Safe cycling routes: Seven road safety indicators for cycling routes

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1 INTRODUCTION

Cycling is healthy, environmentally friendly, faster than walking, and uses less public space than a car, making the bicycle an attractive mode of transportation, especially for shorter journeys. Unfortunately, however, the numbers of fatalities and serious injuries among cyclists have been increasing in recent years in the Netherlands [1]. A proactive approach to preventing bicycle crashes and reducing crash severity requires identifying and avoiding risks to cyclists in the bicycle infrastructure network. Studies investigating safe cycling infrastructure often focus on design choices at road level, such as the provision of separated bicycle paths. In the Netherlands this has led to the development of Safety Performance Indicators to prioritize safe road design choices [2]. However, sometimes the safest option may be an alternative route altogether; therefore, it is worthwhile to consider how safety varies across different types of cycling routes. For cars, route safety indicators have already been proposed in 2011 [3]. With these as a starting point, this study proposes route safety indicators for cyclists based on established literature on safe cycling infrastructure.

2 SEVEN INDICATORS FOR SAFE CYCLING ROUTES

The proposed indicators for safe cycling routes bring together principles from Sustainable Safety, the already established indicators for cars, and existing literature on safe cycling infrastructure.

2.1 Background

As part of the Sustainable Safety vision, traffic with a 'flow' function should be separated from traffic with an 'exchange' function (Functionality principle) and traffic with a high speed and/or high mass should be separated from traffic with a low speed and/or mass such as vulnerable road users (Biomechanics principle) [4]. For cyclists, the first priority is therefore a separation from motorized vehicles, especially where speeds are higher. In addition, a further distinction between cyclists in terms of their functionality (flow vs. exchange cyclists) or biomechanics (lighter and/or slower cyclists vs. heavier and/or faster cyclists) may be desirable depending on the feasibility of providing different infrastructure and route options for different target groups [5].

A previous study [3] used the Sustainable Safety criteria to develop network safety indicators for car routes. From a safe route choice perspective, the safest car route should coincide with the fastest route. Dijkstra [3] identified nine criteria for safe car routes relating to safe transitions between road types (access, distributor and flow roads), limiting the share of the trip spent on access and distributor roads, minimizing travel distance and travel time to minimize exposure, and limiting the number of intersections and left turns.

2.2 Indicators for safe cycling routes

A literature review [6] has been conducted to identify factors at the levels of road design, route choice, and network structure which are important for the safety of cycling routes. Together with the original indicators for motor vehicles, this led to seven indicators which are relevant for cycling route safety:

1. **Travel distance as short as possible:**
   The shorter the distance of a route, the less risk a cyclist is exposed to.
2. **Travel time as short as possible:**
   The shorter the cycling time, the less risk a cyclist is exposed to.
3. **As few intersections as possible, especially with distributor roads:**
   Relatively many crashes happen at intersections, where cyclists come into potential conflicts with motor vehicles. Especially (at-grade) intersections between distributor roads should be avoided as much as possible as they are relatively unsafe for cyclists. At these intersections, roundabouts are preferred over signalized intersections.
4. **Cyclists should follow exclusive bicycle tracks as much as possible:**
   Exclusive bicycle tracks are not bound to a road and are only accessible to cyclists. This makes the road segments safer compared to roads shared with motor vehicles.
5. **Cyclists should use distributor roads without separate bicycle tracks as little as possible:**
   When speeds are higher than 30km/h, conflicts between motorized traffic and cyclists should be prevented. Therefore, roads with a 50 km/h speed limit or higher should have a separated bicycle track.
6. **As few left-turns as possible:**
   Left-turns at intersections are known to be a risky maneuver for cyclists. They should therefore be limited as much as possible in a route.
7. **As few transitions and discontinuities as possible:**
   Transitions between and discontinuities in the type of cycling infrastructure (e.g. a cycling path that continues on the other side of the street or changes into a cycling lane) lead to an increased safety risk and should therefore be avoided as much as possible.

These seven indicators focus on limiting exposure and conflicts with motorised traffic. In addition, it may be advantageous to protect the most vulnerable road users (pedestrians and vulnerable cyclists) from large flows of fast and potentially higher-weight bicycle through-traffic and other potential users of bicycle facilities, like upcoming Light Electric Vehicles (LEVs). While research is lacking on the safety implications, an eighth route indicator may be considered regarding the separation of these different groups of cyclists (in line with the Sustainable Safety functionality and biomechanics principles).

3 PRACTICAL APPLICATION

The seven indicators identified above can be used to compare the safety levels of different route options between a given origin and destination (origin-destination pair) to identify locations in a network where route safety can be improved. Ideally, the most attractive and popular routes chosen by travelers in the network should also be as safe as possible for both the traveler and other road users. As routes remain the choices of travelers given the infrastructure available to them, for road authorities the route safety can primarily be influenced indirectly by measures taken at the levels of road design and network structure. Examples of measures to improve route safety at the network and road levels are shown in Table 1.

Table 1: Measures at the network-level and road-level to improve cycling route safety

Approach	Measures for safe cycling routes
Network-level measures	• Separate motor vehicle flow traffic from access roads & bicycle traffic • Create direct cycling routes with minimal detour • Create exclusive bicycle paths where possible • Create bicycle through-routes on exclusive bicycle paths • Grade-separate or avoid cycle route intersections with distributor roads • Avoid left-turns and transitions between infrastructure types which require cyclists to cross motorized traffic • Make safe routes more attractive to cyclists, for example by increasing comfort or adapting traffic light settings
Road-level measures	• Create separated bicycle tracks along distributor roads • Limit speeds where conflicts between cyclists & motor vehicles can occur • No obstacles in the cycling infrastructure • Sufficiently wide bicycle paths • Quality surface: smooth, complete, clean, not slippery • Visual guidance • Forgiving cycle path/track edges and verges

4 DISCUSSION AND RECOMMENDATIONS

Consideration for where and how safe cycling routes fit into an infrastructure network is important not just at the level of road design—as is often the focus in cycling research—but also at the level of network structure and route design. The seven identified indicators of safe cycling routes are a tool to aid in decision-making when designing networks for new safe cycling routes and for identifying safety concerns in existing routes. As no weight factors have been estimated, it is at this point not possible to quantify the relative contributions of each indicator to an overall safety level. Rather, the indicators can be used in a primarily qualitative way to compare route alternatives with each other. Future research may focus on the different cyclist subgroups and functionalities and on realizing safe cyclist through-routes (flow function).

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