Short Paper

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Abstract

This is the abstract.

It consists of two paragraphs.

1. Introduction

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2. Background

2.1. What Affects the Decision To Cycle

Segregated cycling infrastructure[1] has been shown to increase cycling uptake (Aldred et al., 2019; Goodman et al., 2014; Marqués et al., 2015), with the separation from motorized vehicles being key (Winters et al., 2011). Revealed preference of cyclists shows that they are willing to deviate from the most efficient routes in order to commute on safer roads (Crane et al., 2017). However, such deviations are only considered if they do not considerably increase route circuitry; behaviour studies have found that the probability of choosing a route decreases in proportion to its length relative to the shortest route (Broach et al., 2011; Winters et al., 2010). Another defining feature for cycling infrastructure is how well connected it is. Cyclists prefer cohesive infrastructure, particularly when cycling on arterial roads with high levels of motorized traffic (Stinson and Bhat, 2003), and the lack of well-connected cycling infrastructure is one of the main obstacles to increasing cycling uptake (Caulfield et al., 2012). While direct and cohesive cycling networks have been shown to positively impact cycling rates, density[2] of the cycling network is also vital (Schoner and Levinson, 2014).

2.2. Planning Cycling Networks

Optimization techniques have been used to propose improvements to cycling networks. Mesbah et al. (2012) propose a bi-level formulation to optimize allocation of cycling lanes to the network without exceeding a set budget. The upper level is the proposed interventions and the lower level is the route choices made by users in reaction

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[1]Segregated cycling infrastructure refers to road space that is allocated to cyclists only, with physical separation to protect cyclists from other modes of transport.

[2]making an area's bicycle network denser means adding more cycling routes in the area and thereby giving cyclists more route options

to changes in the network. The problem accounts for the effect of cycling lanes on car traffic, and attempts to maximize utilization of said lanes with minimal impact on car travel times. To improve cohesion of the suggested network, a constraint is added so that each link with a bike lane should be connected to at least one destination. Car usage is not considered by Mauttone et al. (2017), who develop an optimization framework that aims to minimize the total user cost of cycling on the network. The aggregate flow on links is obtained by using shortest paths to route existing cycling demand onto the road network, and the solution is a proposed set of links where cycling infrastructure should be added in order to minimize the overall travel cost of cyclists across the network. The cost of traversing a link is given as a function of its length and whether or not it has cycling infrastructure, and a discontinuity penalty is also added to prioritize connected road segments. The problem has also been solved by attempting to find the minimum cost of improving roadway links to meet a desired level of service (LOS) (Duthie and Unnikrishnan, 2014). In this formulation, all OD pairs need to be connected by roads that meet the desired LOS, and a directness constraint is added so that paths between OD pairs do not exceed a certain multiple of the shortest path.

These problem formulations do not explicitly solve for continuity, which is dealt with using a either (a) a constraint specifying that each link with a bike lane should be connected to at least one destination (Mesbah et al., 2012), (b) a constraint on deviation from shortest paths (Duthie and Unnikrishnan, 2014), or (c) a discontinuity penalty (Mauttone et al., 2017). To solve for continuity, the graph-theoretic concept of *connected components*, has been used. Natera et al. (2019) study the existing cycling network in terms of its disconnected components and introduce two different algorithms to connect these components by their most critical links[3] and, in doing so, measure the size of the growth of the largest connected component as a function of the kilometers of network added. They observe that small investments at strategic points have a large impact on connectivity in most cases. The concept of connected components is also at the core of the methodology proposed by Olmos et al. (2020). After routing the cycling demand onto the network links, they use percolation theory to filter out the links based on the aggregate flow[4] passing through them. They vary the flow threshold for filtering to identify the minimum flow at which the whole city is connected by a giant component. The results show a cycling network that connects the entire city, and subtracting links intersecting with current cycling infrastructure identifies links proposed for intervention.

3. Data and Geographical Scale of Analysis

The analysis is heavily dependant on Origin-Destination census data (commuter data). Commuter data in the UK is publicly available at the Middle layer Super Output Area (MSOA) level; the average MSOA has a population of 8209 (ONS, 2018). Iacono et al. (2010) note that such large travel zones are not ideal for understanding route choice behaviour of cyclists and pedestrians. They also give rise to an 'ecological fallacy' whereby average characteristics are assumed to apply to all residents of the aggregated geographical area. Given that more granular data is not publicly available, the study uses MSOA-level commuter data. The methodology is however applicable to more granular commuter data should it become available.

4. Calculating Potential Cycling Demand

The Propensity to Cycle Tool (PCT) (Lovelace et al., 2017) is used to estimate the proportion of cyclists (C_p) for each MSOA pair should the government achieve its target of doubling cycling by 2025. The PCT uses the following logistic regression model to calculate C_p:

$$logit(C_p) = -4.018 - 0.6369d + 1.988\sqrt{d} + 0.008775d^2 \tag{1}$$
$$- 0.2555s + 0.00206ds - 0.1234\sqrt{d}s$$

where d and s are the distance and slope respectively for the OD pair. The authors use square and square-root distance terms "to capture the non-linear impact of distance on the likelihood of cycling", and interaction terms to capture the combined effect of slope and distance (Lovelace et al., 2017).

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[3] *link* refers to a road segment throughout this research

[4] *flow* is used throughout this research to refer to the cycling demand when it is routed onto the road network. The flow on any road segment is the cumulative demand on it, resulting from cyclists commuting between various OD pairs

The potential demand calculations show that the current and potential number of cyclists both follow a bell-shaped distribution, with the number of trips peaking around the 3-5km commuting distance and then going back down for longer distances (See Figure **??**).
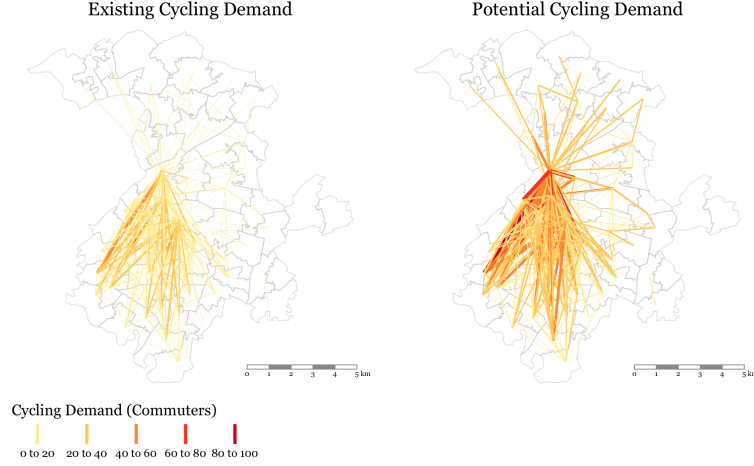

Figure 1: Current and Potential Cycling Demand

5. Routing

The next step is to route the potential cycling demand (C_p) between all OD pairs onto the road network. To conduct routing, the following is considered:

1. **Cyclist Preference**: Work done by Dill and McNeil (2013) on examining cyclist typologies determined that around 60% of Portland residents fit under the *interested but concerned* category. These were people that enjoyed cycling but avoided it due safety concerns. The key to encouraging this group was to create a low-stress cycling network, not only though segregated infrastructure but also by planning routes that passed through residential streets.
2. **Low-Traffic Neighborhoods**: The UK Department for Transport is allocating funding to local authorities to invest in Active Transport, partially through the creation of LTNs (DfT, 2020). This includes closing off residential streets to motorized traffic
3. **Existing Cycling Infrastructure**: Utilizing existing cycling infrastructure makes economic sense, as small investments may lead to large connectivity gains as the disconnected cycling infrastructure gets joined together.

The weighting profiles are therefore adjusted to favor less-stressful streets (based on information from Table **??**), and roads with existing cycling infrastructure. This is also in line with the creation of LTNs, as residential streets are those where motorized traffic is most likely to be banned in the creation of LTNs.

6. Road Segment Prioritization

7. Conclusions

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