Accident Analysis and Prevention 102 (2017) 181–190

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

On the effect of networks of cycle-tracks on the risk of cycling. The case of Seville

R. Marqués[a,*], V. Hernández-Herrador[b]

[a] Department of Electronics and Electromagnetism, Faculty of Physics, University of Seville, Av Reina Mercedes s/n, 41012 Sevilla, Spain
[b] Independent Consultant, Santa Cleta Soc. Coop. And, C/Fray Diego de Cádiz, 24, 41003 Sevilla, Spain

ARTICLE INFO

Article history:
Received 17 October 2016
Received in revised form 17 January 2017
Accepted 3 March 2017

Keywords:
Bicyclists
Risk of cycling
Bikeways
Networks
Sustainable transport
Seville

ABSTRACT

We analyze the evolution of the risk of cycling in Seville before and after the implementation of a network of segregated cycle tracks in the city. Specifically, we study the evolution of the risk for cyclists of being involved in a collision with a motor vehicle, using data reported by the traffic police along the period 2000–2013, i.e. seven years before and after the network was built. A sudden drop of such risk was observed after the implementation of the network of bikeways. We study, through a multilinear regression analysis, the evolution of the risk by means of explanatory variables representing changes in the built environment, specifically the length of the bikeways and a stepwise jump variable taking the values 0/1 before/after the network was implemented. We found that this last variable has a high value as explanatory variable, even higher than the length of the network, thus suggesting that networking the bikeways has a substantial effect on cycling safety by itself and beyond the mere increase in the length of the bikeways. We also analyze safety in numbers through a non-linear regression analysis. Our results fully agree qualitatively and quantitatively with the results previously reported by Jacobsen (2003), thus providing an independent confirmation of Jacobsen's results. Finally, the mutual causal relationships between the increase in safety, the increase in the number of cyclists and the presence of the network of bikeways are discussed.

1. Introduction

Growing public awareness about the negative effects of car-based mobility on environment and health has attracted considerable attention to alternatives based on active mobility in urban environments. Such alternatives include utilitarian cycling, that appears as a valid option for short trips below 5–10 km (Dekoster et al., 2000; Pucher and Buehler, 2012). Bicycles are also a good alternative as feedering mode for public transport networks (Martens, 2004; Dekoster et al., 2000; Pucher and Buehler, 2012). However, cyclists (as well as pedestrians) are vulnerable because they cannot benefit of the protective metallic shell of car drivers, nor can develop a comparable kinetic energy. These facts make difficult to develop appropriate traffic safety measures to protect cyclists in the street (Elvik, 2010).

Fortunately, there is a wide evidence showing that the number of bicycle traffic accidents does not grow linearly with the number of cyclists (Elvik, 2009). Seemingly, the number of accidents varies as a less-than-one power of the number of cyclists in the streets, which implies that the risk of cycling drops when the number of cyclists increases. This effect has been named *safety in numbers* (Jacobsen, 2003; Elvik, 2009). Safety in numbers implies that policies aimed to promote cycling are also policies promoting cycling safety. However, as Wegman pointed out (Wegman et al., 2012) "... if numbers of cyclists are correlated with risk and these numbers are assumed to be the only explanation, we are in error. Large numbers of cyclists in countries such as the Netherlands, Denmark and Germany are associated with high densities of bicycle facilities. If not both numbers of cyclists and bicycle facilities are taken into account, the wrong conclusions may be arrived at. There is no solid evidence that the low fatality rates ... can only be explained by 'numbers'. Therefore, Jacobsen's conclusion may be wrong if we simply add numbers of cyclists to the system without adding safety quality, that is to say, risk reducing measures." Actually, it could happens that causality just goes in the opposite direction of what a careless interpretation of Jacobsen's analysis could suggest: There would not be more safety because there are many cyclist. Instead, there would be many cyclists because there is more safety.

* Corresponding author.
E-mail addresses: marques@us.es (R. Marqués), vicenth_arq@hotmail.com (V. Hernández-Herrador).

http://dx.doi.org/10.1016/j.aap.2017.03.004
0001-4575/

Therefore, it is necessary to analyze the effects of bicycle facilities on cycling safety. Among the aforementioned bicycle facilities, building bicycle lanes and bicycle tracks[1] are probably the most common measures (Pucher et al., 2010). Most planners and bicycle advocates (with the exception cited below) firmly believe that these facilities reduce the risk of cycling. In fact, statistics on a national scale in countries with a well developed cycling infrastructure, like the Netherlands, Denmark or Germany, point in the direction desired by such planners and cycling advocates: bicycle kilometers traveled per inhabitant continued to increase, while the number of cycling fatalities continued to decline (Pucher and Buehler, 2008a,b). However, there is a number of bicycle advocates, grouped around the *vehicular cycling* theories, which firmly believe that cycling on bike lanes and cycle tracks is less safe than cycling in the traffic. They argue that statistical evidence cannot substitute rational causality analysis and, through the analysis of a number of practical examples, try to show that cycling in the traffic is less dangerous than cycling on bikeways provided some basic skills are shared by the bicyclists (Forester, 2001; see also Puchers's reply, 2001). Although most cycling advocates does not follow such theories and support building bicycle lanes and tracks, the influence of vehicular cycling theories has been determinant for cycle traffic policies in some countries. For instance, in the USA, the guidelines of the American Association of State Highway and Transportation Officials (AASHTO) favored bicycling on roadways for many years, discouraging the implementation of cycle tracks (Lusk et al., 2013). Thus, the controversy about the actual contribution of segregated bicycle facilities to cycling safety is still ongoing (Wardlaw, 2014).

This paper presents a longitudinal study of the effect on cycling safety of the implementation of a network of bi-directional and segregated cycle tracks in the city of Seville (Spain) between 2006 and 2013. Our main motivation for this analysis was to shed light on the above mentioned controversy about the effect of cycle tracks and bikeways on cycling safety. Regarding this effect, we feel it is important to differentiate between the effect of the bikeways itself and the effect of connecting them in order to make a network covering all the area of interest. Therefore, we have developed a methodology suitable for differentiating both effects. Besides, motivated by the above mentioned Wegman's discussion about causality and safety in numbers, we also have investigated the possible causal relationships between cycling safety, the implementation of the network of bikeways and the increase in the number of cyclists associated to such implementation. Finally, we tried to obtain some practical lessons from the analysis, regarding how to increase cycling safety in cities.

We feel that the choice of Seville as a case study is appropriate because this city experienced a big growth of utilitarian cycling, from negligible values to near a 6% of all trips, after the implementation of the aforementioned network of cycle tracks (Marqués et al., 2014; Marqués et al., 2015; Castillo-Manzano et al., 2015a), which was followed by the implementation of a successful system of bicycle sharing (Castillo-Manzano and Sánchez-Braza, 2013; Castillo-Manzano et al., 2015b). As far as we know, there is no other similar experience in terms of growing of utilitarian cycling in parallel to the implementation of a network of bicycle tracks. Therefore, we feel that this case study offers a unique opportunity for evaluating the effects of bicycle facilities on cycling safety and to elucidate the causal relationships involved in such process.

The analysis spans over the whole period 2000–2013 (i.e. seven years before and seven years after the implementation of the bikeways network). We analyze the time evolution of the risk of cycling in the city, studying the relations between this variable and the main possible causes and/or consequences of such evolution, i.e. the presence and the length of the bikeways network, and the evolution of the number of bicycle trips, including the possible presence of a safety in number effect as it was reported by Jacobsen (2003) and Elvik (2009). Finally, changes in other meaningful variables, such as the percentage of Killed or Seriously Injured (KSI)[2] cyclists over the total number of bicycle traffic accidents, are also briefly discussed.

The paper is organized as follows: In Section 2 we present a review of the existing literature regarding the effects of bikeways on cycling safety. In Section 3 we present and discuss the main data supporting our study and develop the methodology for the analysis of such data. In Section 4 we present the main numerical results of our analysis. In Section 5 we discuss and interpret these results. Finally, in Section 6, the main conclusions of our work are presented.

2. Literature review

Despite the evidence of the positive effect of bikeways on cycling safety coming from statistics at the national level (Pucher and Buehler, 2008a,b), the evidence coming from the microanalysis of specific infrastructures is much lower. In a review dated on 2009 (Reynolds et al., 2009), Reynolds and co-workers analyzed 23 papers dealing with the effects on bicycle safety of several kinds of bicycle infrastructures and indicated that the literature on the topic was very sparse. They also highlighted that only a few types of infrastructures were studied at that time. Among the infrastructures not studied before 2009 were cycle tracks (except at roundabouts). Notwithstanding, the general conclusion of the review was that "purpose-built bicycle-only facilities (e.g. bike routes, bike lanes, bike paths, cycle tracks at roundabouts) reduce the risk of crashes and injuries compared to cycling on-road with traffic".

A more recent review (Thomas and DeRobertis, 2013) specifically devoted to cycle tracks analyzed 23 papers dating from 1987. The review pointed out that only four of such papers (Welleman and Dijkstra, 1988; Wegman and Dijkstra, 1988; Gårder et al., 1994; Lusk et al., 2011) included exposure in the analysis, something that is essential for risk evaluation. From these four papers, only one was relatively recent (Lusk et al., 2011). The remaining three papers dated from more than 20 years ago. The papers from Welleman, Wegman and Dijkstra (Welleman and Dijkstra, 1988; Wegman and Dijkstra, 1988) were focused on bicycles and mopeds (which were allowed to ride in cycle tracks at that time in the Netherlands) and reported a general improvement of safety for bicyclists on cycle tracks but not for moped riders. They also found that most injuries in cycle tracks occur at intersections and recommended to end the cycle tracks before intersections, a practice that is not presently recommended in the Netherlands (see, for instance, Ploeger et al., 2007). The paper from Gårder et al. (1994) also concluded that cycle tracks may enhance safety between intersections, but not at intersections, and also recommended to end the cycle tracks before intersections. The overall conclusion of Gårder's paper was that cycle paths increase the risk "in average". The paper from Lusk and co-workers (Lusk et al., 2011) compared accident rates in several two-ways cycle tracks built in Montreal (Canada) with some reference streets, and concluded that this ratio in streets with cycle tracks was 0.72 times the corresponding ratio for the reference

[1] An urban cycle track is an exclusive bicycle path alongside a city street that is separated from the motorized vehicle traffic by a physical barrier. It can run at the level of the carriageway, at the level of the sidewalk (but clearly separated from pedestrian's paths) or at an intermediate level, as in the city of Copenhaguen. Bicycle lanes are exclusive bicycle paths separated from the motorized traffic by a white or colored line, or by any other mark painted on the pavement.

[2] "Severely injured" is defined as those victims who need hospitalization for more than 24 h.