population	Trips / 1,000 Pop	Vehicles / 1,000 Pop	Utilisation Rate	Spatial Coverage (%)	PCI % (Pop Coverage)	Vehicles / km2
Urban Nodes (500.000+ Einwohner)	Antwerp	544.759	65,6	15,0	4,4	77,6%	90,3%	98,9
	Frankfurt	775.790	39,8	16,9	2,4	76,2%	81,7%	125,7
	Cologne	1.087.353	30,0	9,4	3,2	56,4%	77,8%	53,4
	Düsseldorf	658.245	25,7	14,8	1,7	87,3%	81,7%	95,7
	Hamburg	1.910.160	24,3	10,4	2,3	76,8%	79,0%	60,2
	Milano	1.371.850	23,4	13,4	1,7	66,6%	76,4%	150,1
	Berlin	3.782.202	16,7	12,1	1,4	61,0%	74,1%	88,4
	Munich	1.510.378	14,9	9,5	1,6	78,5%	80,0%	128,4
Großstädte (100-250.000 Einwohner)	Potsdam	187.119	10,3	8,0	1,3	53,0%	66,9%	62,7
	Heilbronn	166.414	7,5	5,7	1,3	52,7%	51,0%	97,6
	Neuss	154.317	5,8	5,3	1,1	74,7%	84,6%	25,6
	Monza	135.490	4,9	5,0	1,0	71,6%	72,2%	35,3
	Leverkusen	130.093	3,7	3,6	1,0	75,3%	73,9%	28,8
	Offenbach	123.121	0,4	0,4	1,0	90,5%	93,4%	3,7
	Bergisch Gladbach	112.660	0,1	0,1	0,8	7,9%	9,4%	6,1
	Hanau	103.184	0,0	0,0	0,0	0,0%	0,0%	0,0
Klein- und Mittelstädte (20-100.000 Einwohner)	Pinneberg	35.268	21,3	13,6	1,6	77,6%	83,5%	70,9
	Elmshorn	45.009	19,2	10,8	1,8	78,6%	93,8%	47,8
	Unterschleißheim	29.661	10,2	6,4	1,6	82,6%	85,0%	35,6
	Brühl	45.515	9,7	6,9	1,4	81,6%	78,4%	30,5
	Mühlheim am Main	29.452	9,5	5,1	1,9	80,8%	81,9%	29,9
	Dachau	48.337	8,4	4,6	1,8	52,8%	68,4%	36,3
	Germering	41.822	7,9	3,6	2,2	90,4%	88,6%	26,5
	Monheim am Rhein	35.359	6,6	5,6	1,2	97,0%	91,9%	27,7
	Langenfeld (Rheinl,)	59.975	5,8	5,3	1,1	74,7%	84,6%	27,5
	Hilden	55.157	5,7	3,3	1,7	66,2%	86,7%	19,1
	Rüsselsheim am Main	67.656	5,1	6,0	0,8	53,1%	69,5%	50,0
	Fürstenfeldbruck	38.187	4,2	2,1	2,0	53,9%	78,2%	14,3
	Kleinmachnow	20.152	4,1	11,7	0,3	99,8%	91,9%	30,6
	Norderstedt	82.719	2,8	3,0	0,9	14,7%	14,7%	69,2
	Gauting	21.435	1,7	1,1	1,5	16,9%	17,2%	22,9
	Meerbusch	57.078	1,5	3,8	0,4	65,4%	75,3%	19,7
	Haar	23.056	1,2	9,1	0,1	72,4%	80,6%	57,8
	Eschborn	22.551	0,8	0,8	1,0	57,9%	58,8%	5,7
	Friedrichsdorf	25.937	0,3	1,2	0,2	29,3%	93,0%	17,2

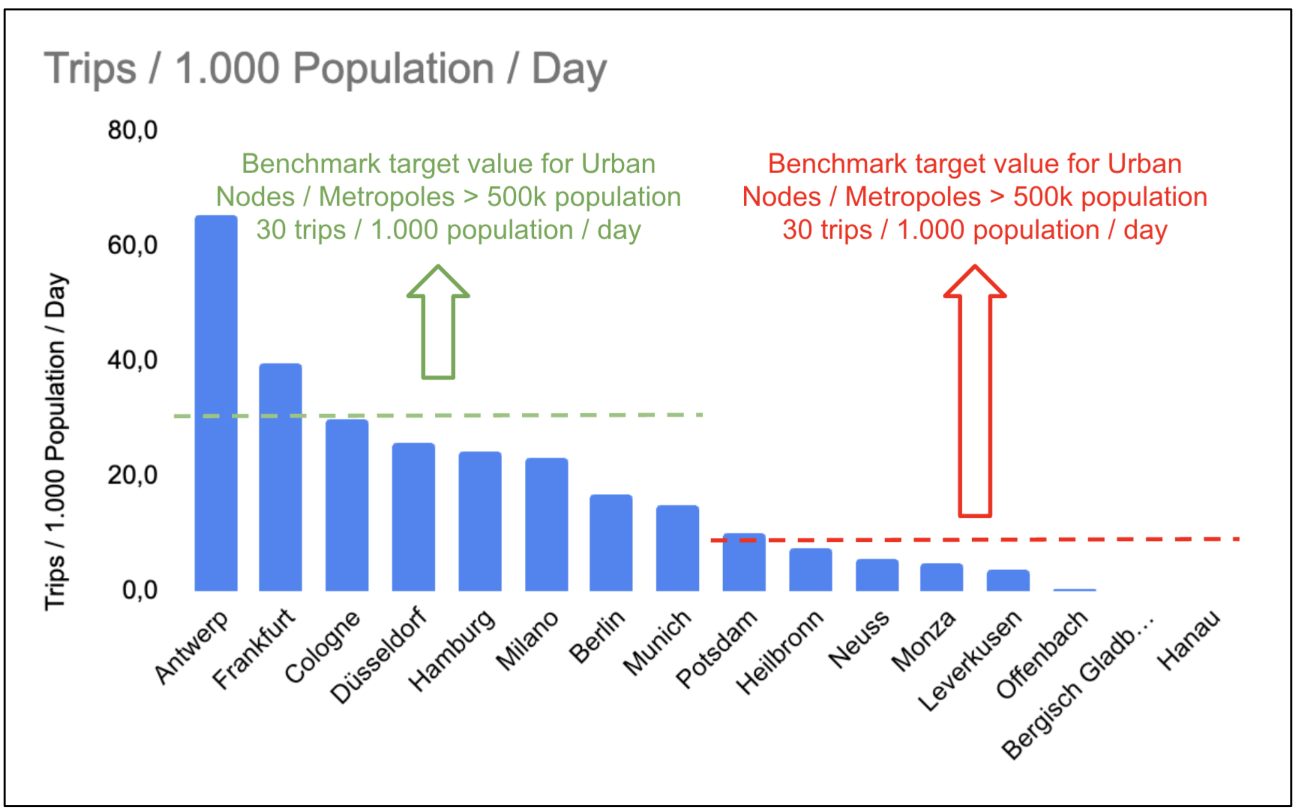
Table 12: List of 35 cities of various sizes and the performance of their shared micromobility offerings.

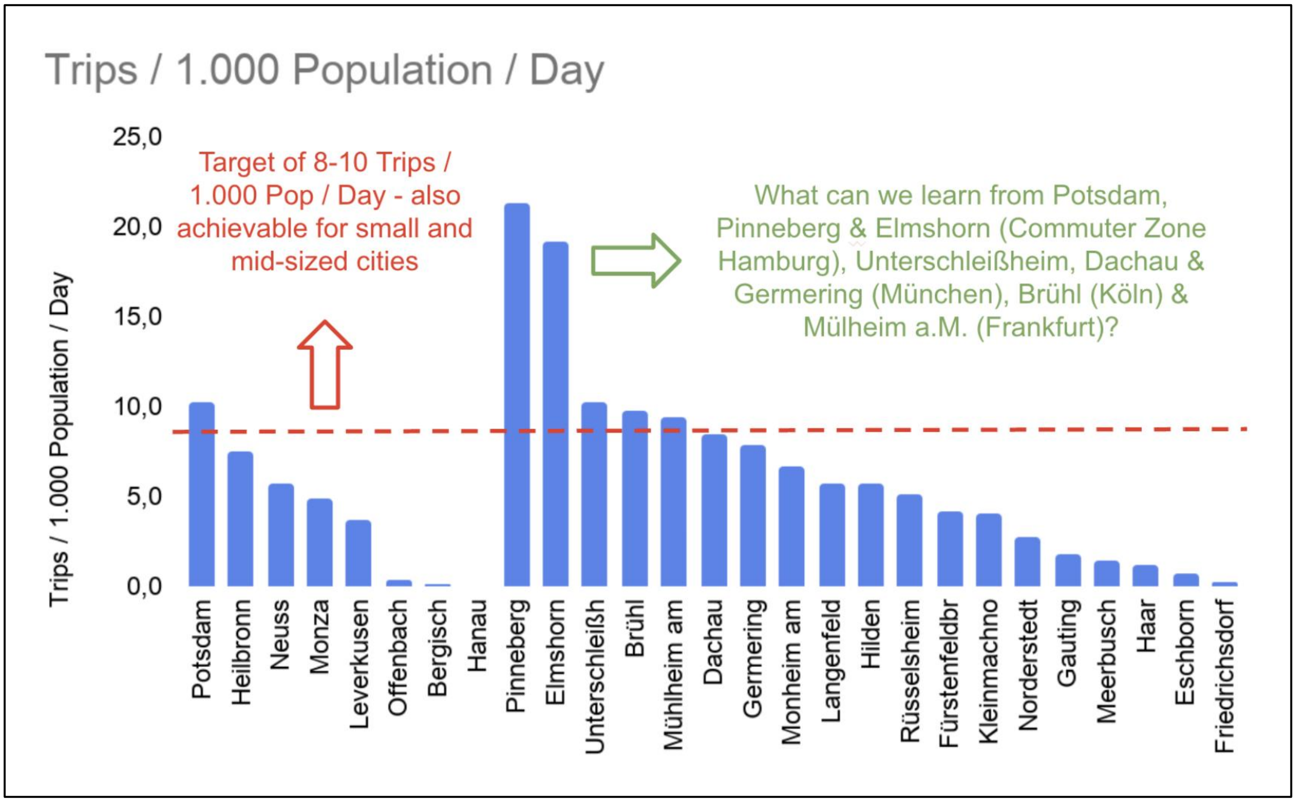
Through the direct comparability of data, quantitative benchmarks can now be defined that are equally ambitious and realistic and, for example, to be achieved within Sustainable Urban Mobility Plans (SUMPs). The point is therefore no longer to merely make services available in traditional public transport logic, but to strengthen the use of services and thus the transport impact of shared micromobility.



Figures 11 & 12: Example FUAs of Hamburg and Frankfurt with active shared micromobility markets

Let us look at the usage intensity of the studied cities in comparison:





Figures 13 & 14: Possible benchmarks for usage intensity of shared micromobility systems in different city size classes

Urban Nodes naturally have more mobility demand than cities and municipalities in the commuter zone due to the higher daytime population. Accordingly, benchmarks can be set higher than in smaller cities. Nevertheless, the data shows that even smaller large cities, medium and small towns can achieve high usage intensity of shared micromobility services if they create the right conditions. From the list of studied cities, particularly noteworthy are Pinneberg (21.3 trips / 1,000 residents), Elmshorn (19.2), Potsdam (10.3), Unterschleißheim (10.2), Brühl (9.7), Mühlheim am Main (9.5), Dachau (8.4), Germering (7.9), and Heilbronn (7.5).

By aggregating to FUA level, the SMM-CPI also allows defining regionally integrated benchmarks that can be achieved through integrated regional mobility governance and SUMP governance. For example, Frankfurt, although Germany's top performer, could set itself the goal of helping to strengthen the region and supporting the small and medium-sized cities in its commuter zone in their efforts to bring multimodal services to the area, where they have not yet arrived in FUA comparison, as evidenced by the availability and consistency of services in the commuter zone around Frankfurt (see color coding in Table 13).

Urban Node	Country	Population Urban Node (Eurostat 2024)	Population FUA (Eurostat 2024)	Public Bike Sharing (PBS) System	Concessions for Shared Micromobility	Commuter Zone					
						Trips / 1,000 Pop	Vehicles / 1,000 Pop	Vehicles / km2	Utilisation Rate	Spatial Coverage (%)	PCI % (Pop Coverage)
Antwerp	Belgium	544.759	1.095.708	harmonised	only core city	1,1	2,1	0,5	4,3	13,4%	22,7%
Berlin	Germany	3.782.202	5.552.922	only core city	only core city	1,3	1,3	1,0	2,1	3,4%	8,7%
Frankfurt	Germany	775.790	2.867.121	no / unknown	fragmented	0,3	0,3	1,0	1,2	6,0%	10,3%
Hamburg	Germany	1.910.160	3.570.631	only core city	fragmented	1,4	0,9	1,5	2,4	4,6%	6,6%
Milano	Italy	1.371.850	2.391.491	only core city	fragmented	1,2	1,1	1,1	1,3	3,3%	14,2%
Munich	Germany	1.510.378	2.989.356	harmonised	fragmented	1,2	0,9	1,3	3,1	13,4%	16,9%
Düsseldorf	Germany	658.245	1.606.232	no / unknown	only core city	1,9	1,7	1,1	6,1	26,5%	32,4%
Cologne	Germany	1.087.353	2.021.534	fragmented	fragmented	1,5	1,7	0,9	5,7	24,9%	29,0%
Heilbronn	Germany	130.093	485.452	no / unknown	only core city	0,0	0,0	#DIV/0!	0,0	36,7%	10,1%

Table 13: Commuter zone results in comparison

Due to the granularity of the data, a comparison between different vehicle types can also be made. In the dataset it becomes very clear that the performance of some cities in shared micromobility is primarily secured by e-scooter offerings (e.g. Düsseldorf, Frankfurt, Hamburg & Munich). Other cities show a substantial share of rental bicycle usage, primarily through the existence of long-established public bike sharing systems (Antwerp, Berlin, Cologne, Milan). However, the current data suggests that both vehicle types are needed to achieve a good position in comparative city rankings.

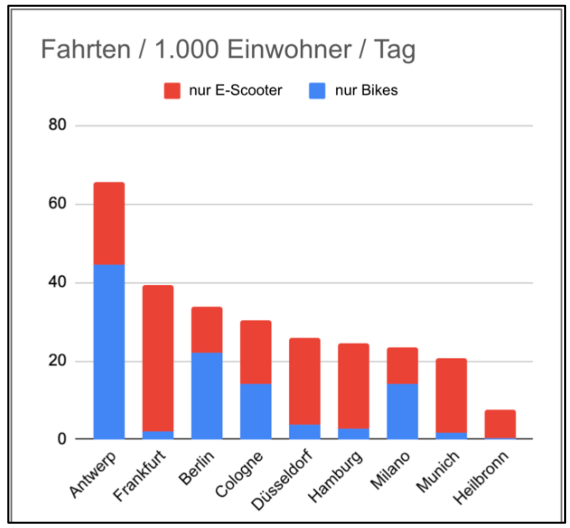


Figure 15: Comparison of Urban Nodes, separated for e-scooters and (e-)bikes

But which factors most strongly influence usage intensity and performance of micromobility offerings? What levers do administrations have to strengthen the performance of their micromobility systems? We address this question through a correlation analysis.

5.2.2 Correlation Analysis: Factors Influencing High Usage Intensity

Let us examine the various indicators and their Pearson correlation coefficients - the measure of the relationship between two variables, which can be either positive (values between 0 and 1) or negative (values between 0 and -1) - more closely. These are bivariate Pearson correlations; multivariate relationships are not controlled for. Additionally, the indicators "trips / 1,000 residents / day", "vehicles / 1,000 residents", and "trips / vehicle / day" are mathematically closely related, as they are derived from the same basic quantities (trips, vehicles, residents). High correlation values may therefore partly reflect this algebraic dependency and should be interpreted with caution.

Rang	Indicator	Parameter	Pearson Koeffizient (r)			
			Total (34 Cities)	*Only Urban Nodes (500.000+ Population*	*Only Big Cities (100-250.000 Einwohner)*	*Only Small- & Midsized Cities (20-100.000 Einwohner)*
1	Utilsation Rate	Trips / Active Vehicle / Day	0,91	0,96	0,92	0,85
2	Fleet Availability	Active Vehicles / 1.000 Population	0,85	0,90	0,85	0,80
3	Service Density	Active Vehicle / km2	0,55	0,72	0,58	0,38
4	Spatial Coverage	Service Area ∩ Urbane Area	0,47	0,60	0,47	0,32
5	population-weighted Coverage (PCI)	Population ∩ Service Area	0,43	0,56	0,42	0,27
6	Population Size	Population	0,40	0,28	0,35	-0,08

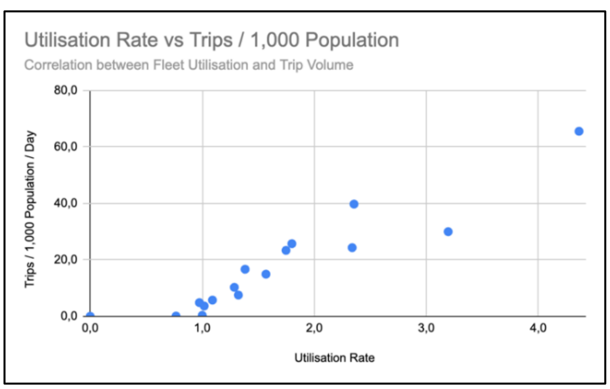
Table 14: Correlation coefficients of various SMM-CPI indicators with usage intensity (trips / 1,000 residents / day)

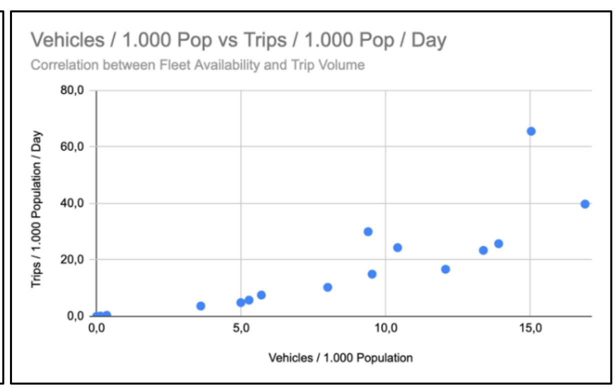
Utilization rate and fleet availability show the strongest associations with usage intensity. The data supports the assumption of network effects: a larger fleet per resident correlates strongly with higher trip volume and thus greater potential for modal shift. This suggests - although correlation analyses cannot provide formal proof of causality - that artificial restrictions, e.g. arbitrarily set fleet caps by administrations, limit the transport utility of shared micromobility.

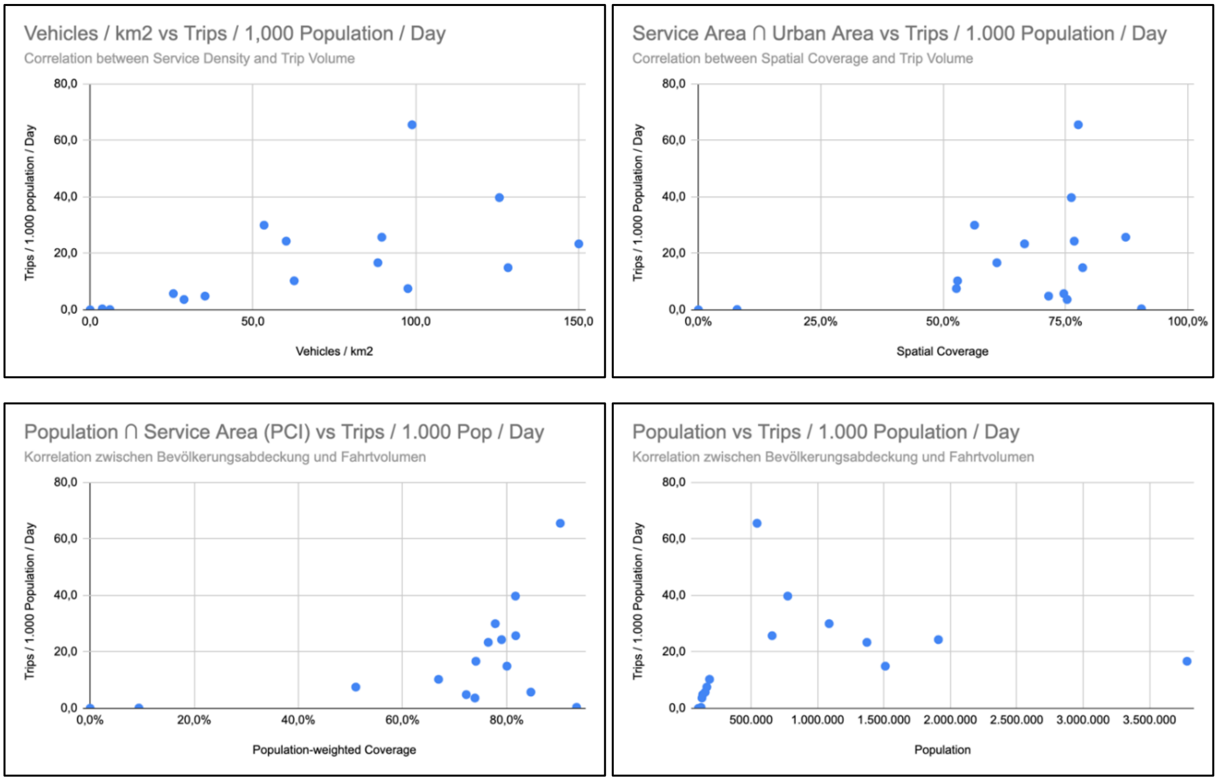
Service density and spatial coverage also have a moderate to strong influence on usage intensity. Service density becomes more important with increasing city size. The larger the city, the more important service density becomes - i.e. the spatial proximity to the next vehicle - especially for spontaneous trips.

Population size explains little of the differences in usage. While it does have an influence due to the significantly higher daytime population in Urban Nodes when correlating across all cities of different sizes, it plays a subordinate to no role within individual city size classes.

The following figures show the correlations in detail:







Figures 16–21: The correlations in detail (large cities and Urban nodes only)

5.2.3 Findings on the Influence of Fleet Size and Density

The correlation analysis (Ch. 5.2.2) supports the significant role of utilization rate and fleet availability for the performance of shared micromobility systems. The concept of network effects is empirically supported: a larger fleet per resident correlates strongly with higher trip volume and thus greater displacement potential. This provides strong evidence - though not formal proof of causality - that artificial constraints, particularly arbitrarily set fleet caps by administration, limit the positive transport effect of shared micromobility.

Service density (vehicles per unit area) and spatial and population-weighted coverage (PCI) have a moderate to strong influence on usage intensity. Service density gains importance with increasing city size, as spatial proximity to the next vehicle is essential for spontaneous trips and the attractiveness of the overall service. Population size itself is not a primary explanatory factor for usage differences within homogeneous city size classes.

5.2.4 System Logic and Vehicle Mix as Influencing Factors

A look at the vehicle mix in commuter zone cities indicates that a service based exclusively on bicycles and e-bikes is not a sufficient condition for high performance. Only the combination with e-scooter services enables small and medium-sized cities to achieve significant transport impact (Figure 21).

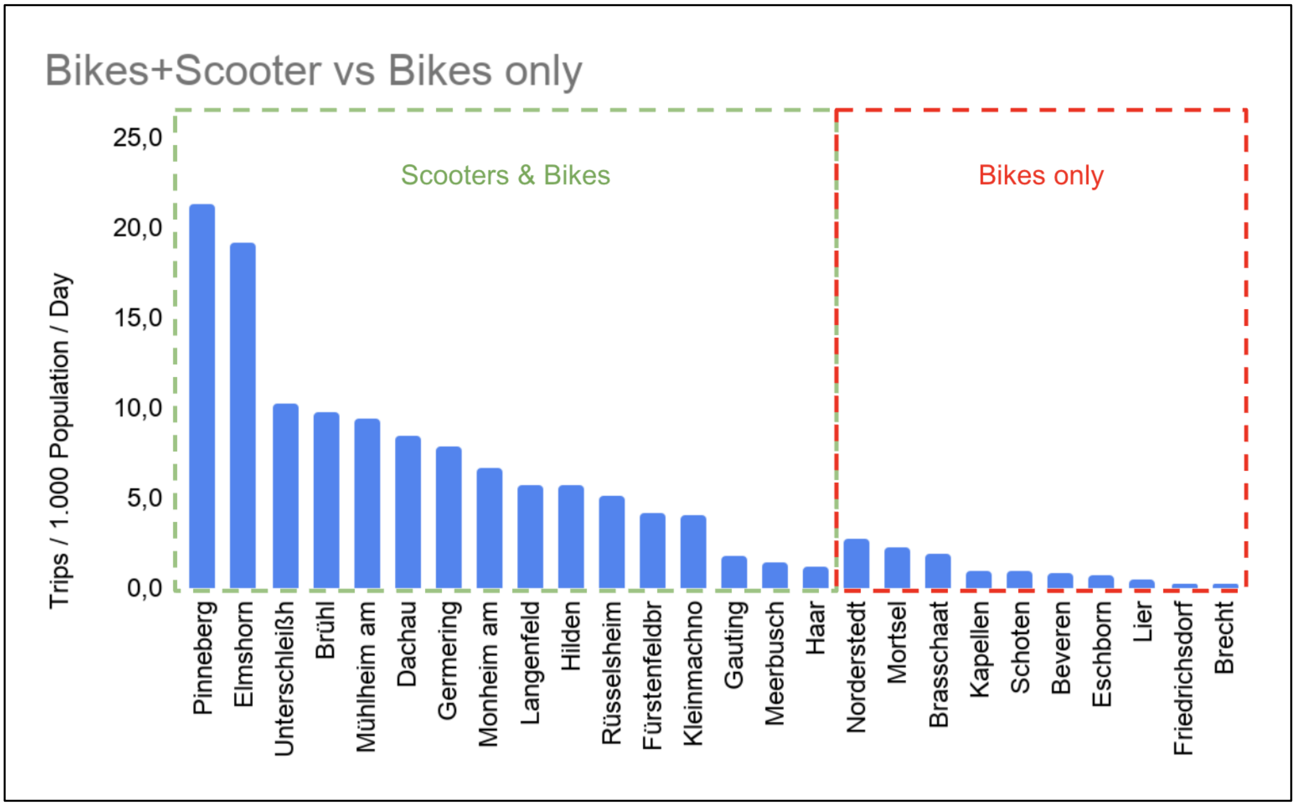


Figure 22: Comparison of primary indicator between cities with a vehicle mix and cities with only bicycles and e-bikes, including commuter zone cities of Antwerp for comparison.

Let us look more closely at those cities that generate at least 7.5 trips / 1,000 residents / day. It is notable that all these cities have a broad vehicle mix of bicycles and e-scooters. It is also noteworthy that all 9 cities have high spatial and population coverage.

City	FUA	Country	Population (Eurostat 2024)	Public Bike Sharing (PBS) System	Concessions for Shared Micromobility	Mode	Trips / 1,000 Pop	Vehicles / 1,000 Pop	Utilisation Rate	Vehicles / km2	Spatial Coverage (%)	PCI % (Pop Coverage)	Comment
Pinneberg	Hamburg	Germany	35.268	no	yes	E-Scooter E-Bikes	21,3	13,6	1,6	70,9	77,6%	83,5%	
Elmshorn	Hamburg	Italy	45.009	no	yes	E-Scooter E-Bikes	19,2	10,8	1,8	47,8	78,6%	93,8%	
Potsdam	Berlin	Germany	187.119	yes	yes	E-Scooter E-Bikes Fahrräder	11,5	10,3	1,1	81,0	53,0%	66,9%	
Unterschleißheim	Munich	Germany	29.661	yes	yes	E-Scooter E-Bikes Fahrräder	10,2	6,4	1,6	35,6	82,6%	85,0%	
Brühl	Cologne	Germany	45.515	yes	yes	E-Scooter E-Bikes Fahrräder	9,7	6,9	1,4	30,5	81,7%	78,4%	one service estimated
Mühlheim am Main	Frankfurt	Germany	29.452	no	yes	E-Scooter	9,5	5,1	1,9	29,9	80,8%	81,9%	
Dachau	Munich	Germany	48.337	no	yes	E-Scooter E-Bikes	8,4	4,6	1,8	36,3	52,8%	68,4%	
Germering	Munich	Germany	41.822	yes	yes	E-Scooter E-Bikes Fahrräder	7,9	3,6	2,2	26,5	90,4%	88,6%	
Heilbronn	Heilbronn	Germany	130.093	no	yes	E-Scooter E-Bikes	7,5	5,7	1,3	97,6	75,3%	73,9%	

Table 15: SMM-CPI results table for top performers outside metropolitan areas

This is because all cities with high usage have awarded concessions to private-sector services operating predominantly with flexible free-floating/hybrid systems. Those cities that only have publicly funded bike sharing systems, which tend to be station-based and thus provide reduced spatial coverage, fall significantly behind in results.

	Vorbilder (>7,5 Fahrten / 1.000 EW / Tag)	Mittelfeld (2,5 - 7,5 Fahrten / 1.000 EW / Tag)	Nachholbedarf (<2,5 Fahrten / 1.000 Einwohner / Tag)
E-Scooter	**1** (Mühlheim am Main)	0	0
E-Scooter, E-Bikes	**5** (Brühl, Dachau, Elmshorn, Heilbronn, Pinneberg)	**6** (Monza, Neuss, Monheim, Hilden, Kleinmachnow, Langenfeld)	**1** Meerbusch
E-Scooter, E-Bikes, Fahrräder	**3** (Germering, Potsdam, Unterschleißheim)	**2** Rüsselsheim, Fürstenfeldbruck	**2** Haar, Gauting
E-Bikes, Fahrräder	0	**2** Leverkusen, Norderstedt	**6** Bergheim, Bergisch Gladbach, Erftstadt, Frechen, Kerpen, Pulheim
E-Bikes	0	0	**2** Bergisch Gladbach, Friedrichsdorf
Fahrräder	0	0	**2** Eschborn, Offenbach

Table 16: Distribution of commuter zone cities by vehicle mix and usage intensity

The analysis of spatial and population coverage demonstrates that high usage intensity in the commuter zone is achieved through a system design that is either based on free-floating models or a very dense network of parking areas (e.g. Pinneberg, Brühl). Such a system design is deemed necessary to generate high usage, as it maximizes flexibility and accessibility for users.

	⌀ Spatial Coverage	*⌀ Population Coverage*
Urban Nodes	72,6%	80,1%
Performer	74,8%	80,0%
Midfield	66,6%	73,7%
Low Performer	31,3%	37,5%
E-Bikes, Fahrräder	27,0%	34,1%
E-Scooter, E-Bikes, Fahrräder	68,0%	75,7%

Table 17: The influence of system coverage

5.2.5 The Fleet Density Adoption Threshold

The evidence-based analysis identifies a clear adoption threshold for shared micromobility systems, i.e. a minimum service level necessary to generate substantial demand. An increase in usage is only observed from a fleet density of approximately 3–6 vehicles per 1,000 residents. Below this threshold, usage is practically negligible.

Phase	Fleet density (vehicles / 1,000 res.)	Demand (trips / 1,000 res.)	Implication
Phase 1 – Sub-critical fleet	*< 3*	*0-1*	No significant demand due to lack of availability; system appears as "weak market".
Phase 2 – Early adoption	*3-6*	*3-7*	Demand begins to rise moderately.
Phase 3 – Functioning market	*6-10*	*10-25*	Clear scaling of demand; network effects become effective.
Phase 4 – High-performance systems	*> 10*	*25-65*	Disproportionate growth in demand; system is an integral part of Urban transport.

Table 18: Phases of demand and usage, depending on fleet size

This finding has direct regulatory and market implications, as too-small fleets prevent both network effects for providers and perceived reliability and spontaneous usage by the population.

6. Conclusions and Outlook

6.1 Conclusion: Performance of the SMM-CPI and Key Findings

The Shared Micromobility City Performance Index (SMM-CPI) is intended to contribute to a more consistent and methodologically enhanced evaluation of shared micromobility services. Compared to existing approaches, it particularly extends the cross-modal perspective, the spatial-demographic coverage dimension (PCI), and the quality of the data basis. It can thus provide an additional foundation for Urban policy decisions but does not yet replace a comprehensive impact analysis. A broader data basis would also be necessary for full methodological validation.

The Node performance of the index lies in the standardization of the reference basis (FUA, urban areas) and the integration of spatial-demographic equity aspects (PCI). The index thus serves not only as a performance measurement instrument, but as a governance tool that provides municipalities with an evidence-based negotiating foundation with mobility providers.

Descriptive findings from the data analysis:

- **Influence of fleet availability:** The analysis demonstrates a direct correlation: a higher density of active vehicles per resident significantly increases usage.
- **Adoption threshold:** Shared micromobility systems generate substantial demand only from a density of 4–6 vehicles per 1,000 residents.
- **Necessity of a vehicle mix:** A multimodal offering integrating e-scooters, e-bikes, and bicycles is necessary to achieve high performance values even in small and medium-sized cities.

6.2 Recommendations for Municipal Decision-Makers

Based on the structured findings of the SMM-CPI, the following concrete recommendations for municipal actors can be derived:

Focus area	Recommendation	SMM-CPI reference
Data governance	**Mandatory integration of MDS specification** in licensing and concession contracts for all sharing services in public space.	Supports more reliable and standardized data provision as a basis for Node indicators.
Regional governance	**Integrated governance with clearly defined KPIs** for the entire functional urban area (FUA) and elaboration of consistent, regional regulations and processes.	Scalability of services into the area, to reduce structural mobility deficits in the commuter zone.
Fleet management	**Avoidance of artificial fleet caps** below the empirically determined adoption threshold of 4-6 vehicles per 1,000 residents.	Increase of usage intensity and transport utility by enabling network effects.
Service areas & parking infrastructure	**Expansion of a dense network of parking areas** (mobility stations, sharing zones), both to maximize spatial coverage and to avoid conflicts in public space.	Increase of population coverage (PCI), accessibility, and availability of services in the area.
Strategic planning	**Use of SMM-CPI indicators** as metrics for monitoring and progress tracking, e.g. within mobility concepts or SUMPs.	Establishment of a consistent benchmarking framework for the strategic development of sustainable mobility in Urban Nodes and their commuter zones.

Table 19: Recommendations for municipal actors

6.3 Outlook

The SMM-CPI offers three complementary development pathways that build on each other and mutually reinforce one another.

Scaling to all European Urban Nodes and FUAs. The immediately obvious next step is the systematic application of the SMM-CPI to all 431 TEN-T Urban Nodes and their functional Urban areas in Europe. This would for the first time create a robust, methodologically consistent European benchmarking framework for shared micromobility - as an evidence-based foundation for SUMP reporting obligations from 2027 and as an instrument for strategic resource allocation at national and European level. The necessary data infrastructure (MDS mandate in concession contracts, central data platforms) is already being established in a growing number of European cities.

Extension to further new mobility service forms. The index architecture of the SMM-CPI is conceptually transport-mode-neutral and can be transferred to car-sharing, moped-sharing, and in the medium term to ride-hailing and autonomous taxi services. The methodological building blocks - population-weighted PCI, MDS-based trip and fleet data, FUA as reference area - remain unchanged, while vehicle-type and service-specific metrics are added.

Methodological development: intersection with qualitative context data. The most important substantive development of the SMM-CPI lies in linking quantitative performance indicators with qualitative context data, particularly from standardized user surveys. Currently, shared micromobility providers collect survey data on usage motives, intermodal journey chains, multimodality, and demographic user profiles - but separately, methodologically heterogeneously, and not comparably across cities. Centralized, harmonized surveys, conceived uniformly and established jointly across all providers, vehicle types, and cities, would be a decisive next step. They would enable the usage intensity and spatial coverage measured in the SMM-CPI to be related to actual transport impact - such as the share of substituted private motorized vehicle trips or the role of shared micromobility in intermodal journey chains. This would serve the common interests of providers, cities, and research, and would develop the SMM-CPI from a performance measurement instrument into a complete impact evaluation instrument.

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