Contribution to the safety study of pedestrians and users of active modes with the introduction of scooters and electric bicycles

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Abstract

This dissertation evaluates the implications generated by the entry into the urban mobility offer of vehicles with semi-active modes such as electric scooters or electric bicycles. These assessed implications mainly concern accidents involving pedestrians or active mode vehicle users, with special attention to those occurring at intersections.

The evaluation is divided in two parts, an initial part that assesses the current operating framework, namely the factors that generate insecurity and possible solutions to apply at intersections, and a second part which evaluates the implementation of solutions identified in two cases, from the urban area of Lisbon.

The initial assessment presents all the elements and contours involved in an accident, the vehicles, vehicle users, track users and infrastructure are considered. During this evaluation we try to compare users' opinion and the studies already done to understand the current situation and, therefore, to gain understanding about the predominant factors in conflict situations. This approach made it possible to define solutions for minimizing the risk of intersection accidents for the most vulnerable users.

The final evaluation seeks to define how to apply the solutions presented in real study cases, allowing a simplified inference on the aspects that have the most influence on the users safety. Thus, we seek to contribute to the definition of a consistent intervention at urban intersections, in order to minimize the risk of accidents for those who use it, the first object of the study.

Keywords: Mobility, Transportation, Intersection, Bike Path, Safety and Shared Vehicles

1. Introduction

In recent years there has been a large increase in the number of electric bicycles and electric scooters on the streets of major urban centers around the world, including the municipality of Lisbon. This increase is mainly due to the creation of a sharing system for these vehicles which made their use simpler and more practical, therefore agitated the mobility system that was practiced in large cities.

Large urban centers were already trying to adapt to velocipedes, such as bicycles, by investing in adequate structures to protect them, but the entry into the market of small shared vehicles like the many electric scooters created many advantages for urban mobility but also created many challenges that needed to be overcome, solutions to improve the quality of life and safety of all road users.

This dissertation objectives are to contribute to the identification of the main safety disturbing factors introduced by the increasing use in public space of electric bicycles and scooters, endowed with the ability to use a relatively high operating speed, and also a contribution to the improvement of fluidity and safety of traffic at intersections of an urban network, as they are the most sensitive points of circulation for vulnerable users (pedestrians, bicycle and scooter users, electric or not) and two or four wheeled vehicles (motorized and all variants). This last aspect considers the adaptation of known solutions that have application potential at any intersection. The goodness of these solutions is translated by applying them in detail in two case studies developed in the urban fabric of Lisbon.

2. Vehicles with semi-active mode in urban centers

2.1. Introduction

The bicycle and scooter are two types of vehicles that had so far similar growth paths, both are two-wheeled series and a handlebar that began as a hobby and has evolved to the present day where they play an important role as part of the range of choices, mobility in urban centers.

During this evolution, one of the most prominent elements, that was integrated in these vehicles, was the auxiliary engine. Nowadays the predominant version of the engine is running on electricity (Observador, 2019). Based on this characteristic of having or not motor, in this dissertation all vehicles are defined in the following types:

- Vehicle with active mode: This is the vehicle that requires only active human traction to move (example: conventional bicycle; conventional scooter).
- Vehicle with semi-active mode: is the vehicle that needs active human traction to start the movement only and that has a motor to aid human activity (example: electric bicycle; electric scooter).
- Vehicle with non-active mode: vehicles that do not require active human traction to move are then driven completely by motorized traction (example: motorcycle; automobile).

The insertion of vehicles with active and semi-active modes in cities is not new, but in recent years we have been seeing an increase in number and popularity due to the creation of a new sharing system for bicycles and scooters for both cities, conventional versions as for the electric ones.

All sharing companies have a similar customer base, which is a mobile app that allows the user to find and pay a period to use small vehicles such as scooters or bikes owned by the app company. In-service bikes have both active and semi-active versions, but the scooters for these services all work in semi-active mode.

According to journalist Schneider (2018), the entry of this new system of sharing in cities is having a public reception divided into three phases: displeasure, epiphany and mass adoption. The dislike is for many the first phase, given the appearance of several small landless vehicles that are scattered across the sidewalks like lost toys used by children. Then comes the epiphany, the moment when the user first experiences and realizes that this kind of shared car is not only a fun, but also a practical alternative to the car. In mass adoption it encompasses all small active mode and semi active mode vehicles used in the city, even the non-shared ones. If taken seriously by cities, small vehicles will cut car numbers and fill up sidewalks and may play an important role in helping cities achieve their unachievable environmental and road safety goals to date (Schneider, 2018).

The increase in vehicles with active and semi-active modes also presents new challenges to the safety of the most vulnerable road players that need to be addressed. Thus, this dissertation considers two phases in addition to Schneider's, the divergence phase and the convergence phase.

2.2. Divergence phase

It is the phase when displeasure and mass adoption intersect creating divergent opinions. Mass adoption leads to an increase in the level of dislike of those who continue to be pedestrians because they are not attracted to or need small vehicles to move around cities. Many of the situations that create displeasure have been shared by citizens on social networks which has increased the proliferation of opinions on the subject. This phase can be divided in three main areas.

Disadvantages of mass adoption, only for pedestrians, is the area of greatest importance as pedestrians are the most vulnerable element in the street so their safety is especially important:

- High number of vehicles circulating in pedestrian coexistence areas;
- High number of vehicles parked in pedestrian zones;
- The use of landless vehicles in acts of vandalism in the streets.

Other disadvantages of mass adoption, including for vehicle users, is the area which, while like the previous point, is disadvantageous to both pedestrian and semi-active vehicle user rather than pedestrian only:

- Hazardous behaviors when using vehicles;
- Reduction of physical activity;
- Excessive speed in the use of these vehicles.

Advantages of mass adoption is the area that demonstrates the positive strands strong enough to share opinions on the previous points:

- Bigger attraction to appeal new users for the vehicles;

- Greater security on investing in the business of sharing systems;
- Motivation to increase the number of vehicles thus increasing the offer of mobility.
- Possibility of reducing cars in the streets.

2.3. Convergence Phase

This phase is a slow path that depends on both studies and strategically weighted solutions, then it is still necessary for the solutions to be applied for the time needed to reach a significant range that reduces risks and therefore decreases. The division of opinions from the divergence phase to the point where the acceptance of the circulation of these vehicles is at the level of the current integration of vehicles with non-active modes.

With the treatment of risk situation records, it is then possible to carry out scientific studies that allow the analysis of all situations in order to converge on possible strategic solutions. Lisbon does not yet have enough data for the studies needed, so the studies analyzed below are from other countries.

"Comparative Analysis of Risky Behaviors of Electric Bicycles at Signalized Intersections" (Bai, Liu, Guo, Yu, 2014)

"Related Risk Factors for Injury Severity of E bike and Bicycle Crashes in Hefei" (Hu, Lv, Zhu, Fang, 2014)

"The casualties from electric bike and motorized scooter road accidents" (Siman-Tov, Radomislensky, Israel Trauma Gourp, Peleg, 2017)

"Road traffic injuries among riders of electric bike electric moped in southern China" (Zhang, Yang, Yang, Hu, Li, Wu, Stallones, Xiang, 2018)

Through the analysis of the studies it was possible to verify that exists are several factors that influence the risk of conflicts in the streets where the vehicles with semi-active modes circulate. Conflicts range from simple discomfort situations to accidents that can result in serious injury. In rare cases it may result in the death of pedestrians and vehicle users. Speed was mentioned as an influencing and aggravating factor of risk situations and changes in infrastructure were mentioned as an important factor to be considered in improvement of the traffic safety. Regulation is also very much mentioned, but the dissertation is focused on regulation that is mainly related to infrastructure issues.

Knowledge of the problem is the first part of the convergence phase. The second part of this dissertation is to consider possible solutions that contribute to the definition of a strategy to minimize the risk of accident at intersections.

3. Risk Minimization Solutions

The strategy presented for risk minimization consists of a set of solutions to be applied at intersections where the central focus of the strategies is to protect the pedestrian and the vehicle user with active or semi-active mode from the risk behaviors of the vehicle user with semi-active mode. In this dissertation, five possible different solutions were described.

3.1. Bicycle lane protected at intersections

The main element of these bike lane intersections is the corner refuge island which is essential for bike lane safety. It acts as a protective barrier to the bike lane in the corner curves of the intersection. The island allows a vehicle driver with non-active mode to be partially facing the crossing zone of vehicle with active or semi-active mode thus extinguishing the blind spot that exists in this zone (Falbo, 2014).

The second element of great importance is the possibility of integrating a revolving circulation system of vehicles with active or semi-active modes in any intersection of vehicles with non-active modes, even if they are junctions or intersections (Falbo, 2014). It is equivalent to the roundabouts of vehicles with non-active modes (Figure 1).

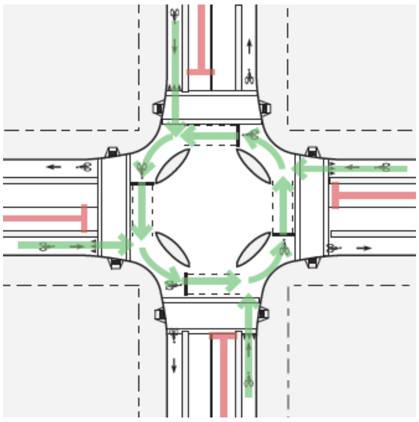

Figure 1 - Hypothesis of rotary circulation (Alta Planning + Design, 2015).

In Lisbon, the information is scarce, but there is at least one intersection that already adopts elements of this system. At the intersection between “Alameda da Universidade” and “Avenida do Brasil” (Figure 2).

Figure 2 - Intersection between “Alameda da Universidade” and “Avenida do Brasil” (2019).

In brief analysis, it was possible to see that corner refuge islands are the ever-present element while the revolving circulation is left out mainly in cases where one or more intersection corners are left out of reach of the bike path.

If the event that the available space does not allow the placement of a corner refuge island as an inner radius equal to the outside one must adapt. In the adaptation can be considered a version in which it is possible to apply in the largest number of cases of this kind so in this sense an adaptation to the conventional island of refuge presented in Figure 3 is recommended

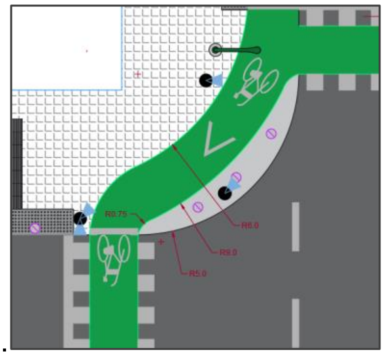

Figure 3 - Example corner refuge island for cases with limited space.

The corner refuge island is an element that should allow the driver of a vehicle with non-active mode to make a right turn by visualizing as much as possible the existence of vehicles with active or semi-active modes on his right, thus ending the existence of a dangerous blind spot at the intersection. But in the realization of this dissertation it is necessary to consider the factor of human ignorance about the existence of this system.

To prevent an accident, this dissertation suggests three types of possible elements (pillars, signaling and vegetation) that make the island more visible to the user of vehicles with active or semi-active modes (Figure 4).

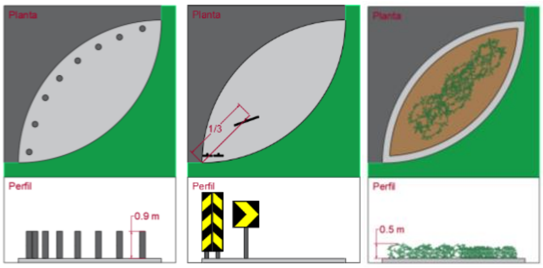

Figure 4 - Corner refuge islands with different prominent elements.

A rotating circulation of vehicles with active and semi-active modes favors simplicity of intersection and space saving, especially if the intersection area available for the bike path is reduced. For this simplicity to work from the bike learner's perspective, the bike lane user must be informed in advance of the revolving circulation, so it is suggested that two new signals be created (Figure 5).

Figure 5 – B7b e D4b, signs for a bicycle lane with revolving circulation (adapted from Infraestruturas de Portugal and Diário da República, 1998).

3.2. Pedestrian Island Elimination between Bike Path and Lane

In many bike lane intersections, it is part of the basic design that there is an island for pedestrians, where they wait to cross, and which separates the lane of vehicles with non-active mode from the cycle lane of vehicles with active and semi-active mode. But there are two following disadvantages (Figure 6):

- Volume may exceed island capacity
- Possibility of the island being full and pedestrians waiting for the crossing on the bike path

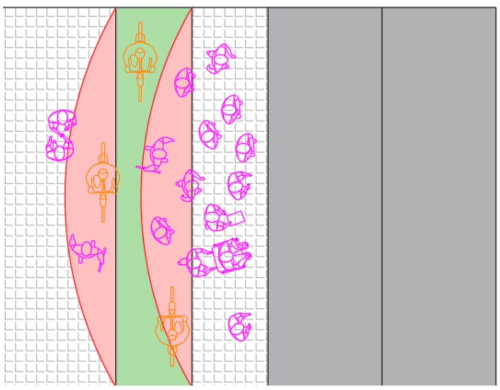

Figure 6 - Possible scenario of dangerous situation with pedestrians waiting on the bike lane.

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3.3. Counter curve for speed reduction

The entrance of a bike path at a safer intersection is usually made by right turning curve, which aims to provide a comfortable transition between the road and intersection bike path (Falbo, 2014; Alta Planning + Design, 2015). This type of bike path entry at the intersection offers no resistance to approach speeds of vehicles with active or semi-active modes, which can create a small level of monotony that could cause accidents due to loss of reaction time. It is then proposed to enter a light counter curve with the objective of encouraging the speed reduction of vehicles that circulate in the bike path (Figure 7).

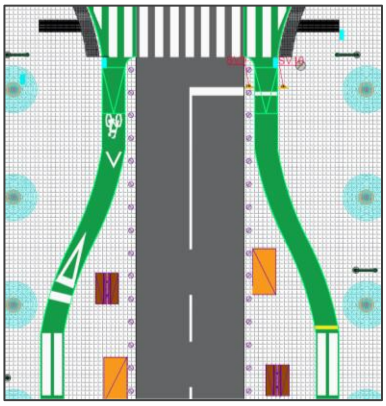

Figure 7 – Counter curve to encourage speed reduction.

3.3. Low bike path at pedestrian crossing

Most of today's bike lanes that seek to be protected from active vehicles are level with the pedestrian promenade. Given that the bike lane intersections are a more sensitive point, then this dissertation proposes to lower the bike lane in the intersection zone to obtain the following advantages:

- The pedestrian will circle before the curb to protect a walk higher than the adjacent carriageway and bike lane in the intersection zone.

- The user of a bicycle or scooter will not have to dodge pedestrians standing on the bike path to avoid an accident.

3.4. Bicycle speed control

This solution is the only one that compels rather than induces and is based on the simple process of warning the vehicle user that they are required to moderate speed in the intersection zone.

This solution is based on an existing method that covers any vehicle but only applies to registered vehicles which are mostly vehicles with non-active modes.

If we add this capability to the fixed radar system and the "Via Verde" system, then theoretically, there is already the technology needed to create a first version of cycleway speed control.

This speed control must be created in partnership with the entities that develop the software for the sharing companies and all location data of any shared vehicle, whether active or semi-active, must be shared with the entity, responsible for controlling.

4. Case study selection

Data on deaths, serious injuries and minor injuries on the roads of the municipality of Lisbon between 2010 and 2017 (Autoridade Nacional de Segurança Rodoviária, 2018) make it possible to approximate the most dangerous intersections. The two intersections with the most victims were chosen as case studies:

- Case 1 with 4 victims: Intersection between "Avenida Almirante Reis" and "Rua Pascoal de Melo", it is composed of a cross between an avenue and a street, both of which are important for traffic in the municipality of Lisbon.

- Case 2 with 3 victims: Intersection between "Paço da Rainha" and "Calçada Conde Pombeiro", is a misaligned intersection composed of a set of junctions, in all there are three, but given that one of the junctions is slightly further away then the most attention is given to two other major junctions.

5. Application of solutions at Lisbon intersections

5.1. Introduction

In the place, the conditions of each intersection were raised for the realization of drawings. Among the various constraints, the two most important were reduced space and traffic levels. Interest was raised in assessing service levels of pedestrian traffic. The intersection of case 1 can be conservatively considered to have a high level of pedestrian service. While in case 2 the level of pedestrian service is reduced.

5.2. Things to keep in mind from case study 1

Solutions were applied to case study 1 that transformed the intersection and throughout the process aspects that are worth retaining were interpreted.

Negative aspects:

- Reduced space: The available area between the boundaries of the streets is small compared to the number of intersection users.
- High traffic: The dense pedestrian and road traffic that was recorded throughout the on-site surveys, confirming the high numbers already expected due to the most important road at this intersection.
- Addition of light signaling: The intersection currently has light signaling but applying the desired solutions it is necessary to increase the

number of elements and consequently the complexity of orders, two stages for three stages (Figure 8).

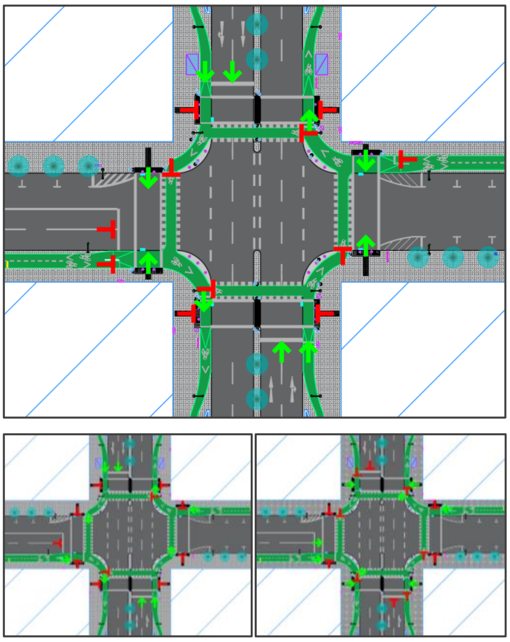

Figure 8 - Proposed phasing of the light signaling of the case study 1.

- Tight right-hand turn: Makes it particularly difficult for heavy vehicles such as the buses that travel to those streets.

- Interruption of the “wish line”: The relocation of the pedestrian passages farther from the center of the intersection, thus interrupting the pedestrian's desired direction of movement in two passages.

Positive aspects:

- Application of all solutions: All the presented solutions are possible to be applied in this case.

- Street symmetry: The two streets at this intersection have symmetry between sidewalks, which is a feature that has advantages.

- Speed Influence: The application of the solutions that have been weighted to reduce risk situations. It is expected that the speed of vehicles with semi-active modes no longer have such an influence on intersection risks.

- Bike lane reach: The solutions do not create any difficulty in intersecting mobility at bike lane level.

- Intact driving directions: It was possible to achieve it without changing the driving directions of vehicles with non-active modes.

5.3. Things to keep in mind from case study 2

Solutions were applied to study case 2 that transformed the intersection and aspects that are worth retaining during the process were interpreted.

Negative aspects:

- Reduced space: The available area between the structures is small, except for “Paço da Rainha”.

- Asymmetry of Roads: None of the roadways at this intersection have symmetry between sidewalks which is a feature that has disadvantages.

- Interruption of the “wish line”: The relocation of the pedestrian passage farther from the center of the intersection, thus interrupting the directions of circulation desired by the pedestrians.

- Impossibility of the raised passage: The Lisbon City Council has a project with an raised passage for pedestrians in “Paço da Rainha”, but due to the integration of the solution consisting of the lowered bicycle lane at the intersection, it is impractical to raise the passage.

- Reduction of parking: The reduced space meant the reduction of places dedicated to the Italian embassy.

Positive aspects:

- Application of all solutions: All the presented solutions are possible to be applied in this case.
- Low traffic: It should be noted that the low pedestrian and road traffic that was recorded throughout the site analysis, confirming the low numbers already expected due to the most important intersection streets, being local distributors of Lisbon.
- Speed Influence: The remaining solutions that have been weighted to reduce risk situations it is expected that the speed of vehicles with semi-active modes no longer have such an influence on intersection risks.
- Reach of the bike lane: The solutions have been designed in such a way as to avoid difficulties in intersection mobility at the bike lane level.
- Intact driving directions: The integration at the intersection of the bike lane with its solutions demonstrates that it was possible to achieve it without changing the driving directions of vehicles with non-active modes.

6. Conclusion

This dissertation contributes to the definition of a strategy to minimize the risk of intersection accidents for the most vulnerable users. Assuming that in this way the stated objectives were initially achieved.

Through an evaluation, the main intervening factors were identified in the dimension of the stated risk, which was introduced by the increasing urban use of vehicles with semi-active modes such as electric bicycles and electric scooters.

Based on the knowledge gained from the initial assessment described and the regulation of the municipality of Lisbon and national, this dissertation presented five possible solutions to minimize the risk of accident in more vulnerable areas and situations within an intersection of different roads.

Of the solutions presented there are two that focus on the main risk factor, the speeding. The light counter curve and speed control on the bike lane are solutions designed to combat speeding in different ways.

Finally, the dissertation applied the solutions presented in two case studies located in the city of Lisbon with the objective of demonstrating how they can be applied in real cases and under what conditions, in order to allow a better generalization of their use. Case study 1 was the most problematic, mainly because the intersection has a small footprint, high road traffic and high pedestrian traffic, but it was still possible to apply the solutions to mitigate the risks at the intersection. In case of study 2, it was more accessible to apply the weighted solutions for the dissertation, even in the case of a misaligned intersection.

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