Quantifying Europe’s Cycling Infrastructure using OpenStreetMap (QECIO) 2.0

Our Methodology

By the European Cyclist’s Federation (ECF)

Contents

ABSTRACT.. 2
Background.. 2
Methodology.. 3
Disclaimer.. 5
Authors.. 6
References.. 6
Annex I.. 7

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 in 37 countries from the EU, and the information was gathered at governmental regions NUTS 3 (Nomenclature of territorial units for statistics). The information collected from OSM, was processed to obtain the information needed. We keep track of whether a given segment of infrastructure is unit or bidirectional, and to scale the length, we divide the length of unidirectional segments by two. The availability of some additional data for cycle infrastructure (surface, smoothness, width) was also analyzed. 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 greatly 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 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 bike infrastructure, and additional information available in the map, and extrapolate the analysis to inter and 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 be useful in accessible urban planning (Ferster et al., 2019, Timaite et al, 2022). Information about appropriate cycle infrastructure is crucial to enhance safe biking and encourage cycling as a sustainable mode of transport. Therefore, information on current infrastructure is needed to continued development or optimization (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 cycle infrastructure. More info on OSM bicycle-related tags can be found on wiki.openstreetmap.org/wiki/Bicycle and taginfo.openstreetmap.org. After analysing the tags, we defined to extract the following types of infrastructure, and measures following the logical thinking in the Annex I.

Technical details

In this edition, for optimization, we made use of 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 optimize the size of the data frames.

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. The analysis was performed according to the availability of information in the PBF files, territories outside of the European area were not included (ex. French territories in America or Africa, Canary Islands, etc).

2) The main road network and the local road network were calculated from the extracted highways following the criteria established previously.

3) Then we estimate 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 1.

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 with the European Certification Standard.

Explanation of the indicators in the dashboard:

A: Ratio of cycling infrastructure over the main road network:

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

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

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

B: Ratio of cycling extended infrastructure over the main road network:

The ratio of cycle infrastructure to public roads, is an indicator of road coverage by cycle infrastructure. The extended cycle infrastructure used in the numerator were cycle tracks, shared pedestrians (cycle and pedestrian paths), cycle lanes, limited access roads, bus lanes and cycle streets. While the road network used in the denominator was calculated by integrating main roads plus local roads. The local roads were selected using the following tags: residential, living street, unclassified.

$$\begin{aligned} extended\ infrastructure &\\ &= cycle\ tracks + shared\ pedestrians + cycle\ lanes + limited\ access\ roads \\ &+ bus\ lanes + cycle\ streets \end{aligned}$$

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

B: Cycle tracks surfaces

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

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

C: Availability of Additional Data

The availability of aditional data, is an indicator of completeness of OSM tags. The data is an averaged percentage of ways tagged with either surface, smoothness, or width. The types of infrastructure included: track, shared tracks (cycle and pedestrians), limited access roads, and cycle lanes. We explored which percentage of each one of the different infrastructures were labeled over the total.

$$certain\ tag\ (\%) = \frac{total\ length\ cycle\ infrastructure\ tagged\ with\ certain\ tag\ (km)}{total\ lenght\ (tracks + lanes + shared\ pedestrians + limited\ access)\ (km)}$$

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

D: 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.

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

Disclaimer

The data featured in this dashboard only represent OpenStreetMap 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 do not imply that the cycling infrastructure is necessarily high quality. To infer the cyclability of a given city's cycling network, one needs to consider 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, or compare OSM with official database and call back when differences are occurring. Other way to improve completeness of the database is to incentive mappers by policies encouraging citizen sciences as stated by Hardinghaus & Panagioties, (2020).

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 reflect high quality 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.

Authors

The main authors of the project QECIO 2.0 are Andrea Chavez (Data Analysis Intern) and Aleksander Buczyński (Infrastructure Policy Officer). We received technical assistance from John Hammerschlag and Gautier Radermecker (Data Scientist at Agilytic) as part of the 1% for the Planet program.

References

Hardinghaus, M., & Papantoniou, P. (2020). Evaluating Cyclists' Route Preferences with Respect to Infrastructure. *Sustainability*, *12*(8), 3375. MDPI AG. Retrieved from http://dx.doi.org/10.3390/su12083375

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Ferster, C., Fischer, J., Manaugh, K., Nelson, T., & Winters, M. (2019). Using OpenStreetMap to inventory bicycle infrastructure: A comparison with open data from cities. *International Journal of Sustainable Transportation*, *14*(1), 64–73. https://doi.org/10.1080/15568318.2018.1519746

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","motor_vehicle","agricult
ural","access:agricultural",'length_km','geometry',"tracktype","maxspeed",'width','cycleway:right:width',"cycle
way: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	CSV column name	Dashboard column name	Applied OSM tags	Definition
Infrastructure Type	overview-cycle_tracks-km	Cycle tracks	highway=cycleway cycleway=track |opposite track cycleway:left = track |opposite track cycleway:right = track | opposite track cycleway:both = track | opposite track	Bicycle infrastructure that is separated from *motorized* traffic by physical infrastructure (curbs, grass, etc.)
	overview-cycle_lanes-km	Cycle lanes	cycleway*=(lane | opposite_lane)	Bicycle infrastructure that is an inherent part of the road but set aside for the use of bicycles by paint or other markings but without a physical separation from motorized traffic.

	overview-shared_pedestrians-km	Cycle-pedestrian	highway=footway & bicycle=designated	Generic path that is used by pedestrian and cyclists.
			highway=footway & bicycle=yes	
			highway=path & bicycle = (designated | yes)	
	overview_limited_access_km	Limited access roads	highway = ["unclassified", "tertiary", "service", "residential", "track"] Tracktype = ["grade1"," grade2"] access_rights_limited = "no", "agricultural", "forestry", "destination"	Roads where motorized 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.
	Overview_cycle streets	Cycle streets	Cycle street = "yes" | "bicycle_road" = yes	
	Overview bus lanes	Cycleway bus	cycleway*=(share_busway| opposite_share_busway)	

Road Network Coverage	overview-local-road-network	Local road network	Highway = living_street & bicycle = (designated | yes)	The highway=living_street tag is used to tag living streets or other implementations of shared space. These types of roads have lower speed limits, and special traffic and parking rules compared to streets tagged using residential.
			highway = residential & bicycle = (designated | yes)	The highway=residential tag is used on roads that provide access to, or within, residential areas but which are not normally used as through route.
			Highway = unclassified & bicycle = (designated | yes)	The highway = unclassified is used in minor ways but serves as a connection in the general-purpose road network.
			~~highway = service & bicycle = (yes | designated) & access (yes | permissive | destination)~~	The highway = service tag is generally for access to a building, service station, beach, campsite, industrial estate, business park, etc. This is also commonly used for access to parking, driveways, and alleys. Needs to be analysed and not integrate false positives from parking spots. The tag highway=service was excluded for the urban area because it mostly seemed to concern parking spaces in urban areas and would therefore distort the numbers.
	overview-active-road-network	Active roads. Not included in the dashboard.	Highway = ["cycleway", "footway", "path", "pedestrian", "track", 'service', "residential",	

			"unclassified"]	
	overview-main-road-network	Main road network	highway = ["motorway", "trunk", "primary", "secondary", "tertiary", "motorway_link", "trunk_link", "primary_link", "secondary_link", "tertiary_link",]	Total length of main roads, main roads were selected using the mentioned tags. Motorway and motorway link refer to high-capacity highways designed to safely carry fast motor traffic. Trunk important roads that are not motorways.
Directionality analysis	local-oneway	*Excluded from dashboard*	oneway=yes & oneway:bicycle!=no	Street is unidirectional for cars and bicycles.
	local-twoway	*Excluded from dashboard*	oneway!=yes	Street is bidirectional for cars and bicycles.
	local contra	Contraflow on local road network	oneway=yes &	Street is unidirectional for cars and bidirectional (contraflow) for bicycles.
			oneway:bicycle=no	
Metrics	ratio-contraflow	Ratio contraflow over local road network		Formula: local-contra / (local-contra+local-oneway)

	ratio-cycle_tracks-main_roads	Ratio cycle tracks over main road network		Formula: overview-cycle_tracks-km / overview-main-road-network
	ratio-cycle_infra-main_roads	Ratio cycling infra over main road network		Formula: overview-total-cycle-infrastructure / overview-main-road-network
	overview-total-cycle-infrastructure	Total cycling infrastructure		Sum of cycle tracks, cycle lanes and cycle and pedestrian tracks.
	type-track-bidirectional	Two-way cycle tracks		
	type-track-unidirectional	One-way cycle tracks		
	type-lane-bidirectional	Two-way cycle tracks		
	type-lane-unidirectional	One-way cycle lanes		
	type-shared_pedestrians-bidirectional	Two-way cycle-pedestrian		
	type-shared_pedestrians-unidirectional	One-way cycle-pedestrian		

<table>
<tr><td></td><td>type-pedestrian-bidirectional</td><td rowspan="6">Additional infrastructure types are included in CSV summaries but excluded from dashboard</td><td rowspan="2">(highway=path | highway=footway) & bicycle=yes</td><td rowspan="2">Pedestrian tracks with cycling allowed.</td></tr>
<tr><td></td><td>type-pedestrian-unidirectional</td></tr>
<tr><td></td><td>type-street-bidirectional</td><td rowspan="2">cyclestreet=yes | bicycle_road=yes</td><td rowspan="2">Cycle streets.</td></tr>
<tr><td></td><td>type-street-unidirectional</td></tr>
<tr><td></td><td>type-busway-bidirectional</td><td rowspan="2">cycleway*=(share_busway| opposite_share_busway)</td><td rowspan="2">Bus lane with designated use for cyclists.</td></tr>
<tr><td></td><td>type-busway-unidirectional</td></tr>
</table>

Table 3. Determination of whether cycling infrastructure is bidirectional.

<table>
<tr><th>Highway tag value</th><th>Cycling infrastructure is bidirectional if...</th><th>Explanation</th></tr>
<tr><td>cycleway | path | footway</td><td>oneway!=yes & oneway:bicycle!=yes</td><td>Standalone cycle track or cycle and pedestrian track</td></tr>
</table>

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	Surface OSM tags related	Smoothnes OSM tags related
Surface material		
1. asphalt/concrete	surface = ["asphalt", "concrete","concrete:*","metal","chipseal"]	
2. blocks/slabs/cobbles	surface = ["paved","paving stones", "bricks", "cooblestone:*", "wood","sett"]	
3. stabilised gravel	surface = ["compacted","fine_gravel"]	
4. gravel/dirt	surface = ["unpaved","ground", "gravel","pebblestone","grass_paver","dirt","earth", “mud”, “sand”]	
Surface quality		
perfectly rideable		smoothness = ["excellent"]
well rideable	tracktype = ["grade1"]	smoothness = ["good"]
moderatly rideable	tracktype = ["grade2","grade3"]	smoothness = ["intermediate"]
badly rideable	tracktype = ["grade4","grade5"]	smoothness = ["bad"]
not rideable		smoothness = ["very_bad","horrible","very_horrible"]