

Quantifying Europe’s Cycling Infrastructure using OSM (QECIO 2.02): Our Methodology



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Abstract

There is a great demand for data on cycling infrastructure, but as for now, no official source provides this kind of information on a European scale. Therefore, this project aims to quantify the amount of cycle infrastructure using OpenStreetMap (OSM). The first version of the project collected data about three basic infrastructure types (cycle tracks, cycle lanes, cycle and pedestrian paths) for 500+ European cities, including all planned urban nodes of the trans-European transport network (TEN-T).

The second edition expanded the methodology to cover peri-urban and rural areas and to consider three additional infrastructure types (bus and cycle lanes, cycle streets, and limited access roads). We researched 37 European countries, including all 27 EU member states, and the information was gathered at NUTS 3 level (Nomenclature of territorial units for statistics). The information collected from OSM was processed to obtain the information needed. We calculated the length of the cycling infrastructure, taking into account the directionality and also explored the availability of some additional data for cycling infrastructure (surface, smoothness, width). Lastly, we calculated five measures that are displayed on interactive maps.

Changelog

Version 2.00, 2023/07/24:

- Launch of the new dashboard.

Version 2.01, 2023/08/07:

- Added `cycleway=opposite` as an additional criterion for contraflow detection. Mostly used in Germany.
- Fixed an error, where a `cycleway` tag was sometimes not considered.
- Added access checks for cycle infrastructure, to avoid counting cycle infrastructure not publicly accessible.

Version 2.02, 2023/09/05:

- Logic for distinguishing cycle tracks from cycle and pedestrian tracks rewritten to take into account the values of the “foot” and “segregated” keys (if present). The change significantly affected the numbers for Finland.
- Added `cycleway=opposite_lane|opposite_track` (not recommended tagging, but used in a few places) to criteria for contraflow detection.
- Added “surface” check if “tracktype” is not set for `highway=track`.
- Fixed direction check for cycle streets with contraflow cycling.
- Added recognition of `unhewn_cobblestone` as surface value.

- Split surface category “blocks/slabs/cobbles” into two subcategories (acceptable and not acceptable as cycling surface). As for now, the subcategories are not displayed on the maps, only used to determine acceptability of some highway = track features.

Background

Last year, our first project collecting bike infrastructure across the TEN-T urban nodes was launched. The Trans-European Transport Network (TEN-T) is the EU's flagship transport policy to support the construction and renovation of transport infrastructure across the EU. The European Commission's proposal for revision of the TEN-T guidelines expanded the number and role of so-called urban nodes on the TEN-T network. An increase in the modal share of active modes, such as cycling, is listed as one of the priorities for urban nodes. We decided to investigate how well these urban nodes are currently equipped with cycling infrastructure. More information on the TEN-T revision and the amendments proposed by ECF (European Cyclists Federation) can be found [here](#).

Nevertheless, some infrastructure was not considered, such as agricultural roads or cycle streets. Likewise, only the urban nodes were included, without including information on other areas. Working outside urban areas brings a degree of complexity as we must homogenize the data. Therefore, in this project, we aimed to implement additional information about cycle infrastructure, and additional information available in the map, and extrapolate the analysis to rural areas of Europe.

Methodology

Theoretical framework

OpenStreetMap is a free, world-wide, crowdsourced geographic dataset. In certain contexts, OSM data has been found to be more detailed and up to date than municipal data and to be useful in accessible urban planning (Ferster et al., 2019, Timaite et al, 2022). Information about appropriate cycle infrastructure is crucial to enhancing safe cycling and encouraging cycling as a sustainable mode of transport. Therefore, information on current infrastructure is needed for continued development and optimisation (Hardinghaus & Panagiotis, 2020, Ferster, 2020). OSM datasets provide information that can be used for evidence-based transport planning. Previous research projects have acknowledged OSM open database as a source of data that could enhance accessible travel planning. Previous projects have made use of the tool to describe

cycling infrastructure in different places, such as [CicloMapa](#), the [Bicycle Network Analysis](#), and [GrowBike](#).

To extract the data, we did a review of the available information on OSM, and the tags used for cycling infrastructure. More information on OSM bicycle-related tags can be found on wiki.openstreetmap.org/wiki/Bicycle and taginfo.openstreetmap.org. After analysing the tags, we extracted the following types of infrastructure and measures following the logic outlined in Annex I.

Geographic scope

The analysis includes 37 countries covered by the European NUTS (Nomenclature of territorial units for statistics) classification. This includes the 27 EU member states, candidate countries awaiting accession to the EU, potential candidates, and countries belonging to the European Free Trade Association (EFTA).

Certain more remote EU territories outside of the European continent were not included (French territories in America or Africa, Canary Islands).

Technical details

In this edition we used Protobuf (PBF) files from European countries available from the Geofabrik website (<http://download.geofabrik.de/europe.html>). Highways and a subset of their parameters were extracted per country using the PyOsmium package (<https://osmcode.org/pyosmium/>).

The cleaning and processing of the data were performed in several steps.

- 1) The analysis was performed at NUTS-3 level, clipping the highway per NUTS-3 administrative boundary.
- 2) The main road network and the local road network were calculated from the extracted highways. We assume that on the main road network segregation of cycle and motorised traffic is necessary, on the local road network both types of traffic can safely share the carriageway.
- 3) We analysed OSM ways, which are linear features representing segments that connect two points in the space. We estimated which ways from the highway network contain cycle infrastructure. Based on the OSM tags, we assigned each way to a specific cycling infrastructure type. See Table 2.
- 4) Later, we defined the directionality of the way, aiming to identify contraflow and scale the length of the way. In some cases, we translated a single highway feature into two cycling infrastructure features (for example when `cycleway:both` is used or `cycleway:left` and `cycleway:right` on the same highway). For the length calculations, we divided the length of the unidirectional cycling infrastructure by two. Finally, we

calculated the total lengths and the road network coverage of the cycling infrastructure.

- 5) In this edition we have added information on the surface type and quality, grouping the information available in OSM in line with the EuroVelo [European Certification Standard](#).

Explanation of the indicators in the dashboard

Ratio of segregated cycling infrastructure to the main road network

The ratio of segregated cycling infrastructure to main roads is an indicator of road coverage by cycling infrastructure. The segregated cycling infrastructures considered are cycle tracks, cycle and pedestrian tracks and cycle lanes. While the road network was calculated by adding highways labelled as motorway, trunk, primary, secondary, tertiary, motorway link, trunk link, primary link, secondary link, and tertiary link in OSM.

segregated infrastructure = cycle tracks + cycle lanes + shared pedestrians

(1)

$$ratio = \frac{total\ length\ segregated\ infrastructure\ (km)}{total\ length\ main\ roads\ (km)}$$

(2)

About the interpretation of the ratios: ratio of 100 can be roughly interpreted as 100% of main roads having bidirectional cycling infrastructure. The ratio can exceed 100% for various reasons:

1. At least some streets in the main road network have bidirectional cycling infrastructure on both sides of the road.
2. The city has cycle tracks (tagged as highway=cycleway) or cycle and pedestrian tracks outside the road network (for example crossing green areas, alongside a river etc.); these are included in the numerator but not denominator of the ratio.
3. The city has segregated cycling infrastructure located also alongside residential roads (which are excluded from the main road network).

As mentioned, these numbers on cycling infrastructure do not directly reflect the quality of infrastructure or cyclability. Similarly, there may be roads that are of high quality and regularly used for cycling, such as residential roads, that do not have explicit infrastructure. This may negatively bias the ratios.

Ratio of extended cycling infrastructure to public roads.

The ratio of cycling infrastructure to public roads is an indicator of road coverage by cycling infrastructure. The extended cycling infrastructure used in the numerator included: cycle tracks, cycle and pedestrian tracks, cycle lanes, limited access roads, bus lanes and cycle streets. The length of the road network used in the denominator was calculated by adding main roads and local roads. The local roads were selected using the following tags: residential, living street, unclassified.

$$\text{extended infrastructure} = \text{cycle tracks} + \text{cycle and pedestrian tracks} + \text{cycle lanes} + \text{limited access roads} + \text{bus lanes} + \text{cycle streets} \quad (3)$$

$$\text{ratio} = \frac{\text{total length extended infrastructure (km)}}{\text{total length public roads (km)}} \quad (4)$$

Ratio of cycle tracks to main roads (plus information on surfaces)

The ratio of cycle tracks to main roads is an indicator of road coverage by cycle infrastructure. Only cycle track length was used in the numerator. The length of the road network used in the denominator was calculated by adding main roads. The different types of surfaces were grouped according to EuroVelo European Certification Standard (ECS) criteria. See Table 4.

$$\text{ratio} = \frac{\text{total length cycle tracks (km)}}{\text{total length main roads (km)}} \quad (5)$$

Availability of additional data

The percentage of additional data is an indicator of the completeness of OSM tags. The numerator represents the average amount of information on cycling infrastructure available for that area, taking into account surface, smoothness and width tags. The cycling infrastructure considered for these statistics includes cycle tracks, cycle lanes, cycle and pedestrian tracks and limited access roads, because these are the types of infrastructure where the parameters are most likely to affect usability. We explored which percentage of each one of the different infrastructures were labelled over the total.

$$\text{infrastructure analysed} = \text{cycle tracks} + \text{cycle lanes} + \text{cycle and pedestrian tracks} + \text{limited access roads} \quad (6)$$

$$x \text{ tag (\%)} = \frac{\text{total length cycle infrastructure tagged with } x \text{ tag (km)}}{\text{Length of infrastructure analysed (km)}}$$

(7)

Where x could be surface, smoothness or width.

$$\text{available data (\%)} = \frac{\text{surface tag (\%)} + \text{smoothness tag (\%)} + \text{width tag (\%)}}{3}$$

(8)

Ratio of contraflow cycling

The contraflow cycling is a ratio of local one-way streets with contraflow cycling allowed to the total length of local one-way streets.

$$\text{ratio} = \frac{\text{total length of local ways with contraflow (km)}}{\text{total length for local roads oneway + contraflow (km)}}$$

(9)

Note: there are several cases, where a street or its section is classified by our algorithm as one-way street without contraflow cycling allowed, while a human would probably make a different judgement. These are:

- Dual carriageway – relatively rare for residential streets, but nevertheless happens; it should however be noted that some cities in such cases do enable contraflow on one or both carriageways anyway.
- One-way street with a parallel cycle track represented as a separate OSM feature; again quite rare for a residential street.
- Connectors on intersections, for example when a bidirectional residential street splits into separate carriageways for both directions to join a main road; these are relatively short, and the good design practice is to keep the intersections simple and compact.

Overall, the human-made reports, with manual classification of streets and their contraflow status, give ratios up to 25% higher than the ones automatically extracted from OSM. As the OSM data coverage and our algorithms continue to improve, we will be able to provide better and better estimation

Disclaimer

The data featured in this dashboard only represents OSM contributions. The lower numbers may therefore reflect missing OSM data rather than the actual absence of cycling infrastructure in each area. Besides missing data, these numbers may not be fully representative in cases where OSM's thorough universal tagging guidelines do not account for certain local or informal cycling infrastructure types.

Lastly, the data does not imply that the cycling infrastructure is necessarily high quality. To infer the cyclability of a given city's network, one needs to consider additional factors

beyond the OSM tags that are currently extracted and analysed. - **we aim to explore this in the future.**

Since OSM is an open dataset, anyone can improve the accuracy of the database, and thus this dashboard, by adding and updating OSM data. Also, if there any differences between official databases and our results, please do not hesitate to contact us back. Lastly, we point out that other way to incentive the completeness of OSM database is to incentive people to add information through policies or citizen science campaigns as stated by Hardinghaus & Panagioties, (2020).

Authors

The main authors of the project QECIO (Quantifying Europe's Cycling Infrastructure using OpenStreetMap) 2.0 are Andrea Chávez-Pacheco (Data Analysis Intern) and Aleksander Buczyński (Infrastructure Policy Officer). The first edition of QECIO was prepared by Eleanor Denneman (Policy Intern). We received technical assistance from Arnaud Briol, John Hammerschlag and Gautier Radermecker (Data Scientists at [Agilytic](#)) as a part of the [1% for the Planet programme](#).



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Annex I. Cycle infrastructure types

| Infrastructure type | Description | Example |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Cycle track | An independent road or part of a road designated for cycles, signposted as such. Cyclists are physically separated from motorised traffic, for example by a dividing verge, a kerb or a safety barrier. |  |
| Cycle and pedestrian track | As above, but the same space is shared with pedestrians. |  |

| Infrastructure type | Description | Example |
|---------------------------|--------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Cycle lane | A part of a carriageway designated for cycles. Distinguished from the rest of the carriageway by paint only. |  |
| Bus and cycle lane | A lane reserved for (public transport) buses and cycles. |  |

| Infrastructure type | Description | Example |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Cycle street | A road where (some) motorised traffic is allowed, but cycle traffic is prioritised on the carriageway. Signage and exact rules vary across countries. |  |
| Limited access road | A road where motorised traffic is limited (for example, only agricultural vehicles or vehicles of the residents are allowed), but fully open to cycles (but, contrary to cycle street, cyclists are not indicated as priority users). |  |

| Infrastructure type | Description | Example |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| <p>Pedestrian track with cycling allowed</p> | <p>A road or a part of the road originally designed for pedestrians, where cycling has been (conditionally) authorised, either by general rules or through a cycle panel under the pedestrian track sign. <i>Not included in the dashboard as for now.</i></p> |  |

Annex II. OSM tags considered

List of tags that are kept when extracting the highways:

'highway', 'tracktype', 'maxspeed',
 'cycleway', 'cycleway:right', 'cycleway:left', 'cycleway:both',
 'oneway', 'oneway:bicycle',
 'surface', 'smoothness', 'width',
 'cycleway:oneway', 'cycleway:surface', 'cycleway:smoothness', 'cycleway:width',
 'cycleway:left:oneway', 'cycleway:left:surface', 'cycleway:left:smoothness', 'cycleway:left:width',
 'cycleway:right:oneway', 'cycleway:right:surface', 'cycleway:right:smoothness', 'cycleway:right:width',
 'cycleway:both:oneway', 'cycleway:both:surface', 'cycleway:both:smoothness', 'cycleway:both:width',
 'cyclestreet', 'bicycle_road',
 'bicycle', 'foot', 'segregated',
 'access', 'vehicle', 'motorcar', 'motor_vehicle', 'agricultural',

Table 1. Explanation of logical operators used.

| Explanation of symbols | |
|------------------------|------------------------------------------------------------------------------|
| | or |
| & | and |
| = | equals |
| != | does not equal |
| * | cycleway* includes cycleway, cycleway:left, cycleway:right and cycleway:both |

Table 2. Summary of the tags employed, and the definition of the variables used.

| Analysis type | Dashboard column name | OSM tags | Definition |
|----------------------|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Infrastructure types | Cycle tracks | (highway = cycleway) & ((foot != designated) (segregated = yes)) | Cycle infrastructure that is separated from motorised traffic by physical infrastructure (curbs, grass, etc.) and reserved for exclusive use for cycles. |
| | | (highway = footway path pedestrian) & (bicycle = designated) & (segregated = yes) | |
| | | cycleway* = track opposite_track | |
| | Cycle lanes | cycleway* = lane opposite_lane | Cycle infrastructure that is an inherent part of the carriageway, set aside for the use of bicycles by paint or other markings but without a physical separation from motorised traffic. |
| | Cycle and pedestrian tracks | (highway = footway path pedestrian) & (bicycle = designated) & (segregated != yes) | Track designated (signed) for use by pedestrian and cyclists. |
| | Pedestrian track with cycling allowed | (highway = footway path pedestrian) & (bicycle = yes) | Pedestrians track that cyclists are allowed to use, but not formally designated for cyclists (for example, a path in a park). As for now, included in the GPKG but not displayed in the dashboard, because the category includes many tracks without practical added value for the cycle network. |
| | Limited access roads | (highway = unclassified tertiary service residential) & (access = no agricultural forestry destination) & (bicycle = yes designated) | Roads where motorised traffic is restricted (for example, only to residents or agricultural vehicles), but fully open to cycle |

| Analysis type | Dashboard column name | OSM tags | Definition |
|---------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | highway = track & (tracktype = grade1 grade2) (surface =)) Classified as cycle track, cycle and pedestrian track or pedestrian track with cycling allowed in first approach & (access motorcar motor_vehicle agricultural vehicle) = (yes designated agricultural forestry destination delivery permissive private) | traffic. In case a limited access road is signed as cycle street, the later takes precedence. |
| | Cycle streets | cycle_street = yes | Cycle streets – road where (some) motorised traffic is allowed, but cyclists are somehow prioritised (“cars are guests”). Must be signed as such, only exists in selected countries. |
| | | bicycle_road = yes | |
| | Bus and cycle lanes | cycleway* = (share_busway opposite_share_busway) | Bus lane with designated use for cyclists. |
| Road network | Main roads | highway = (motorway trunk primary secondary tertiary motorway_link trunk_link primary_link secondary_link tertiary_link) | Main arteries for motor traffic, where we assume that the cycle traffic should be somehow segregated. |
| | Local roads | highway = (living_street residential unclassified) | Local roads, where we assume it is safe to mix cyclists and motorised traffic on the carriageway. |
| | Active roads | highway = (cycleway footway path pedestrian track service) | Other types of highways that are not a part of the public road network but might potentially |

| Analysis type | Dashboard column name | OSM tags | Definition |
|-----------------------------------|--------------------------------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| | | | contribute to the active mode network (sometimes depending on additional tags). |
| Local roads directionality | Two-way streets | oneway != yes | Street is bidirectional both for cars and for bicycles. |
| | One-way streets with contraflow cycling | (oneway = yes) & ((oneway:bicycle = no) (cycleway = opposite opposite_lane opposite_track)) | Street is unidirectional for cars and bidirectional for bicycles. |
| | One-way streets without contraflow cycling | (oneway = yes) & (oneway:bicycle != no) & (cycleway != opposite opposite_lane opposite_track) | Street is unidirectional both for cars and for bicycles. |

Table 3. Determination of whether cycling infrastructure is bidirectional.

| Cycling infrastructure type | Is bidirectional if... |
|---------------------------------------------------------------------------------------------------------------------------|---------------------------------------|
| Cycle track, cycle and pedestrian track, cycle street or limited access road represented as a standalone highway feature. | oneway != yes & oneway:bicycle != yes |
| Cycle track, cycle lane or cycle and bus lane represented as a “cycleway” tag of a highway feature (cycleway* = *). | cycleway*:oneway= no |

Table 4 Definition of surface and quality criteria based on the ECS.

| ECS criteria | OSM tags related | | Acceptable as track surface? |
|----------------------|-------------------------------------------------------|--|------------------------------|
| ECS surface material | OSM surface tag | | |
| asphalt/concrete | asphalt concrete metal chipseal | | yes |
| blocks/slabs/cobbles | paved paving stones bricks wood | | yes |
| | cobblestone grass_paver sett unhewn_cobblestone | | no |
| stabilised gravel | compacted fine_gravel | | yes |

| | | | |
|----------------------------|---------------------------------------------------------------------|-------------------------------------|-----|
| gravel/dirt | unpaved ground gravel pebblestone dirt earth mud sand | | no |
| ECS surface quality | OSM tracktype tag | OSM smoothness tag | |
| perfectly rideable | | excellent | yes |
| well rideable | grade1 | good | yes |
| moderately rideable | grade2 | intermediate | yes |
| | grade3 | | no |
| badly rideable | grade4 grade5 | bad | no |
| not rideable | | very_bad horrible very_horrible | no |

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