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# Automated Detection of Missing Links in Bicycle Networks with OpenStreetMap

*Keywords: bicycle network, network analysis, urban planning, sustainable mobility, OpenStreetMap*

## Extended Abstract

Cycling is an effective solution for making urban transport more sustainable [1]. However, bicycle networks are typically developed in a slow, piecewise process that leaves open a large number of gaps, even in well developed cycling cities like Copenhagen [2]. Here, we develop the IPDC procedure (Identify, Prioritize, Decluster, Classify) for finding the most important missing links in urban bicycle networks, using data from OpenStreetMap. In this procedure we first identify all possible gaps following a multiplex network approach, prioritize them according to a flow-based metric, decluster emerging gap clusters, and manually classify the types of gaps.

Importantly, the IPDC procedure can be run with minimal data availability requirements, using only the street network topology as input. In order to mitigate the so-called network edge effect [3], which creates a bias when utilizing edge betweenness centrality metrics for flow estimation [4, 5], the IPDC procedure implements Simon's moving window approach [6]. By taking into account the whole city network for consolidating urban bicycle infrastructure, our data-driven framework can complement localized, manual planning processes for more effective, city-wide decision-making.

**Case study: Copenhagen** We apply the IPDC procedure to Copenhagen and report the 105 top priority gaps, as shown in Figure 1. For evaluation, we compare these gaps with the city's most recent Cycle Path Prioritization Plan [7] and find considerable overlaps. These results show how network analysis with minimal data requirements can serve as a cost-efficient support tool for bicycle network planning.

**Generalization to other locations: The IPDC online toolkit** After validating our approach on the example of Copenhagen, we generalize the IPDC procedure, and make it applicable to any user-defined location. The outcome is an online toolkit, consisting of a collection of interactive scripts that can be run with little programming knowledge, which allows the user to apply the IPDC procedure to any city in the world where corresponding OpenStreetMap data are available.

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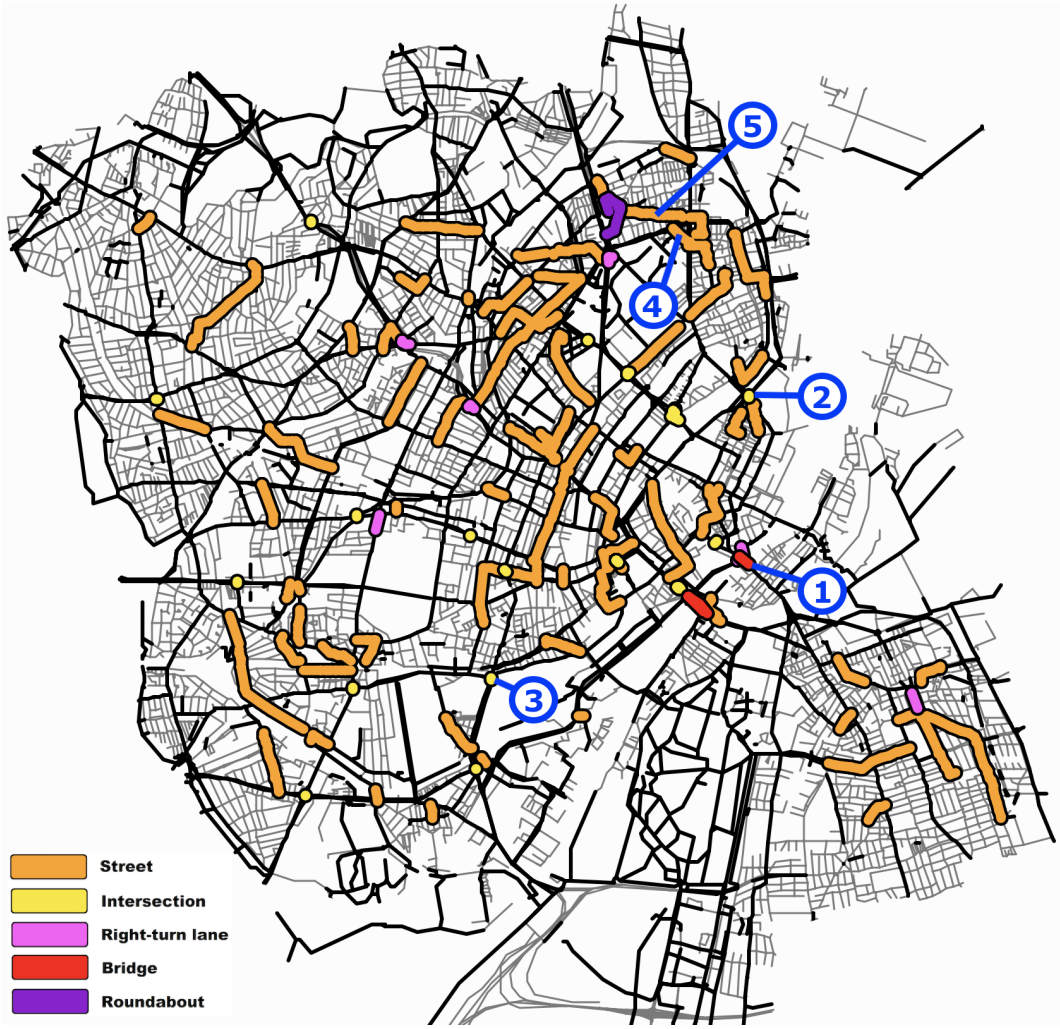


Figure 1: Overview map of Copenhagen's top 105 gaps by class, as identified by the IPDC procedure: streets in orange, intersections in yellow, bridges in red, right-turn lanes in pink, roundabouts in violet. Numbered blue circles indicate the top 5 gaps. The street network is shown in grey, the bicycle network in black.