**Safety-related behaviours of e-cyclists on urban streets: An observational study in Israel**

**Methodology**

Three observational surveys were conducted in this study: traffic counting, speed measurements and video recordings.

b. Speed measurements

The speed measurements were conducted for electric and ordinary bicycles, on the same street sections. The measurements were conducted on six sections of streets in two cities in the central region of Israel, near the same intersections where the traffic counts for this study were conducted. The survey sites represent typical streets for these cities, with mixed traffic. They differed in terms of road users, type of street and intersection, land uses, and the presence or absence of bicycle paths. The sites included: single-lane local streets (A, F); a two-lane arterial boulevard with commerce and without a bike path (B); a two-lane local street with commerce and with a bike path (C); a two-lane arterial boulevard without commerce and with a bicycle path (D); a two-lane local street without commerce and without a bicycle path (E).

Speeds were measured using a laser gun. They were performed in the middle of each street section, far from the intersections, and with conditions enabling uninterrupted bicycle riding. Measurements were conducted on weekdays between the hours of 8:00 -17:00. Each measurement was recorded on an observation page, and included personal details about the bicycle riders: gender, age bracket, riding location, and whether they were wearing a helmet. At each site, data were collected for 30-50 electric bikes and 10-30 regular bikes, with more measurements taken on busier streets (types B-D).

Data processing included the production of summative indices for riding speeds and rider characteristics, at each type of site, for both types of bikes. Measurements of average speed, standard deviation and maximum value were used to characterize the riding speeds. A T-test (significant difference, with p < 0.05) was used to examine differences in riding speeds between the two groups of riders. In addition, statistical models were adapted to identify variables that affect riding speeds and other rider behaviours such as wearing a helmet and choice of riding location. The model for predicting riding speed was adjusted using stepwise linear regression, in which the following explanatory variables were examined: type of bicycle, type of street, gender of the rider, age group (aged 19-34 compared to aged 35+), riding location (road versus bike path or sidewalk). The other models were constructed using logistic regression, with the explanatory variables examined: type of bicycle, type of site, rider gender and age group.

c. Video recordings

In order to document the behaviours of e-cyclists in urban traffic, field observations were made using video footage. Because e-bikes appear on the streets irregularly, placing a static camera would be ineffective. Therefore, the observations were made using a dynamic method, with the observer standing at the site and activating a camera only when e-cyclists appeared. The observers stood near an intersection and when they saw an e-cyclist traveling towards the intersection, the observer videotaped the rider approaching the intersection, crossing through the intersection, and moving away from the intersection (if visibility conditions at the site allowed for this). Additionally, the video needed to show the street scene and other road users in the e-bike rider’s environment. Video recordings were only made showing adult riders. In addition, the observation conditions were defined as primarily requiring video footage in which the rider of the e-bike was interacting with other road users: motor vehicles, pedestrians or other cyclists. Observers were instructed not to video record a rider alone on the street. The videos were taken between the hours of 9:00 -16:00, i.e., during daylight hours, when there is vehicular and pedestrian activity on the street.

The video recordings were taken in the city of Tel Aviv, near intersections where there is significant traffic consisting of various types of road users. A total of ten observation sites for video recordings were selected to represent three types of areas: (a) near intersections at traffic lights on separated main streets - 4 sites, (b) near intersections in single-lane local streets - 3 sites, (c) near intersections in wide main boulevards - 3 sites.

The research team coded the videos to characterize the road and traffic conditions at the time that the riders were crossing the intersection, and how they interacted with other road users. The coding results were quantitatively analysed to characterize traffic patterns and behaviours of e-bike riders under varying infrastructure situations, as well as to identify common interactions and dangerous situations (conflicts). A conflict is defined as an interaction between two road users requiring emergency braking / stopping or change of riding / walking / traveling direction by one or both parties in order to avoid a collision.

Summaries of the data underwent statistical tests to examine the effect of various infrastructure characteristics on the behaviours of e-cyclists. For a single-parameter test, the Pearson’s test was used. For multi-parameter tests of selected behaviours, adapted logistic regression models were applied.

The traffic counts at the intersections were conducted in September - November 2016. The other observations in the study were conducted in January - March 2017.

**3. Results**

b. Riding speeds and other behaviours of e-cyclists, based on speed measurements

 As part of the speed measurements, data were collected on 349 riders, of whom 229 were e-cyclists and 120 regular cyclists. Table T1 presents a summary of the metrics of riding speeds and rider characteristics for both types of bicycles at each site. Figure F1 shows the average riding speeds. It can be seen that the riding speeds on the e-bikes were higher than on regular bicycles, with gaps of 4-7 km / h for the average speed. The average riding speeds of the e-bikes were 19-20 km / h at most sites and about 14 km / h at sites A and E. The difference between the travel speeds of the two types of bicycles was significant (p < 0.05) at all sites.

Speeds were not uniform across the various site types. However, no tendency was detected for higher speeds on the two-lane streets compared to one-lane streets, or on streets without commerce as compared those with commerce. Also, the effect of the bike paths was inconsistent: higher speeds were observed at the two sites with bike paths (C, D), as compared to one of the streets without a bike path (E), but were similar to those recorded on another street without a bike path (B). Trends in riding speeds, according to the types of sites, were similar for the two types of bicycles.

Most of the riders on both types of bicycles were males, except for two sites where more female riders of regular bicycles were observed (D, F). At all types of sites, most riders on both types of bicycles were between the ages 19-34. Cyclists aged 65+ were rare and observed at only two sites. Most riders on both types of bicycles did not wear helmets, although those riding regular bicycles were more likely to wear helmets.

The choice of riding location (road or sidewalk/bike path) was different at the various sites, regardless of the type of street or intersection. The findings show that at sites with bike paths (C, D), the percentage of riders on the road was lower, but the presence of bike paths does not lead to their exclusive use by the cyclists. At these two sites, between 40% and 60% rode on the bike path and between 20% - 40% of riders were observed on sidewalks.

Table T2-a shows an explanatory model for riding speed. According to the model, riding speed was affected by three characteristics (p < 0.001): site type, riding location and type of bicycle, with no significant effect found for the riders’ gender or age group. The model shows that riding speed increased on arterial boulevards and two-lane local streets, as compared to single-lane local streets. According to the model, after controlling for other riding characteristics, the speed of a regular bicycle was lower than that of an e-bike by an average of 4.7 km / h. Further, riding speed on sidewalks / bike paths was lower compared to that on roads, by an average of 4.1 km / h.

Table T2-b presents an explanatory model for predicting the use of a helmet while riding, including a presentation of the odds ratio for the explanatory variables. The model shows two characteristics with significant impact: site type and bicycle type. The impact of age and gender was not significant. The probability of using a helmet was twice as high for riders of regular bicycles versus e-cyclists. Helmet use was higher among those riding on one-lane versus two-lane streets. The incidence of riders wearing a helmet was particularly low at sites with bike paths (C, D).

Table T3-a presents an explanatory model for choosing to ride on the sidewalk (as opposed to on the road) on streets that do not have designated bike paths. Three influential characteristics are identified in the model: site type (p < 0.001), age group (p < 0.05) and gender (p < 0.1). The type of bicycle did not have a significant effect on the choice of riding location. According to the model, the incidence riding on the sidewalk was twice as low among males compared to females, and 2.6 times higher for those aged 35+ compared to riders in the younger age group. The incidence of riding on the sidewalk was lower along a two-lane arterial boulevard with commerce.

Table T3-b presents an explanatory model for the choice of riding on a bike path versus a sidewalk or road, on streets that have bike paths. In this model, three characteristics had an impact: site type and age group (p < 0.05), and type of bicycle (p < 0.1), while the riders’ gender did not have a significant impact. According to the model, the incidence of riding on a bike path was twice as high on a street without commerce (D) as compared to a street with commerce. It was also twice as high for ordinary bicycles compared to e-bikes. On the other hand, the incidence of riding on a bike path was 3.4 times lower for riders aged 35+ as compared to younger riders.

c. E-cyclist behaviours based on video-recordings

 Figure 2F shows images of the filming sites. After examining the quality of the films, 337 videos of e-cyclist behaviors remained for coding and analysis in the study. Most of the riders observed (86%) were aged 19-34, 12% were aged 35-64, and 3% were aged 65+. Most users of this means (79%) were male; 99% were without a helmet. Similar characteristics of cyclists were found in the analysis of traffic counts at intersections and the speed measurements of cyclists along the sections of streets.

The distribution of video recordings by street type was fairly uniform: 38% of the videos were recorded on two-lane main streets, 29% on single-lane streets, 33% on wide main boulevards. The characteristics of the riders in the different types of sites were similar. There was no statistical difference between the types of sites in terms of the riders’ gender, age group or helmet use.

Following the coding of the videos, samples of riders’ behaviors were obtained for the following situations: 1) a rider traveling in a section of street leading up to an intersection, N = 304; 2) a rider passing through the crosswalk at an intersection, N = 237; 3) a rider passing an intersection together with a vehicle, N = 105; 4) a rider traveling on a section of street after the intersection, N = 321. Table 4T presents a summary of the riders’ behaviors in each of these situations. The findings indicate the following:

When traveling in the section of a street leading to an intersection, 29% of cyclists chose to ride on a sidewalk, 35% on a bike path, 36% on the road. However, at sites with a designated bike path, 75% rode on the bike path, while 10% rode on the sidewalk and 15% on the road. There was a significant difference at sites without bike paths: 46% rode on the sidewalk and 54% on the road.

When traveling on the section of road leading to an intersection, most cyclists rode in the right-hand lane. Most riders (61%) were observed in heavy vehicular traffic, and in half of these cases the rider’s speed was slower than that of the motor vehicles. As expected, the percentage of cases with heavy vehicular traffic was higher (over 80%) on the main streets. Additionally, the percentage of cases in which the cyclist was slower than the rest of the traffic was greater on the main streets (79%), as well as on the two-lane streets versus one-lane streets (69% and 23% respectively) (significant differences, p < 0.001). While riding on the road, most cyclists did not change their position on the road and did not move up onto the sidewalk, although 17% did move up to the sidewalk and 11% changed their riding position on the road. In 5% of the cases, a conflict was observed between a cyclist and a vehicle traveling in the section of street.

In most cases of cyclists riding on the sidewalk or a bike path leading to an intersection, there was little or no traffic of pedestrians or other bicycles on the street. When riders were observed near a pedestrian, as a rule, they moved faster than pedestrians. When riding on the sidewalk or bike path, for the most part, the cyclist did not change position and did not get off onto the road. In 5% of cases, a conflict was observed between a cyclist riding on the sidewalk and a pedestrian. No conflicts were observed in interactions with other bicycles.

The behaviors of the cyclists traveling in the section of a street after an intersection were similar those observed in the sections before the intersection. In total, 29% of cyclists chose to ride on a sidewalk, 34% on a bike path, and 37% on the road. At sites with a designated bike path, 76% of cyclists rode on it. While traveling on the road, most cyclists traveled in the right-hand lane. A significant proportion of the riders (about 40%) were observed among significant vehicular traffic, and their speed was slower compared to the rest of the traffic. As expected, there was a greater percentage of cyclists whose speed was slower than the vehicular traffic on the two-lane roads as compared to the one-lane roads, and on the main boulevards as compared to other types of sites (significant differences). Most cyclists did not change their position on the road, although, 17% did make a change. In 6% of cases, a conflict was observed between a cyclist and a vehicle.

In the observations of cyclists on a sidewalk or bike path following an intersection, there tended to be little traffic of pedestrians or other cyclists. If there were pedestrians, in most cases the cyclists travelled faster than them. If other bikes were observed, the speed of the cyclist who was recorded was often similar to the speed of other cyclists. As a rule, cyclists did not change their position on the sidewalk or bike path and did not move onto the road. In 6% of cases, a conflict was observed between a cyclist on the sidewalk and a pedestrian. No conflicts were observed in interactions with other bicycles.

Of the riders observed in crosswalks at intersections, about half crossed through one crosswalk, the rest crossed two or more crosswalks at the same intersection. Most of the crossings (55%) were crosswalks at a traffic light for pedestrians only, 35% were crosswalks at a traffic light for pedestrians and cyclists, the other 10% were crosswalks at intersections with no traffic light.

In 19% of the observed cases, the cyclist crossed the crosswalk when the traffic light was red. In almost half of the cases, the rider did not stop or slow down prior to crossing. In most cases, the cyclist crossed the crosswalk to a sidewalk or a traffic island on the other side, but in 16% of cases they went down onto the road in the crosswalk area. In the model adapted for predicting crossing against a red light, a significant effect of site type was found. At intersections on single-lane streets and on wide main boulevards, crossing against a red light was twice as common, or even higher, as compared to intersections on two-lane local streets. Also, for these types of sites, there is a higher incidence of riding on the road (the cyclist went down onto the road while crossing the crosswalk). The incidence of staying on the road increased when the rider crossed through several crosswalks at the same intersection.

In half of the cases in which cyclists crossed through crosswalks, there were pedestrians in the crosswalks as well. In most of these cases, the cyclist rode slowly parallel to the crossing pedestrians. However, in 30% of the interactions with pedestrians, the rider passed the crossing pedestrians faster than they were walking. In 3% of cases, a conflict was observed between the rider and a pedestrian crossing the crosswalk. Further, in 2% of cases, a conflict was observed between a cyclist and vehicles in the area of the crosswalk.

In the observed situations in which cyclists passed through an intersection on the road, like a motor vehicle, in 20% of these cases the cyclist passed through a red light at the intersection. In 56% of cases the rider did not change riding speed while crossing the intersection. In 10% of cases, the rider drove against the direction of traffic. In 13% of cases, the cyclist went up onto the sidewalk while crossing the intersection. In 5% of the cases, a conflict was observed between the cyclist and vehicles in the area of the intersection.

Overall, the proportion of conflicts recorded in the videos was not low relative compared to the other observations conducted in this research. However, their severity was usually mild, with 5 cases (8%) being moderately severe. The time to collision (TTC / PET) was between 1-2 seconds when the cyclist interacted with a passenger car.

4. Discussion and Conclusions

According to various field observations conducted in the study, most e-bike users in Israel are young adults aged 19-34, similar to the findings reported in Europe and the US (e.g., MacArthur et al., 2018; Scaramuzza et al. 2015). As expected, the riding speeds of the e-bikes were higher than that of regular bikes. However, the gaps in the measured average speeds were not large: the raw data in the study indicated gaps of 4 -7 km / h in the average speed between the two types of bikes, while in the explanatory model a gap of 4.7 km / h was obtained, on average.

The gaps measured in this study were slightly higher compared to the findings of previous studies (Langford et al, 2015; Petzoldt et al, 2017; Schleinitz et al., 2017), which found gaps of 2-4 km / h. This may be related to differences in how speed was measured. in previous studies, the average speed of riding in a section of street was reported, while the present study used speed measured at one point. Additionally, the average riding speeds measured in this study, of 19-20 km / h or less, were similar to the values reported in studies in Europe (Petzoldt et al., 2017; Twisk et al., 2021).

Overall, the study did not identify a significant phenomenon of unusual speeds among e-bike riders. The study did find an effect of riding location on speed: riding speeds were higher among those riding on the road compared to on the sidewalk; this is similar to findings in studies in other countries (Schleinitz et al, 2017).

The various observations in this study indicate that half or more of e-cyclists riding along urban streets travelled on the road. However, when there is a designated bike path, a significant proportion of cyclists rode on the path, thus lowering the risk level of conflict with other road users. When riding on the sidewalk, most riders were faster than pedestrians and in 5% -6% of cases a conflict between riders and pedestrians was observed. It is clear that riding an e-bike on designated bike paths is the desired solution for their integration onto urban streets.

When riding on the road, most e-cyclists used the right-hand lane, as required by law. Nevertheless, riding on the road was associated with an increased risk, because in many cases the cyclists were in heavy vehicular traffic, and their riding speeds were slow compared to the rest of the traffic, especially on the main streets. In addition, cyclists on the road were more likely to change their riding location: some cyclists went up onto the sidewalk (e.g., 17% of those traveling on a street section leading to an intersection). In 5% -6% of cases, a conflict was observed between a cyclist and a motorized vehicle, and the consequences of such conflicts may be serious. Therefore, riding an e-bike on the road poses a higher risk compared to riding on the sidewalk or bike path, both in terms of traffic conditions and the behaviours of the cyclists.

When crossing an intersection, about 20% of e-bike riders crossed against the red light; a rate similar to that reported in Europe (Schleinitz et al., 2019) but lower than the rate found in China (Du et al., 2013). More e-cyclists crossed through intersections at the crosswalks rather than on the road along with the motor vehicles. However, 16% of the riders went down into the crosswalk area, then continued to travel on the road. Similarly, in 30% of the interactions with pedestrians in the crosswalk, the cyclist overtook the crossing pedestrians and rode faster than they walked. That is, the potential for conflicts between e-cyclists and other road users tends to be higher when cyclists use crosswalks designed for pedestrians.

On the other hand, cyclists crossing through intersections exhibited more dangerous behaviours, including traveling against the direction of traffic at an intersection, and ascending onto the sidewalk while crossing an intersection. In 5% of cases of cyclists crossing through an intersection, a conflict was observed between the rider and vehicles. Conflicts between cyclists and vehicles are characterized by a high potential for severity. Therefore, the desired and safest solution for the passage of e-bikes at intersections is to create designated crossings for cyclists.