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Investigation of Vulnerable Road Users' Behavior on Shared-use Space

Abstract: Coexistence of pedestrians and cyclists, on a shared infrastructure, consist an extremely important issue due to the lack of space in the built environment. Moreover, the importance of that issue is enhanced owing to the transport policy objectives for walking and cycling promotion. In the direction of better planning and operation of these infrastructures, the present paper aims to investigate factors which affect cyclists' and pedestrians' behavior while using shared use sidewalks and pedestrian streets. For that reason, counts were conducted on two sidewalks and one pedestrian street of the Municipality of Thessaloniki, Greece on which a bicycle lane is located. Measurements lasted three weeks (one week for every segment) and they were related to pedestrian and bicycle speed, pedestrian and bicycle flow, as well infrastructure geometric characteristics. The measurements started on July 18, 2017 and finished on August 4, 2017. Data collection is followed by statistical data analysis. The paper presents a correlation analysis in order to identify the impact of specific functional and geometric attributes of the infrastructure on their users' behavior. The analysis showed that pedestrians' speed is highly correlated with the bicycle lane width and the pedestrian unit flow rate, while cyclists' speed is affected by the type of pedestrian-cyclist segregation, the sidewalk width and the pedestrians' speed. Moreover, type of pedestrian-cyclist segregation, sidewalk width and pedestrian unit flow rate found to have an impact on the percentage of bicycles moving outside the bicycle lane.

Keywords: vulnerable road users, pedestrians, cyclists, shared-use space, active modes

Introduction

In the previous years, transport planning was mainly seen from motorized traffic perspective, largely ignoring users of non-motorized vehicles. In recent years, there is a shift in how transport planning is being approached. European Commission's White Paper on Transport 2011, recognizes the need to promote walking and cycling in order to achieve a competitive and sustainable transport system (COM 144, 2011). Moreover, European Commission suggested that local authorities of the Member States should implement Sustainable Urban Mobility Plans (SUMP) which, among others, focus on active modes promotion. Active modes are those which only use human's physical activity and among them walking and cycling are the most widespread.

That transport policy shift is largely due to the environmental, social and economic benefits which active modes offer. Studies have shown the benefits of walking and cycling on issues such as public and personal health, congestion reduction, environment improvement and economy (Litman, 2017, Dannenberg et al., 2017, Morettini et al., 2015, Oja et al., 2011, Mulley et al., 2013, Blondiau et al., 2016).

On the other hand, the promotion of active modes of transport is hampered by the low level of safety which vulnerable road users (pedestrians and cyclists) perceive. For that reason and

considering the economic constraints that do not allow the implementation of exclusive traffic corridors for each category of road users, in many cases bicycles are encouraged to use pedestrians' infrastructure (e.g. sidewalks, pedestrian streets), in which fatality and serious injury risk is much lower (Grzebieta et al., 2011, Chong et al., 2010). It is understood that the coexistence of pedestrians and cyclists is a matter of great importance and of imperative need.

Coexistence of pedestrians and cyclists also creates problems to the specific users as the number of conflicts between them is increased and the available space for the pedestrians is reduced. However, these conflicts lead extremely rarely to a serious injury (Austroads, 2006, Henley and Harrison, 2012).

The aim of this paper is to investigate cyclists' and pedestrians' behavior on shared-use sidewalks and pedestrian streets and more specifically to identify infrastructures' geometric and functional features with impact on pedestrian speed, bicycle speed and cyclists' choice to move outside the bicycle lane. This is a crucial issue as users' behavior along with the inadequate infrastructure design are the two main reasons for producing pedestrian-cyclists conflicts (Queensland Transport, 2006). According to questionnaire surveys, pedestrians tend to blame cyclists for a collision or conflict, while cyclists put the blame on pedestrians (Hatfield and Prabhakaran, 2016, Paschalidis et al., 2015).

Study area

The study area is the Municipality of Thessaloniki, located in northern Greece. Since 2009, a bicycle network of around 12 km has been operating in the city of Thessaloniki (Kartsoviti, 2011). In the framework of that research, sidewalks and pedestrian streets with bicycle lane were examined. Moreover, it was desirable to identify sidewalks and pedestrian streets with different geometric and functional features. Based on the above criteria, the following three sections were selected:

- Ethnikis Amynis: that sidewalk constitutes the west border of the Aristotle University of Thessaloniki (AUTH) campus. AUTH is the largest university in Greece, with more than 70.000 students and about 3.000 employees (Aristotle University of Thessaloniki). It is a relatively narrow sidewalk where the bicycle lane occupies a large part of the total width.
- Aggelaki: that sidewalk constitutes the west border of Thessaloniki International Fair premises. Thessaloniki International Fair is an annual commercial exhibition event of great importance, which lasts 9 days and hosts more than 200.000 attendants (Thessaloniki International Fair – Helexpo). It is a medium-width sidewalk in which the cycle path is narrower by half a meter compared to the other two sections (1,5 meters instead of 2 meters).
- Agias Sophias: that pedestrian street is located in Thessaloniki's city center. It is a highly commercial street which also connects historical sites with the seafront. It has a wide breadth and there are many retail shops and cafes on it.

Figure 1 presents those three segments. It should be noticed that in the case of Agias Sophias pedestrian street, the bicycle lane is signified differently from the two sidewalks. More specifically, there is no color change in the bicycle lane, but there are only some horizontal signals along the route. As a result, in many cases pedestrians do not realize the existence of the bicycle lane.



Figure 1: a) Ethnikis Amynis sidewalk, b) Aggelaki sidewalk, c) Agias Sophias pedestrian street

Data collection

The field counts conducted from July 18, 2017 to August 4, 2017, during morning peak hour (Nikiforiadis, 2017). The counts were related to the following:

- geometric features: total width, effective width, bicycle lane width,
- functional features: pedestrian and bicycle volume, pedestrian and bicycle speeds using the timing method.

Concerning volume and speed counts, they have been conducted for one hour for every day of the week except weekends (five hours of counts in total for every segment). For every day of counts, the average pedestrians' and cyclists' speed was calculated. Average pedestrian speed varies from 1,22 m/sec to 1,38 m/sec, while average bicycle speed varies from 3,52 m/sec to 5,75 m/sec. These values broadly agree with the values given in the literature (Highway Capacity Manual, 2010, Botma and Papendrecht, 1991, City of Copenhagen, 2013). The above mentioned data were imported in a database. That database contained 15 observations (one observation for every day of measurements) and 8 variables. Table 1 presents the 8 variables used in the analysis. Except "type_of_seg", all other variables are scale. The "type_of_seg" variable is binary and it takes values 0 (differentiation of surface coloring) or 1 (surface symbols along bicycle lane).

Table 1: Coding and description of the variables used in the study

Code	Description
type_of_seg	Type of pedestrian-cyclist segregation
eff_side_width	Effective sidewalk/pedestrian street width [m]
bic_lane_width	Bicycle lane width [m]
ped_fl_rate	Pedestrian flow rate [ped/min/m]
bic_fl_rate	Bicycles flow rate [bic/min/m]
ped_speed	Pedestrians' average speed [m/sec]
bic_speed	Cyclists' average speed [m/sec]
percent_bic_out	Percentage of cyclists moving out of the bicycle lane

Statistical analysis

The purpose of the research is to investigate factors which have impact on cyclists' and pedestrians' behavior while they are both active on shared-use space. As a result, the analysis firstly aims to identify those factors and secondly to realize the way in which they influence users' behavior. In the present research, indications of users' behavior are

considered to be speed for pedestrians, while for cyclists the speed and the percentage of them moving outside the bicycle lane.

In order to identify variables which affect pedestrian speed, bicycle speed and the percentage of bicycles moving outside the bicycle lane, Pearson’s correlation coefficient was computed. Figure 2, presents Pearson's r results. The intense blue color symbolizes positive correlation, while the intense red color negative correlation.

It is noted that pedestrian speed has strong positive correlation with bicycle lane width and pedestrian flow rate. Bicycle speed is affected, but not to a large extent, by the type of segregation, effective sidewalk width and pedestrian speed. Finally, the percentage of bicycles moving outside of the bicycle lane is strongly affected by the type of segregation, effective sidewalk and pedestrian flow rate. Correlation could be also mentioned between the percentage of bicycles moving outside the bicycle lane and the bicycle flow rate or the bicycle speed, but bicycle volume was very low during the counts and as a result the interaction between bicycles was an extremely rare phenomenon.

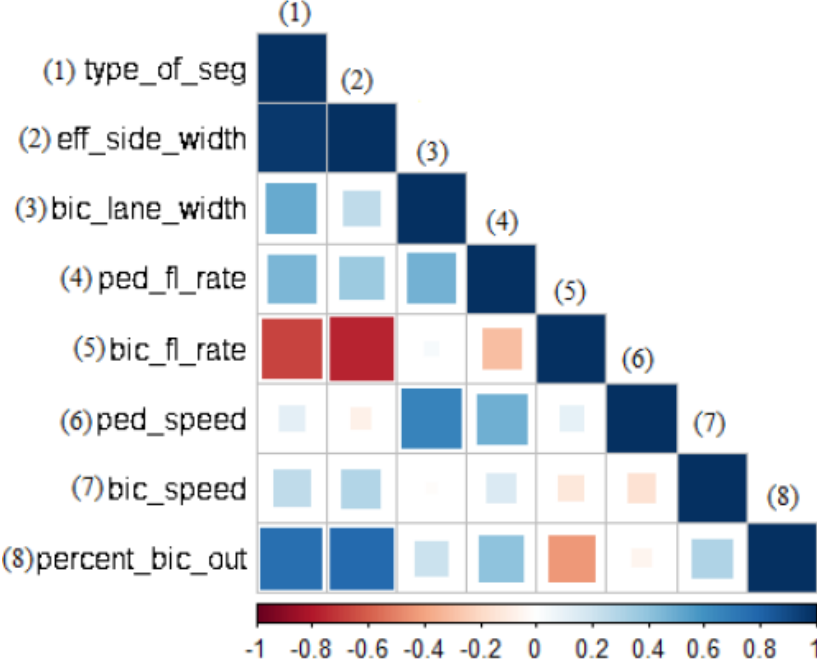


Figure 2: Pearson’s correlation coefficient among study’s variables

Figures 3 and 4 demonstrate the impact of bicycle lane width and pedestrian flow rate on pedestrian speed. It is understood that pedestrians tend to walk faster in cases of wider bicycle lanes and higher pedestrian volumes. The increased values of pedestrian speed in case of higher pedestrian volumes demonstrate that pedestrian and bicycle traffic during measurements was not congestive (even in the most traffic-intensive hours) and as a result pedestrians were able to select their speed.

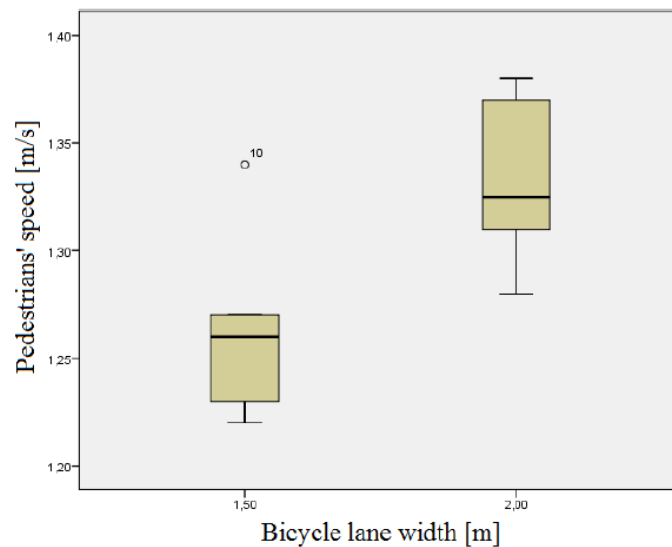


Figure 3: Relation between bicycle lane width and pedestrian speed

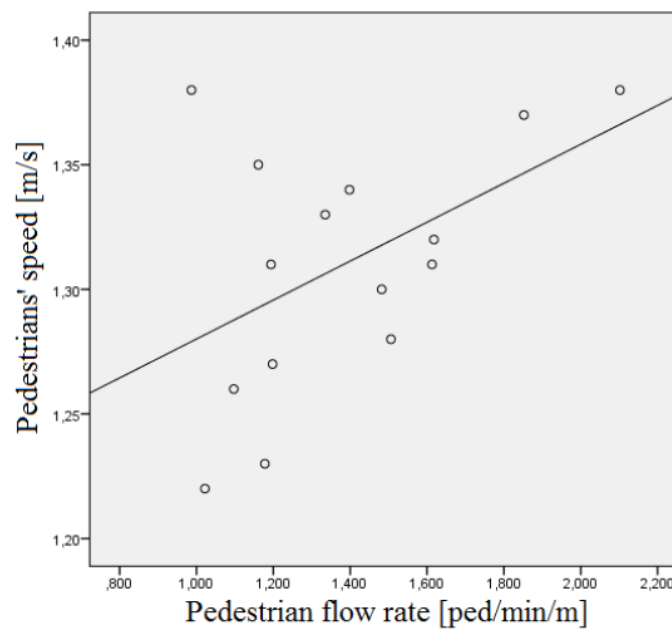


Figure 4: Relation between pedestrian flow rate and pedestrian speed

Figures 5 – 7 present the impact of type of segregation, effective sidewalk width and pedestrian speed on bicycle speed. Concerning the type of segregation, in both cases applies the same, but as it has already been mentioned the non-color differentiation of the bicycle lane contributes to the difficulty of its recognition by the pedestrians. It is noted that in the case of non-color differentiation cyclists move faster. Moreover, cyclists tend to move faster in wider sidewalks/pedestrian streets and when pedestrians' speeds are low.

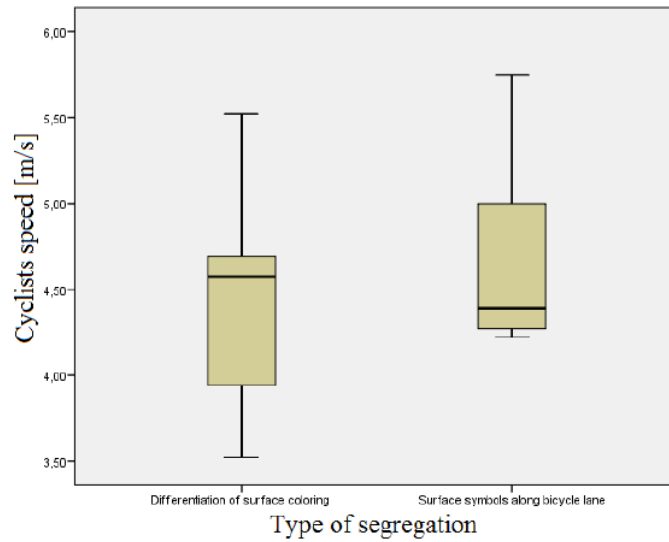


Figure 5: Relation between type of segregation and bicycle speed

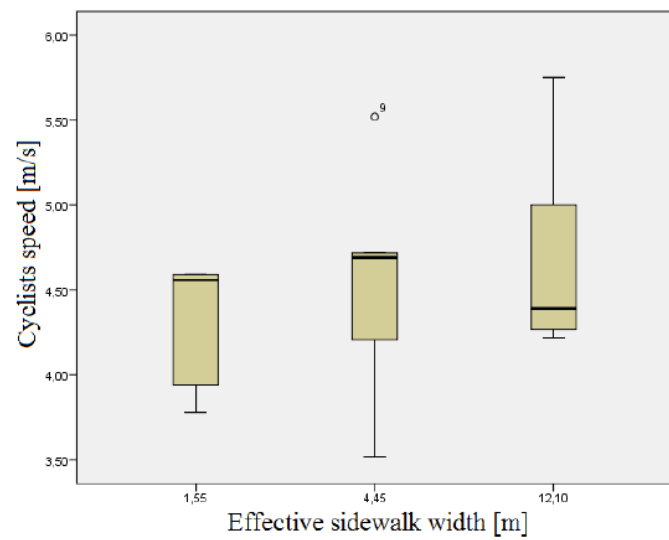


Figure 6: Relation between effective sidewalk width and bicycle speed

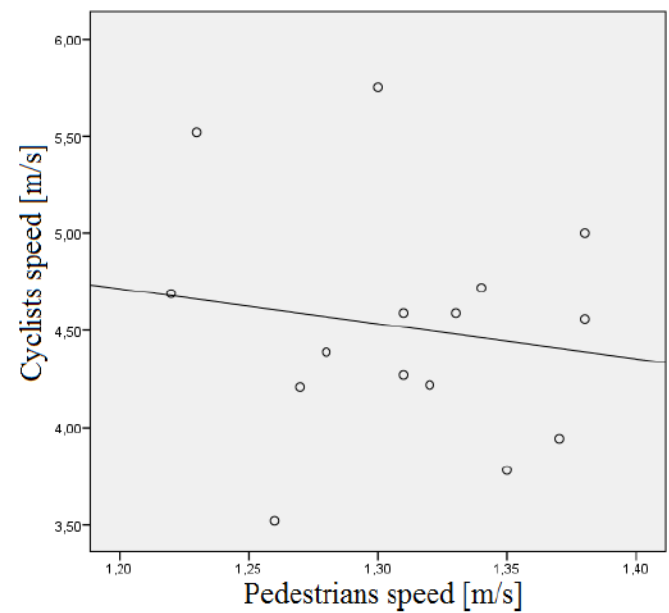


Figure 7: Relation between pedestrian speed and bicycle speed

Figures 8 – 10 demonstrate the relation between the percentage of bicycle moving outside the bicycle lane and the type of segregation, the effective sidewalk width and the pedestrian flow rate. Cyclists commonly choose to ride outside the bicycle lane when the pedestrian-cyclist segregation is not so clear, the sidewalk/pedestrian street is wider and the pedestrian volume is increased.

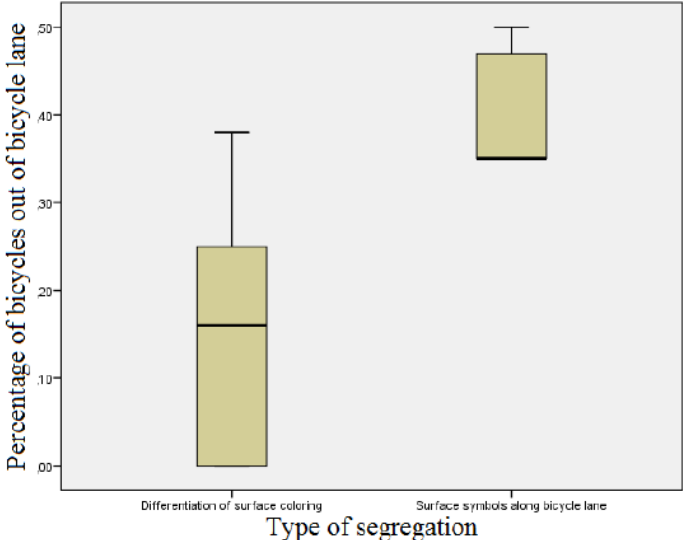


Figure 8: Relation between type of segregation and percentage of bicycles moving outside the bicycle lane

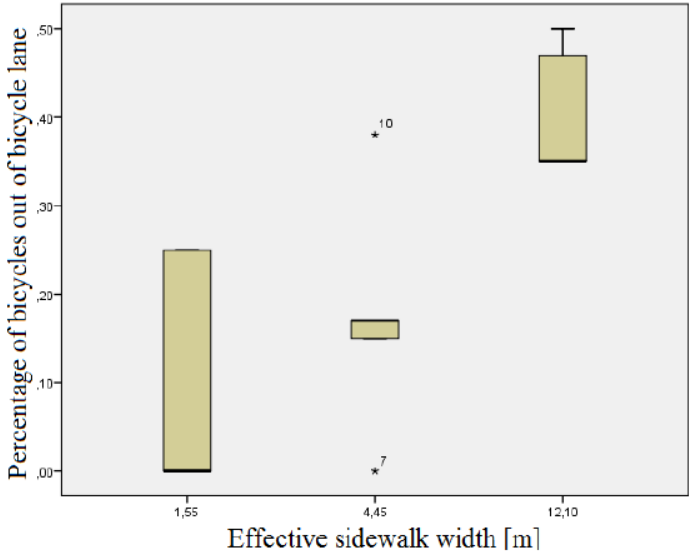


Figure 9: Relation between effective sidewalk width and percentage of bicycles moving outside the bicycle lane

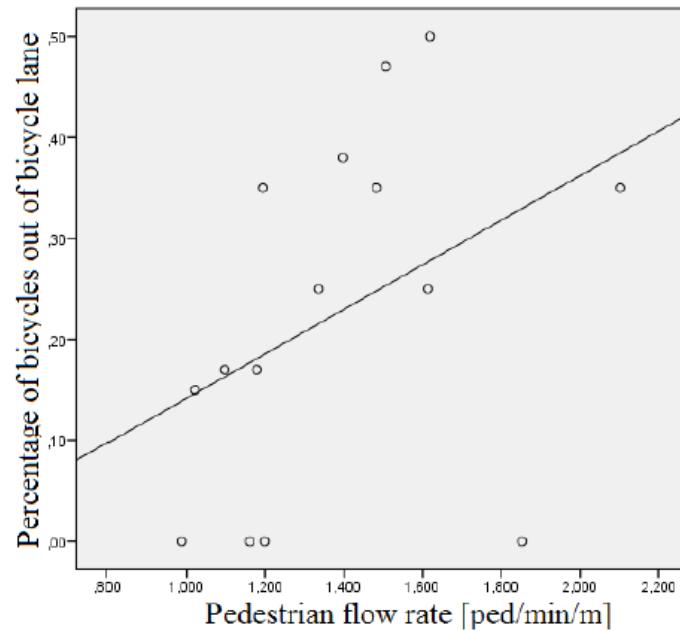


Figure 10: Relation between pedestrian flow rate and percentage of bicycles moving outside the bicycle lane

Discussion

Statistical analysis shows that pedestrians walk faster in cases of wider bicycle lanes (2 meters instead of 1,5) and when pedestrian flow rate is higher (for values up to 2,1 ped/min/m). A plausible assumption for that result is that pedestrians increase their speed in order to be exposed in uncomfortable conditions as little as possible. A conclusion is that planners should be extremely careful when sizing a bicycle lane, as pedestrians perceive lower levels of comfort, even if the flow of bicycles is low. Moreover, planners should not rule out the possibility of mixed pedestrian-cyclist traffic (without segregation), when pedestrian and bicycle volumes are too low.

Another outcome of the statistical analysis is the adaptation of cyclists' behavior in the prevailing traffic conditions. More specifically, cyclists reduce their speed in narrower segments and in cases of higher pedestrian speed. Therefore, it can be said that they ride slower when the possibility of a conflict is higher. In addition, results demonstrate that cyclists choose to ride outside the bicycle lane when the segregation is not so clear (40,4% of cyclists moving outside the bicycle lane in case of an unclear bicycle lane and 13,7% in case of a clearly delineated bicycle lane), the segment width is increased and pedestrian flow rate is higher. This may indicate that cyclists are maneuvering to avoid a possible conflict with a pedestrian.

The main limitation of the results of this research is the small number of observations due to the aggregation of the observations per day. Further research could include extended counts for more robust results and also a questionnaire-based survey in order to investigate users' perceptions. Also, efforts should be made with a view to minimizing pedestrian-cyclist conflicts in shared-use spaces.

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