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Effect of width and boundary conditions on meeting maneuvers on two-way separated cycle tracks

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ABSTRACT

Cycle track design guidelines are rarely based on scientific studies. In the case of off-road two-way cycle tracks, a minimum width must facilitate both passing and meeting maneuvers, being meeting maneuvers the most frequent. This study developed a methodology to observe meeting maneuvers using an instrumented bicycle, equipped with video cameras, a GPS tracker, laser rangefinders and speed sensors. This bicycle collected data on six two-way cycle tracks ranging 1.3–2.15 m width delimitated by different boundary conditions. The meeting maneuvers between the instrumented bicycle and every oncoming bicycle were characterized by the meeting clearance between the two bicycles, the speed of opposing bicycle and the reaction of the opposing rider: change in trajectory, stop pedaling or braking. The results showed that meeting clearance increased with the cycle track width and decreased if the cycle track had lateral obstacles, especially if they were higher than the bicycle handlebar. The speed of opposing bicycle shown the same tendency, although were more disperse. Opposing cyclists performed more reaction maneuvers on narrower cycle tracks and on cycle tracks with lateral obstacles to the handlebar height. Conclusions suggested avoiding cycle tracks narrower than 1.6 m, as they present lower meeting clearances, lower bicycle speeds and frequent reaction maneuvers.

1. Introduction

Urban areas account for 40% of road fatalities (European Commision, 2013a). Although traffic safety has improved remarkably in recent years, it has been focused on the safety of motor vehicles. However, 50% of the victims of urban road crashes were pedestrians or cyclists (European Commision, 2013b).

In general, bicyclists identify safety as one of their highest priorities in selecting bicycle routes. A common characteristic of countries with a high cycling mode share is the provision of cycle tracks (separated bikeways along streets) on major routes. For this reason, physically separated bicycle paths have received increasing attentions from researchers. Wardman et al. (2007) forecasted that a completely segregated bicycle roadway would result in a 55% increase in bicycling. A survey conducted in Canada corroborated that physically separated pathways were preferred by cyclists and encouraged more cycling (Winters and Teschke, 2010). Another study in Canada reported that the injury risk of cycling on cycle tracks is less than cycling in streets (Lusk et al., 2011).

In absence of regulation, most of existing cycle tracks in Spain are two-way cycle tracks. These bicycle facilities accommodate the following maneuvers (Allen et al., 1998):

- Following: a faster bicycle reaches a slower one.
- Passing: after following, a faster bicycle passes the slower one.
- Meeting: two bicycles traveling in opposing directions cross.

Manar and Desmaris (2013) studied bike-following behavior. They collected data in a controlled experiment installing GPS receivers in two bicycles. The bicycles ran on a 1.7 km, 1.5 m-wide (each direction) exclusive off-street cycle track. A similar cycle track was monitored, observing 253 couples of leading and following bicycles using a video camera mounted on a mast. They adapted and calibrated existing car-following models based on the observations. The results showed that the following bicycles did not move freely when headways were under 16 m. The authors suggested a minimal headway of 2.2 m, including bicycle length, which would lead to a 2700 bicycles/h one-way capacity.

In order to increase capacity, passing maneuver allows faster bicyclists to travel at their own desired speeds. Passing maneuvers on cycle tracks have been also investigated. Khan and Raksuntorn (2001) observed passing events on a separated 3 m-wide cycle track. This study used two video cameras installed on the sidewalk

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of a bridge over the cycle track. They measured passing and passed bicycle speeds, as well as bicycle lateral placement during the maneuver. The results showed that passed bicycles tended to move to the right while they were passed (from 0.86 to 0.58 m on average), while lateral spacing between the passing and the passed bicycle was 1.78 m. On average, a passing maneuver needed a distance of 91 m. Recently, Li et al. (2013) collected data of passing maneuver on cycle tracks in order to calibrate and validate a microsimulation model. Video cameras were installed to collect data in nine locations. Authors proposed a cellular automation model to predict the number of passes, and to classify them according to the lateral position of the passing and the passed bicycle.

Allen et al. (1998) analyzed the frequency of both passing and meeting maneuvers on separated cycle tracks. The number of maneuvers determined the level of service of a cycle track, according to these authors. Their results showed that, on two-way cycle tracks meeting maneuvers are more than ten times frequent than passing maneuvers. The higher frequency of meeting maneuvers contrasts with the very limited knowledge about them. Only Khan and Raksuntorn (2001) analyzed meeting maneuvers in detail. Using a 100 meeting maneuvers sample on a 3 m-wide cycle track, they concluded that the average lateral spacing between meeting bicycles was 1.95 m. Although authors expected a correlation between the spacing and the cycle track width, this was not explored as they only observed a 3 m width.

Most of the previous studies on either passing or meeting maneuvers were based on video recordings at fixed locations. However, other authors collected data from instrumented bicycles. This facilitated continuous data along segments, in contrast to fixed locations. Walker (2007) and Chapman and Noyce (2012) equipped bicycles with either laser or ultrasonic distance measurement devices to analyze the lateral spacing between bicycles and motor vehicles during passing maneuvers on two-lane rural roads. Parkin and Meyers (2010) used also an instrumented bicycle to study how motor vehicles passed bicycle on cycle lanes adjacent to vehicle lanes. They detected that drivers are less respectful with lateral distances when passing bicycles on roads with designated cycle lanes. Lee et al. (2011) used a high-accuracy GPS tracker on an instrumented bicycle to analyze the minimum maneuvering space and lateral clearance on a one-way cycle track. One hundred riders participated in the experiment, at three speeds: 10, 20 and 30 km/h. The minimum maneuver space vary inversely with speed, which indicated that speed reduction increased instability. On a 2 m wide cycle track, the maneuvering space was 1.48 m width and the additional comfortable lateral clearance was 0.42 m at 20 km/h. The conclusions suggested a minimum one-way cycle track width of 2 m. Other authors have used instrumented bicycles to observe the interaction between motor vehicles and bicycles. They used either a naturalistic procedure (Dozza and Fernandez, 2014) or quasi-naturalistic method (Chuang et al., 2013). However, they did not study the influence of road geometry on the interaction between bicycles on cycle tracks.

Additionally, Van der Horst et al. (2013) recently analyzed conflicts between bicycles, mopeds and crossing pedestrians. However, the authors only focused on one location, and not specifically on meeting maneuvers between oncoming bicycles.

Meeting maneuvers and conflicts involving oncoming bicycles should be a critical issue for the selection of cycle track widths. However, there is not much scientific evidence that support that selection. American Association of State Highway and Transportation Official (AASHTO) Guide for the Development of Bicycle Facilities (American Association of State Highway and Transportation Official, 2012) proposes a minimum width of 3 m for separated shared cycle tracks (for pedestrian and cycling), although no recommendation is proposed for exclusive off-road cycle tracks. Many other regional and local guidelines establish different criteria, although they never justify the proposed values. For instance, Transport for London (Transport for London, 2014) recommends a minimum of 2 m for low traffic volumes and a maximum of 4 m for higher. Dutch platform CROW (CROW, 2007) also recommends between 2.4 and 4.0 m widths, depending on traffic volume.

The majority of existing cycle tracks in Spain are located on sidewalks. There is usually a limited space availability and track width does not usually exceed 2 m, which generally is perceived by users as insufficient. However, there is no previous study, which has analyzed the link between width and lateral clearance of meeting maneuvers on such narrow cycle tracks. Therefore, this research was motivated by the absence of scientific basis on the selection of cycle track widths.

2. Objectives

The aim of this research was the observation of meeting maneuvers on two-way separated cycle tracks. This depended on the following objectives:

- Development of a methodology for quasi-naturalistic observation of cycle traffic on separated cycle tracks.
- Data collection of meeting maneuvers on a sample of two-way separated cycle tracks.
- Analysis of meeting maneuver dynamic variables and opposing rider's response, as well as their relation with cycle track width and boundary conditions.
- Establishment of guidelines to determine the minimum cycle track width that ensures safe and comfortable meeting maneuvers.

The following hypotheses justified this study:

- On wider cycle tracks, meeting clearance and opposing bicycle speed are higher than on narrow cycle tracks.
- In presence of lateral obstacles, meeting clearance and opposing bicycle speed is reduced. The effect of obstacles to the handlebar height is higher than the effect of obstacles to the wheel height. In absence of lateral obstacles, clearance and speed are much higher.

3. Methodology

An instrumented bicycle collected the observational data. A cyclist rode along selected cycle tracks in normal conditions, at a

Fig. 1. Instrumented bicycle.