Quantifying Europe's Cycling Infrastructure using OpenStreetMap (OSM) 2.0

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 started aiming to incorporate cycling infrastructure from the database Open Street Map (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 in interactive graphics in our newly developed dashboard.

Help us improve our methodology and dashboard by sending an email to Aleksander Buczyński (a.buczynski@ecf.com) and Andrea Chavez (a.chavez@ecf.com).

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 (ex. French territories in America or Africa, Canary Islands, etc.)

Technical details
In this edition, for optimisation, we used PBF files from European countries available from the Geofabrik website. The highways were extracted per country using the PyOsmium package (https://osmcode.org/pyosmium/). The street handler function was set to extract

the highways and a set of variables within the PBF file and optimise the size of the data frames.

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 following the criteria established previously.

> 3) We analyzed OSM ways, which are linear features representing segments that connects 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.

$$segregated\ infrastructure = cycle\ tracks + cycle\ lanes + shared\ pedestrians$$

<div align="right">(1)</div>

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

<div align="right">(2)</div>

About the interpretation of the ratios, ratio of 100 can be roughly interpreted as 100% of the main road network having bidirectional cycling infrastructure. This 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.

$extended\ infrastructure = cycle\ tracks + cycle\ and\ pedestrian\ tracks + cycle\ lanes + limited\ access\ roads + bus\ lanes + cycle\ streets$

(3)

$ratio\ = \dfrac{total\ length\ extended\ infrastructure\ (km)}{total\ length\ public\ roads\ (km)}$

(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.*

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

<div align="right">(5)</div>

<u>Availability of additional data</u>

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.

$$infrastructure\ analysed\ = cycle\ tracks + cycle\ lanes +\\ cycle\ and\ pedestrian\ tracks + \ limited\ access\ roads$$

<div align="right">(6)</div>

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

<div align="right">(7)</div>

Where x could be surface, smoothness or width.

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

<div align="right">(8)</div>

<u>Ratio of contraflow cycling</u>

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

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

<div align="right">(9)</div>

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 part of the 1% for the Planet programme.

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Annex I

List of tags that are kept when extracting the highways:

highway_columns_to_keep =
['highway', 'bicycle', "pedestrian",'cycleway', 'cycleway:right','cycleway:left',
'cycleway:both', 'oneway', 'oneway:bicycle', 'surface', 'smoothness', 'cycleway:oneway',
'cycleway:surface', 'cycleway:smoothness',
'cycleway:left:oneway', 'cycleway:left:surface', 'cycleway:left:smoothness',
 'cycleway:right:oneway', 'cycleway:right:surface',
'cycleway:right:smoothness','cycleway:both:oneway', 'cycleway:both:surface',
'cycleway:both:smoothness','cyclestreet','bicycle_road','access','vehicle',"motorcar","mot
or_vehicle","agricultural","access:agricultural",'length_km','geometry',"tracktype","maxsp
eed",'width','cycleway:right:width',"cycleway:width","cycleway:both:width","cycleway:left:
width"]

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
colour	blue = OSM key, green = OSM value

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

Analysis type	Dashboard column name	Applied OSM tags	Definition
Infrastructure types	Cycle tracks	highway=cycleway	Cycle infrastructure that is separated from *motorised* traffic by physical infrastructure (curbs, grass, etc.) and reserved for exclusive use for cycles.
		cycleway*=track | opposite_track	
	Cycle lanes	cycleway*=(lane | opposite_lane)	Cycle infrastructure that is an inherent part of the carriageway but 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) & bicycle=designated	Track designated (signed) for use by pedestrian and cyclists.
	Pedestrian track with cycling allowed	highway= (footway | path) & 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 GPKGs but not displayed in the dashboard, because the category includes many tracks without practical meaning for cycle network.
	Limited access roads	highway = (unclassified | tertiary | service | residential) | highway=track & tracktype= (grade1 | grade2)) & access= (no | agricultural | forestry | destination)	Roads where motorised traffic is restricted (for example, only to residents or agricultural vehicles), but fully open to cycle traffic. In case a limited access road is signed as cycle street, the later takes precedence.
		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)	
	Cycle streets	cycle_street = yes | bicycle_road = yes	Cycle streets – road where (some) motorised traffic traffic is allowed, but cyclists are somehow prioritised ("cars are guests"). Must be signed as such, only exists in selected countries.
	Bus and cycle lanes	cycleway*= (share_busway| opposite_share_busway)	Bus lane with designated use for cyclists.

Road network coverage	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 contribute to the active mode network (not displayed in the dashboard).
Local roads directionality analysis	Two-way streets	oneway!=yes	Street is bidirectional for cars and bicycles.
	One-way streets with contraflow cycling	oneway=yes & oneway:bicycle=no	Street is unidirectional for cars and bidirectional (contraflow) for bicycles.
	One-way streets without contraflow cycling	oneway=yes & oneway:bicycle!=no	Street is unidirectional for cars and bicycles.

Note: cycleway* = cycleway | cycleway:left | cycleway:right | cycleway:both

Table 3. Determination of whether cycling infrastructure is bidirectional.

Highway tag value	Cycling infrastructure is bidirectional if...	Explanation
cycleway | path | footway	oneway!= yes & oneway:bicycle!= yes	Standalone cycle track or cycle and pedestrian track
All other	cycleway*:oneway= no	Cycle track, cycle lane or cycle and bus lane alongside a highway

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

ECS criteria	OSM tags related	
ECS surface material	**OSM surface tag**	
asphalt/concrete	asphalt | concrete | metal | chipseal	
blocks/slabs/cobbles	paved | paving stones | bricks | cobblestone | wood | sett	
stabilised gravel	compacted | fine_gravel	
gravel/dirt	unpaved | ground | gravel | pebblestone | grass_paver | dirt | earth | mud | sand	
ECS surface quality	**OSM tracktype tag**	**OSM smoothness tag**
perfectly rideable		excellent
well rideable	grade1	good
moderately rideable	grade2 | grade3	intermediate
badly rideable	grade4 | grade5	bad
not rideable		very_bad | horrible | very_horrible