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MOBISEC

Study about safety of cyclists and pedestrians in crossroads and roundabouts

Deliverable D2.3

CONTENTS:

1.- BACKGROUND

The Distinguished City Council of Murcia is participating in the European MOBISEC project for the three-year period 2012-2012, financed by the European Community. Said project provides for the completion of a cyclist safety study at roundabouts and crossroads, with proposed measures to prevent accidents and improve the co-existence of cyclists and motor vehicles.

For this purpose, a grant agreement was signed by the Distinguished Mayor of the City of Murcia and the European Union on 27 November 2011. The Project is to last a total of 36 months, commencing on 1 January 2012 and ending on 31 December 2014.

2.- PURPOSE

The purpose of this Safety Study is to create a tool that can be used to study a typical roundabout intersection in order to obtain an estimated risk index at the roundabout for cyclists and all other road users based on a series of empirical data.

As is logical, this tool must be assessed in a practical manner and applied, and the results obtained in real cases must be studied to verify whether it is effective and accurately describes the reality of the situation. In order to do this practical verification, the decision was made to choose three roundabout-type intersections in different places in the city of Murcia which are representative of various types. They are different sizes and have a different number of lanes. The traffic intensity varies greatly from one to another. One features traffic lights and has pedestrian pavements whereas the others do not, etc. The aim was to cover a wide range of types so as to achieve the most versatile tool possible.

Once the tool for measuring the hazard level of a roundabout has been designed, the logical result is attempting to reduce the risks for the users. To do so, a different study was conducted to design possible theoretical solutions to eliminate or, at the very least, reduce some of the risks detected for each one of the three roundabouts proposed. After completing this second study, it is quite intuitive to re-apply the tool designed for the same roundabout but assuming the design has been modified based on the alternative proposed which makes it possible to immediately see how the risk can be decreased for each one of the proposed alternatives with regards to the original situation of the roundabout.

It is undeniable that the cost of implementing one alternative or another may be a determining factor in many cases when it comes to deciding whether or not to implement it. For this reason, an approximate budget for the cost involved in carrying out each one of the alternatives proposed for each roundabout was calculated. This way, we can automatically link the reduced risk index to the financial investment used to do so and rationalise the decision making process of the competent administrations.

This financial information is useful as it can be very easy to succumb to the temptation of undertaking very costly works to improve an existing situation when trying to reduce risks for users even though it might be possible to reduce the risk by an equivalent amount with just small actions that are more affordable for the administration meaning it is easier to complete the actions and improve the existing situation.

It is important to note that the aim of this study is not to build bike lanes to the intersections and later figure out what to do with the intersection; that is not the philosophy of this project. The idea is to start with an existing roundabout where cyclists transit without any specific signing. Therefore, the focus will be on attempting to establish the risks cyclists run when passing through the surrounding traffic with a view towards proposing solutions to improve safety at the intersection to the extent possible. The study will be concluded once cyclists are able to abandon the roundabout safely irrespective of whether or not they do so via a bike lane system or not.

3.- PRELIMINARY CONSIDERATIONS

Data that accurately reflects the existing reality is needed in order for this Safety Study to be a truly useful tool for studying the real risk of travelling through a certain roundabout and studying the possible solutions. We believe some preliminary data are necessary as outlined below:

- **Geometric data:** It is essential to know the geometric reality of the existing works. Therefore, it is necessary to have exhaustive surveying of the roundabout that includes data such as the inside and outside radios, longitudinal slope, cross-slope, the geometry of the entrances, the existence of inner and/or outer hard shoulders, the number of lanes, the existence of pavements, drainage, etc.

- **Traffic data:** It is necessary to conduct a traffic study at the intersection to be analysed as a study of this type can provide such revealing data as the Average Daily Traffic (ADT) of vehicles that cross the intersection, which percentage of those vehicles are heavy vehicles, if there is much traffic disparity depending on the time of day and, of course, the number of cyclists that cross the intersection and what their entrance and exit paths are.
- **Availability of nearby land:** In certain cases, the set of circumstances may determine that it is excessively dangerous for a cyclist to transit through a particular intersection. In these cases, it is necessary to know whether there is enough space around it to consider segregating the cyclists or even, if this is not possible, searching for alternative itineraries. The need to establish the actual itineraries used by cyclists; in other words, their places of origin and destinations, is perhaps even more clear.
- **Vehicle speed monitoring campaigns:** As will be explained below, the speed of the vehicles is fundamental when it comes to guaranteeing the safety of the other users. It is necessary to have the most accurate idea possible of the speed at which vehicles enter the roundabout as well as the speed at which they transit through it once they have entered.

4.- RISK ASSESSMENT.

The tool designed to assess the risks at the roundabout intersections is presented below. It consists of a spreadsheet generated with Microsoft Excel, the rows of which show the different conditioning factors which, in our judgement, can influence whether or not a particular roundabout is more or less safe traffic-wise.

It is automatic meaning that the table automatically generates the associated risk when a certain value is entered in each line. Percentage values are used for each one of the conditioning factors in order to obtain a quantitative result for the risk. This means the result is a 0% hazard index before entering any value whereas the spreadsheet result would be 100% if each one of the factors that contribute risks to users were given the worst rating.

It has been divided into five parts based on the nature of each one of the characteristics analysed such as the geometric design, the traffic supported, external conditioning factors, signing and the state of conservation.

Each one of the associated characteristics analysed is outline below with an explanation of the reason for which they were chosen, the risk rating associated to each one of them and which data must be inserted in the corresponding box to obtain the values.

TRAFFIC:

1.- Number of modes of transport simultaneously intervening.

The larger the number of modes of transport converging in an intersection at the same time, the greater the traffic risk is. There are always light vehicles and heavy vehicles, but significant pedestrian traffic may be added to the mix in certain circumstances whether or not this is regulated by traffic lights or there are usable pavements or not. There may also be particularly intense cycling traffic (areas near universities, schools, sports complexes, libraries, etc.) and there may even be additional elements that complicate the situation even more, if possible (train level crossings, tramway, city bus lines, school buses…).

This confluence of circumstances was rated as adding 2% to the total risk index for the intersection. The number of modes of transport that influence the traffic (significantly) is entered in the corresponding box in the table so the risk increases by 0.40% for each additional mode of transport. The maximum risk is attained with five different modes of transport.

2.- Heavy vehicle density.

Heavy vehicle traffic that is much more intense than normal exists in certain areas either because they are a habitual passage area for such traffic or because they are near industrial areas, etc. These vehicles are often slower than the rest and also occupy more space and even occasionally invade the adjacent lanes upon turning as well as drastically reduce the visibility of all other users which sometimes produces dangerous situations.

They are considered to significantly influence intersection safety and; therefore, contribute up to 3.50% to the total hazard index of a roundabout. Values between 0 (for very low density) and 2 (particularly intense density) can be entered into the corresponding box in the table to obtain proportional risk values of between 0 and 3.50%.

3. Average daily traffic (ADT).

This is empirical data which indicates the quantity of vehicles that transit through a particular location throughout the day. Along with this data, it is common to also indicate the percentage of this daily traffic that is comprised of heavy vehicles. Therefore, it is objective data which reports the actual vehicle intensity.

As is logical, this influences the possible dangers of an intersection as the greater the number of users, the greater the vehicle density, the higher the number of possible accidents, the slower the traffic, etc. This data is so important that it has been rated with 5% of the contribution to the total risk at a roundabout. ADT equal to or less than 1,000 vehicles a day is considered to be risk-free; whereas, the maximum risk is obtained with an ADT of 7,000 or higher. As is the case with many other factors to be analysed below for cases with intermediate values, linear proportion is used to calculate the risk between the maximum and minimum.

4.- Variation in the traffic intensity.

This additional data is as relevant as the ADT as it gives us an idea of the way in which traffic is distributed throughout the day, showing whether there are particularly intense times during the day (peak hours) or whether the traffic is distributed throughout the day more or less evenly.

It may be the case that an intersection is safe for bicycle traffic all day long except at a specific time. This variation in daily intensity has been assigned a risk of up to 2% of the total. Up to three different values may be entered at the observer's criteria ranging from unnoticeable variation, slight variation or substantial variation - each one with an associated risk percentage (0%, 1.00% and 2.00%, respectively).

5.- Vehicles waiting inside the roundabout.

When a roundabout features traffic lights, there may be an accumulation of vehicles waiting inside. If this accumulation of vehicles is sufficiently large, the stopped vehicles may invade the rest of the lanes that are free at a given time, thereby producing sudden changes in direction which can generate collisions.

Values of 1 or 2 may be entered in the corresponding box to indicate the presence or lack of vehicles waiting inside the roundabout, adding 0.75% to the hazard index if affirmative.

6.- Predominant movements.

When there are predominant movements in a roundabout and this is not regulated by traffic lights, hold-ups occur in the slip roads with the least traffic intensity. Prolonged hold-ups may produce dangerous situations as they force vehicles to enter the roundabout.

This increased risk has been assessed at 1.50% meaning it is necessary to enter options 1 or 2 in the box for this purpose to indicate whether or not there are any predominant movements.

7.- Compliance with the speed limit at entrances.

This is one of the fundamental characteristics from a road safety perspective in a roundabout which is why this factor has been assessed with a 5% influence on the total risk index.

If the speed of the vehicles entering the intersection is excessive, there is a high risk of accidents either due to collisions with other vehicles or due to the vehicle running off the road surface.

Specific speed measuring campaigns are necessary in order to rate this factor properly. For this data, either a “1”, if drivers observe the speed limit, or “2”, if they do not, needs to be entered. It is important to note in this section that just because an entrance features traffic lights does not mean drivers necessarily observe the speed limit as this point needs to be analysed when a vehicle approaches the entrance when the light is green to see if there actually is compliance or not.

8.- Compliance with the speed limit in the roundabout.

This concept is identical to the one above except this refers to the driving speed inside the roundabout instead of at the entrances. Just as the case above, excessive speed can cause collisions or traffic to run off the road.

When a roundabout is medium or small-sized, the very turning radius imposed by the design prevents reaching very high speeds, but this auto-regulation of speed is weakened when driving through large-sized roundabouts.

The same value (5%) was assigned to the risk index as for the point above, and only a "1", if drivers observe the speed limit, or "2", if they do not, needs to be entered as well.

9.- Vehicles that stop before entering the roundabout.

Vehicles already driving through roundabouts without traffic lights have priority over entering vehicles. There are times when an entering vehicle should stop and wait; yet, sometimes the vehicles may enter after simply taking the necessary precautionary measures. The percentage of vehicles that must stop before entering the roundabout versus the percentage of vehicles that enter without needing to stop provides an idea of the degree of traffic fluidity at the intersection.

If the percentage of vehicles that do not stop at the entrance is very high, the risk index at the intersection increases up to 1%; however, if the percentage of vehicles that stop is high, this risk is eliminated.

10.- Possibility of an accumulation of vehicles in exit slip roads.

Roundabouts with traffic lights many times have traffic lights at the exit slips roads in order to give access to pedestrians who wish to cross the roads. If the traffic light is very close to the roundabout, there is no space in the actual slip road for vehicles to accumulate meaning there is often a line of vehicles invading the very intersection which causes dangerous situations.

This problem is eliminated if the traffic lights are installed at a sufficient distance from the roundabout so as to allow for a greater accumulation of vehicles in the slip road without invading the intersection.

Just as the case above, vehicles invading a roundabout raises the risk index by 1%.

EXTERNAL CONDITIONING FACTORS:

11.- External distractions.

They create an added risk for road users. Normally, they consist of excess advertising signs. However, sometimes this might be a road sign with too much information which distracts drivers trying to read all of the information possible.

This subjective rating increases the risk index up to 2%.

12.- Bad weather.

The weather conditions very much influence the safety of any road, including roundabouts. The paved surface becomes wet on rainy days and; therefore, slippery, especially the road paint used for horizontal signing.

There can also be significant persistent and dense fog in many areas during certain times of the year which decreases the visibility, thereby increasing the risk of an accident.

This situation has been rated with a maximum increase of 1% in the risk index and it has been deemed appropriate to quantify it with the average number of rainy days in addition to the average number of foggy days as these are very usual statistical data in any country. Thus, the total number of bad weather days per year are obtained statistically by adding these two annual averages.

13.- Glare.

The sun’s glare, which reduces drivers' visibility, can be quite common during the early morning hours and at sunset depending on the geometry and orientation of a roundabout. This glare is very bothersome and frequent meaning a 2% increase in the risk index of a roundabout has been considered for this cause despite the fact that it is very localised to certain times of the day.

ROAD SIGNS:

14.- Traffic lights in roundabouts and at entrances.

Some roundabouts are designed to feature traffic lights and others are not, depending on the geometric characteristics and the traffic to which they will be subject. The greatest risk to a cyclist who is going to enter a roundabout is the surrounding traffic passing through next to him/her.

Adding traffic lights to a roundabout eliminates some traffic movements as it stops some of the vehicles to allow the others to move. This reduces the number of vehicles travelling in the roundabout and eliminates a large number of possible interferences between the vehicles entering and those already moving through it as the latter are stopped. It, therefore, amounts to a very significant reduction in the risk to cyclists and, largely, to all of the other surrounding vehicles as it organises the traffic to improve road safety.

This factor is so important that it has been considered to contribute up to 10% to the risk index rating of a roundabout. Moreover, traffic lights at an intersection allows for a specific study on cyclist movements which provides improved definitive safety for cyclists as it separates them from all of the other users. For this reason, this section has been dived into three different possibilities:

1.- There are no traffic lights: A "1" is entered in the corresponding box and the risk index increases by 10% as explained.

2.- There are traditional traffic lights for the surrounding traffic: A “2” is entered in the box, and the risk index increases by 5%.

3.- There are specific traffic lights for cyclists which separate them from all of the other vehicles: In this case, a “3” is entered in the corresponding box and the risk index does not increase because all of the vehicles stop when bicycles pass through the roundabout.

15.- Ideal waiting time at traffic lights.

This factor is less important than others but is worthy of consideration for the study at hand. If vehicles are stopped at a traffic light for an excessive amount of time, they often re-start driving in a more aggressive manner; or, what's even more dangerous, many drivers speed up when the traffic lights is going to change red in an attempt to pass through it instead of stopping. This produces accelerations, excess speeds and a risk of collision into the rear of other vehicles.

This circumstance has been rated with a 0.25% maximum increase in the risk index for the intersection.

16.- Vertical signing in roundabouts and at entrances.

This is another essential safety factor meaning the inadequacy has been rated with an increase in the risk index of up to 8.75% in the worst case scenario. There are various possibilities if the study is conducted from cyclist safety perspective as there are a wide range of visual indications that can help improve their safety. The different situations that can occur are explained below:

1. -There is no vertical signing whatsoever: This situation is extreme and not very common, but it can occur. It increases the risk index by 8.75% when a “0” is entered in the box for this factor.

2.- There is signing, but it is scarce or in a poor state of conservation: A "1" is entered in the corresponding box in this case to obtain an increase in the risk index of 7%.

3.- It exists, it is adequate and is in a good state of conservation: A "2" is entered in the box to obtain an increase in the risk index of 5.25%.

4.- If it not only exists and is adequate, but it includes additional lighted signing to indicate the presence of cyclists, the risks decreases even more because drivers are more aware of the presence of these users in the roundabout meaning the risk index only increases by 3.50%.

5.- Furthermore, there's an additional possibility of additional lighted signals which are not specific for cyclists but get driver's attention so they travel with more precaution. These include light buoys, cascaded lights, vertical LED signing, reflectors or any other similar element. In this case, an additional data is entered into the risk index spreadsheet ranging from "0" to "1" to indicate that this type of lighted signing either does not exist or, on the contrary, does exist and is adequate. Intermediate values between these two values can be entered and, as a result, the increase in the previously-obtained risk index will go down by one-third in the most favourable situation.

17.- Speed limit in the roundabout.

This section refers to the legal speed limit on driving through a roundabout. Depending on several factors, this limit may be higher or lower (inside radius of the central islet, the number of lanes, the longitudinal slope, the entrance and exit radiuses, etc.) and the higher the speed, the more likely it is that accidents will occur. A limit of 30 km/h is considered to be the habitual minimum meaning this limit increases the total risk index of an intersection by 0%. The risk is considered to increase proportionally between 30 and 50 km/h whereas the increase in risk is considered maximum (4%) if the roundabout is designed for vehicles to pass through at more than 50 km/h (inter-city roundabouts).

18.- Speed limit at entrances.

This is similar to the above except this section only refers to the legal speed at which traffic may enter a roundabout. As was the case above, it may be higher or lower depending on various factors (number of lanes in the entrance slip road, the longitudinal slope, the intersection entrance radiuses, visibility, etc.) and the higher the speed, the more likely it is that accidents will occur when one vehicle collides with another already moving through the intersection. The speed intervals are considered to be the same as above meaning the minimum is 30 km/h (increased risk of 0%) and the maximum recommended speed is 50 km/h (increased risk of 4%) with proportional increases for any speed between them.

19.- Horizontal signing in roundabouts and at entrances.

Similar to the vertical signing already explained, yet this refers to the road marks on the paved surface instead of the vertical ones. They influence traffic safety as well meaning the increase in the risk index will be rated in a similar manner depending on the situation:

1. -There is no horizontal signing whatsoever: This situation is extreme and not very common, but it can occur. It increases the risk index by 8.75% when a "0" is entered in the box for this factor.

2.- There is signing, but it is scarce or in a poor state of conservation: A "1" is entered in the corresponding box in this case to obtain an increase in the risk index of 7%.

3.- It exists, it is adequate and is in a good state of conservation: A "2" is entered in the box to obtain an increase in the risk index of 5.25%.

4.- If it not only exists and is adequate, but it includes additional lighted signing to indicate the presence of cyclists, the risks decreases even more because drivers are more aware of the presence of these users in the roundabout meaning the risk index only increases by 3.50%.

5.- Furthermore, there's an additional possibility of additional lighted signals which are not specific for cyclists but get driver's attention so they travel with more precaution. These include light buoys, cascaded lights, vertical LED signing, reflectors or any other similar element. In this case, an additional data is entered into the risk index spreadsheet ranging from "0" to "1" to indicate that this type of lighted signing either does not exist or, on the contrary, does exist and is adequate. Intermediate values between these two values can be entered and, as a result, the increase in the previously-obtained risk index will go down by one-third in the most favourable situation.

20.- Rumble strips.

They are often installed at the entrances to some roundabouts to lower as much as possible the speed at which users enter the inside of the intersection as well as to get drivers' attention with the sound and slight vibration they produce which improves the precaution taken when entering a roundabout. Their presence has been rated with a decrease in the risk index by 1%.

CONSERVATION:

21.- State of conservation of the road surface.

This influences traffic safety as the existence of potholes or irregularities in the road surface produce user discomfort and can even cause sudden changes in direction to avoid the irregularity. It is considered to have a significant influence on safety meaning the rating adds a total of up to 3% to the total risk index. Intermediate values can be obtained by entering values between "0" and "2".

22.- Cleanliness of the sides.

Oftentimes, there may be gravel on the sides of some roads, especially inter-city roads. When vehicles pass over them, the gravel sometimes shoots back at the vehicles behind producing a certain risk of impact. This risk is much higher for motorcycles or bicycles that are not equipped with bodywork to stop the impact. Inadequate road side cleanliness is considered to contribute up to 2% to the total risk index of an intersection and, just like in the case above, entering values between “0” and “2” obtains intermediate values for the result at the observer’s discretion.

INTERSECTION DESIGN:

23.- Number of lanes.

The number of lanes that exist inside a roundabout is a fundamental design factor. The higher the number of lanes means the greater vehicle density at peak times, the greater number of manoeuvres certain vehicles execute in order to avoid other slower vehicles, the larger number of different paths drivers describe to cross through it if the traffic density is not very high, the higher the travelling speed of the vehicles inside it, the higher the speed of entrance into the roundabout, etc.

The number of lanes needs to be entered in the appropriate box to obtain the added rating to the risk index. This factor has been considered to contribute 3% to the overall hazard of the intersection in the worst case scenario. The percentage is distributed linearly in the following way:

- Roundabouts with a single driving lane: If “1” is entered in the box, the result is 1% of the total risk.

- Roundabouts with two driving lanes: If “2” is entered in the box, the result is 2% of the total risk.

- Roundabouts with three driving lanes: If “3” is entered in the box, the result is 3% of the total risk.

Intersections with more than three lanes are considered to be of maximum risk meaning the result in the table will continue to be 3% even if values of four, five or six lanes are entered.

24.- Direct right turns.

Direct rights turns are designed when expecting a generalised movement of vehicles entering an intersection from an entrance slip road and leaving the roundabout by the adjacent slip road to the right. To prevent this quantity of vehicles from entering the roundabout and having to stop if there are traffic lights, an exclusive lane is provided for this manoeuvre without having to enter the roundabout, thereby preventing this traffic from affecting the rest of the users that are going to undertaken different movements. This eliminates a large number of vehicles from the roundabout so the traffic is much less intense and; therefore, less dangerous.

In general, a direct right turn can exist for each entry slip road to the roundabout so two different data must be entered in the spreadsheet. First, the number of possible rights turns is entered and then, then the existing ones.

It has been determined that if there are no direct rights turns, the hazard index of a roundabout will increase by 1%; if all of the entry slips roads allow for the direct turn, the hazard is 0%; and, the risk is calculated linearly between these two options (for example, the risk would be half the maximum for four entry slip roads and two direct turns; in other words, 0.50%).

25.- Total number of entry and exit lanes.

When a user transits through a roundabout, there is a possibility of collision between the vehicle transiting through it and the vehicles that are going to enter it via an entry slip road. The consequences of this collision are much more serious for cyclists given the lack of protection they have in the event of an impact. It may also be the case that a cyclist travelling through the outer lane of the roundabout is run over by a vehicle trying to leave the intersection from an inner lane meaning the number of entry and exit lanes influence the hazards of a roundabout.

The risk added to a roundabout based on whether there are more or less entry and exit lanes has been assessed at 4% of the total, distributed in the following manner: A roundabout with three entry and exit slips roads with one driving lane each means a total of six entry/exit lanes. This number is considered to be small enough that this risk can be considered negligible meaning when you insert a number of lanes that is less than or equal to six in the table, the risk obtained is 0%. If you enter a higher number of lanes, the risk increases proportionately until reaching the maximum which is established at twelve lanes.

26.- Lane angle of entry.

This is a very important variable when designing a roundabout as whether or not vehicle entrances and exits are completed more or less comfortably depends on this value. The greater the angle, the more comfortable the turn is. Likewise, a wide radius curve on a road is more comfortable for drivers than one with a small radius.

Besides influencing the driving comfort, it also directly influences the speed because if the angle is really comfortable, it incites drivers to enter the roundabout at a higher speed which poses a significant increase in the risk.

Given that the angles of entry of the different slip roads can be different in a single roundabout, the arithmetical average of all of them is calculated to obtain a mean entry angle. We have assumed an ideal angle of 25^g (grads, not degrees, which in this case would be the equivalent to one-fourth of a straight angle) as well as a few intervals when rating this characteristic. The intervals are:

- Less than 20^{g}: The risk is maximum.
- From 20^{g} to 25^{g}: The risk value is interpolated linearly between the maximum and minimum.
- 25^{g}: The ideal value, zero risk.
- From 25^{g} to 30^{g}: The value is again interpolated linearly between the minimum and maximum risk.
- Over 30^{g}: Maximum risk.

The risk index added by this characteristic to a roundabout can be 2% of the total.

27.- Raise.

The raise of a roundabout (the cross-section) influences the path of the vehicles. When turning around the central islet, the raise is most likely centripetal meaning the slope descends towards the inside. Thus, the centripetal force generated on the vehicle helps maintain the vehicle on its path.

Given that the vehicle speed is low in many urban roundabouts, the raise factor has little influence on safety given that the force generated is quite small meaning it is common to design them with a centrifugal raise rather than a centripetal one. The most common reason is that when designing the rainwater drainage system it is often preferable to collect the rainwater on the outside of the roundabout because if there were any problems, the water collected affects the traffic less despite slightly worsening user safety.

The best solution on a design level is a mixed raise where two-thirds of the roundabout features a centripetal cross-slope (to help vehicles turn) and the remaining one-third (the most external area of the roundabout) is centrifugal to help the cars leave.

The decision was made to rate a mixed type cross-slope and centripetal type the same and positively, assigning them a minimal risk whereas a centrifugal slope is considered to pose a risk due to possible diversions from the vehicle path. This section accounts for 1% of the risk index.

28.- Longitudinal slope of the ground.

The longitudinal slope directly influences users' driving speed, especially for cyclists and heavy vehicles, the speed and reaction capacity of which are drastically reduced if there are steep ramps. Light vehicles, however, do not suffer such a decrease in speed meaning very dangerous situations are produced when a light vehicle travels at a much higher speed than the speed of a bicycle.

It must also not be forgotten that when the slope is favourable, all vehicles tend to increase their speed which also adds a palpable risk if emergency braking is required.

The risk index added by the existence of ramps/slopes has been assessed as 1% of the total. When entering the data in the corresponding box in the table, if the longitudinal slope is equal to or higher than 3%, the risk is considered maximum; if the longitudinal slope is zero, the risk is 0%. It is linearly interpolated for intermediate situations.

29.- Inner hard shoulder.

The existence of an inner hard shoulder makes driving safer as it offers vehicles an over-width in emergency situations which must be evaluated. It is often scarce and rarely used meaning it has been assessed as adding 0.5% to the total risk index of a roundabout.

The following criteria were used when assessing this concept:

- A hard shoulder equal to or greater than 0.50 m: zero risk index

- A hard shoulder between 0.50 and 0 m: a proportional risk index of between 0.5% and 0%

- No inner hard shoulder: a risk index of 0.5%

30.- Outer hard shoulder.

This is the same as the point above, yet more highly valued as it provides greater safety. This is the area that is often used to stop a vehicle for emergency reasons meaning the measurements are usually larger. It provides such safety that the decision was made to add 2.50% to the total risk index of a roundabout if it doesn't exit, and to lower it to 0% if the measurements are equal to or higher than 1.00 m. For intermediate cases, the risk index is obtained proportionally between these two values.

31.- Existence of pavements.

Pedestrian pavements are habitual at roundabouts within city limits and are many times associated with traffic light regulation. They are considered to help reduce the risk in the case of inter-city roundabouts as it is common to see pedestrians walking along certain roads. In these cases, pedestrians often produce risk situations when arriving at roundabouts if there are no pavements.

It is also rated positively as when it comes to cyclists, it may be preferable that they travel along pedestrian areas if possible before sharing space with vehicles despite the fact that this situation can also generate risk situations between cyclists and pedestrians.

A roundabout without pavement is considered to increase the risk index by 0.5%. There may be cases where there is only pavement between some slip roads and not between others meaning the data entered into the table must be a percentage of the outside perimeter with pavement with respect to the full perimeter. If the percentage is one hundred (the entire perimeter features pedestrian pavement), the risk is zero. If there is no pavement, the risk is 0.5% as stated and intermediate situations are obtained proportionally.

32.- Visibility.

This is an important factor that depends on many different factors. Visibility can be influenced by the existence of very voluminous elements inside the central islet that hide the opposite area of the roundabout, there can be ground level changes, signing panels in the medians that hinder visibility, etc. Given its importance, it has been assigned a maximum addition of 4% to the total risk index of the intersection in the worst case scenario and it may drop to zero if visibility is adequate. Given the number of factors that can have an influence, a subjective value of between 0 and 5 can be entered where zero means visibility is very low and five means adequate visibility.

33.- Artificial lighting.

This largely influences safety when travelling at night. It is assigned 1% of the total risk index and there may be three different levels. A value of "0" is entered if there is none (1% contribution), "1" if it exists but is insufficient or in a poor state (contributes 0.50% to the risk) and "2" if the lighting is considered to be adequate (0% contribution).

34.- Surface drainage.

This consists of the evacuation of rainwater as quickly as possible. This may be achieved with gutters and drainage systems or directly by surface runoff. Both situations have a negative influence on safety if it is not adequate due to the possibility of the formation of puddles and the resulting risk of hydroplaning. It contributes 0.5% to the total risk index and is assesses as adequate (0%) or inadequate (0.5%).

35.- Protective elements against irregularities.

This section assesses the existence of fences, guardrails or any other method that protects users from possible falls from another level. They provide safety and trust.

This contributes 0.25% of the total risk index as the existence or lack of protective elements may be entered into the table.

36.- Existence of manholes covers.

The existence of manhole covers for different city utilities is very frequent in the paved surfaces of intersections. This poses an added risk especially for two-wheeled vehicles because they cause sliding when wet. This has also been rated with 0.25% of the total risk index of an intersection when the existence or lack of manhole covers is indicated in the table.

37.- Bike lanes.

We believed it was appropriate to leave this element for last as their presence greatly eliminates the risks assessed above.

It must be remembered that this instrument designed is aimed at quantitatively assessing the risk index of a roundabout type of intersection in general but placing certain emphasis on the risks that particularly affect cyclists who travel through them. It is obvious that the possible danger of being hit by a car is completely different for a cyclist when travelling on the road and sharing the same space as the rest of the vehicles which are faster and larger or, on the contrary, when travelling on perimeter pavements or even in a segregated and specific bike lane.

In this case, there are several factors that no longer contribute to the risk index for cyclists although it is important to note that they do continue affecting the rest of the vehicles. This means if the tool is applied to calculate the general risk index of a roundabout type of intersection, a “1” must be entered in the corresponding box. However, if you want to know how the risk index decreases specifically for cyclists when there is a segregated cycling lane for their exclusive use, a “2” or “3” must be entered depending on whether the bike lane runs through the inside or outside of the roundabout.

The different possibilities and how each one of them affects the total risk index of an intersection are outlined below:

1.- There is no specific bike lane; cyclists share space with the rest of the users: In this case, the already calculated risk index increased by 5% when you enter a “1” in the corresponding box.

2.- There is a bike lane that is segregated from the rest of the modes of transport along the outside of the roundabout: When you enter a “2” in the box for this purpose, the increase in the risk index for some of the factors explained above is automatically deleted. In particular, those numbered 1, 2, 3, 4, 5, 6, 8, 10, 17, 21, 22, 23, 24, 26, 28, 29, 30, 31, 34, 35, 36 and 37. This happens because, for example, in section number 8 (Compliance with the speed limit in the roundabout), if the limit is not observed there is no added risk for cyclists travelling on the outside of the roundabout independently from all of the other vehicles.

3.- There is a bike lane that is segregated from the rest of the modes of transport along the inside of the roundabout: When you enter a “3” in the box for this purpose, the increase in the risk index for some of the factors explained above is automatically deleted. In particular, those numbered 2, 3, 4, 5, 6, 7, 8, 9, 14, 16, 17, 18, 19, 20, 23, 24, 26, 27, 28, 29, 30, 31 and 37. For example, factor number 14 (Traffic lights in the roundabout and at entrances) no longer influences the risk index for cyclists given that they travel along the inside of the intersection without being affected by the other vehicles.

5.- PRACTICAL APPLICATION.

As mentioned in point 2 of this study, a risk index study was conducted at three roundabout type intersections in the municipal district of Murcia in order to test the tool created and be able to assess different theoretical alternatives designed to reduce the risk of said intersections.

INTERSECTION ROUNDABOUT AVENIDA JUAN CARLOS I - NORTHERN ENTRANCE TO THE ESPINARDO UNIVERSITY CAMPUS

1.- Current situation.

The first intersection chosen was the intersection between avenida Juan Carlos I and the northern entrance to the Espinardo University Campus. It is a heavily-transited intersection as it is one of the main entrances into the city of Murcia from the north and it also converges with the main entrance to the University campus which contributes very heavy traffic.

It consists of a roundabout with three large-diameter driving lanes with a large traffic absorption capacity, rather moderate longitudinal slopes, good visibility and ample entry and exit radiuses, all in consonance with its inter-city nature. The only defects are the non-existence of pavements and a bike lane, especially the latter as rather abundant cycling traffic was observed after the study conducted (mainly because of its proximity to the University and some nearby housing developments that generate heavier cycling traffic than would otherwise be expected).

Given its inter-city nature and the distribution of the traffic flows, it works without the need for any traffic lights and the state of conservation is very good both as far as the road surface as well as all of the existing vertical and horizontal signing.

Upon analysing the intersection from the perspective of the safety of a cyclist transiting through it, we find some disadvantages since there is no segregated bike lane and therefore, cyclists share the space with all of the other vehicles. The speed of the vehicles was noticed to be higher than the speed permitted, in many cases mainly due to the ample geometrical characteristics. While improving the fluidity of the surrounding traffic and the comfort of the motor vehicles, this situation poses a serious decrease in cyclist safety.

The tool designed was applied to the current reality of the intersection in order to analyse the real risk situation posed by travelling through it with the following results:

2.- Alternative No. 1. The implementation of specific traffic lights for cyclists and a segregated bike lane:

The first option studied was to separate cyclists from all of the other vehicles. In this case, it is relatively simple since the roundabout is very large and has paving stone ring on the inside which would allow cyclists to transit through it and largely avoid the current risks of travelling through the roundabout.

The difficulty found in this alternative is that the cyclists would have to be safely taken through the three driving lanes to the central ring which is completely infeasible without acting on the surrounding traffic. For this reason, some traffic light crosses were designed to stop the traffic in the roundabout punctually to allow cyclists to cross to the inside risk-free. The proposed traffic lights were designed with demand-actuated push buttons meaning cyclists must stop before entering the roundabout, push a button and wait a few seconds until the vehicle traffic light turns red to cross safely. Once inside the inner ring, the traffic returns to normal and when the cyclist reaches the crossing he/she wishes to take, he/she must push another button to re-activate the traffic light process to leave the roundabout.

This option is very appropriate from a cyclist safety perspective, but it is worth indicating that it would create very significant disturbances for the surrounding traffic and, as indicated above, it is one of the main entrance roads into the north of the city of Murcia. Despite being an "on-demand" system; in other words, it is only activated when a cyclist activates the button, an intermittent yet continuous flow of cyclists would end up generating significant disturbances for the traffic. Thus, a solution that is appropriate for cyclists is not always the ideal solution as it is equally important to analyse what happens with the rest of the modes of transport the solution would affect.

In any case, this possibility was studied. The traffic lights indicated are shown on a drawing and the budget and resulting risk index for cyclists are indicated.

3.- Alternative No. 2. Implementation of specific warning lights:

The second alternative studied consists of introducing lighted signs specifically designed to warn drivers of the presence of cyclists in the roundabout so they can take extra precautions.

Any additional signing used to warn vehicles is suitable because, as was indicated above, in general they are very vulnerable elements which also travel at low speeds in comparison with the rest of the users. The risk of increasing signing is that even though it may be very effective in the beginning, it gets wearisome for drivers meaning the signing eventually becomes ineffective.

The proposal studied consists of high visibility lighted signing distributed at different points in the intersection so all vehicles will notice it; however, it has been designed on demand. When a cyclist enters the intersection, he/she can activate a push button that connects the circuit so the light signals go into operation and automatically turn off after a certain amount of time so as to warn drivers travelling at that very time alongside the cyclist.

The big advantage is that it may be the case that a driver who uses the intersection daily may only coincide every so often with a cyclist and, therefore, with the lighted signing activated which prevents the user weariness produced by fixed and immutable signing.

The risk index spreadsheet for the roundabout under this alternative is shown below as well as the approximate cost of its implementation.

4.- Alternative No. 3. Implementation of traditional horizontal and vertical lighted signing:

This basically consists of a marked insistence on the horizontal and vertical signing at the intersection. As indicated above, the signing seems to be very adequate for motor vehicle traffic, but it’s true that the excellent design geometrics and large diameter of the intersection produce a certain tendency to exceed the speed permitted. The signing proposed insists on observing the speed limit.

As far as the vertical signing, the proposal is to include signs limiting the speed to 30 km/h featuring LEDs to increase the effectiveness as well as replace the existing roundabout warning signs for others that are also lighted up by LEDs. It has been considered appropriate to include information signing prior to the intersection at all entrance slip roads informing users that they are approaching a roundabout habitually used by cyclists.

With respect to the horizontal signing, the proposal is to situate sequential cascaded lights on the inner edge of the roundabout as well as install reflectors on the outer hard shoulder to make it more visible at night. Rumble strips were also installed at the entrances.

The results of the spreadsheet are shown below as well as the approximate financial cost of implementing this alternative.

5.- CONCLUSIONS:

In summary, the decrease in the risk index of the roundabout in comparison with the original risk index as well as the cost are indicated below for each one of the three alternatives studied. We have also included an assessment of the effect on the surrounding traffic for each one of the options because, as already indicated, this is an essential factor when deciding upon on option or another.

INTERSECTION ROUNDABOUT AV. JUAN CARLOS I - NORTH ENTRANCE TO THE UNIVERSITY CAMPUS

	% Decrease in risk index	Financial cost of implementation	Effect on traffic and other users
Alternative No. 1	64.65 %	€89,663.27	Very high
Alternative No. 2	21.5 %	€71,012.69	Unnoticeable
Alternative No. 3	17.59 %	€41,304.68	Unnoticeable

In view of these results, we would propose the second and third options as the most appropriate, rejecting the first due to the high cost and excessive effect on the surrounding traffic of traffic lights despite operating on demand.

Even though the financial cost is higher, we would choose alternative no. 2 because in our opinion, it is an original action, is only activated on demand, does not alter the traffic (a fundamental conditioning factor at this intersection) and is very interesting. We believe it can capture drivers' attention which, in the end, is the objective sought with increasing cyclist safety.

INTERSECTION ROUNDABOUT HOUSING DEVELOPMENT ROAD - NUEVA CONDOMINA ENTRANCE

1.- Current situation.

This roundabout is radically different from the previous one with very different geometric and design parameters.

It is the intersection of the old entrance road into the housing developments Altorreal and La Alcayna with a recent junction over dual carriageway A-30 towards the business area known as Nueva Condomina and the new football stadium.

Given that the two housing developments are obviously residential, the habitual traffic is found in the early morning, at midday and late in the evening, coinciding with the times when people go in to and get off work. Notwithstanding, there is a large increase at the weekends given the very high attraction of the shopping centre with very elevated peak times if the are football matches.

As far as the geometric characteristics, the diameter is small, there are two driving lanes, three entry/exit slip roads, no traffic lights and a rather elevated longitudinal slope. The artificial lighting, signing, cleanliness and maintenance are considered to be adequate.

From a cyclist’s perspective, there is no segregated bike lane or specific signing. It happens that there is a large number of cycling groups in the two housing developments the road gives access to which produces high bicycle traffic through the intersection either in groups or individually.

If all of these characteristics were analysed separately, there probably wouldn’t be a very high risk to cyclists; but if the occasionally high traffic on the road is added to the large number of cyclists as well as the added danger of the high slope, the situation is completely different.

The calculation tool is applied below to ascertain the hazard index obtained for this intersection.

2.- Alternative No. 1. The implementation of specific traffic lights for cyclists and a segregated bike lane:

As indicated above, one of the essential characteristics of this intersection is the high longitudinal slope. This causes two different effects such as, firstly, the high speed at which the vehicles enter the roundabout from the north (from the housing development) and, secondly, the abnormally low speed of the cyclists when they enter the intersection from the south (Murcia city centre). The combination of the high speed of the entering vehicles and the very low speed of the cyclists moving through it is very dangerous and leads us to think that the first alternative would once again be segregating the cyclists from the rest of the surrounding traffic.

There is no land outside the roundabout to achieve this separation since it is not an urban area meaning we must resort to the inside. For this reason, we propose traffic light just like the ones above, equipped with cyclist-activated buttons which, once activated, will stop all traffic in the roundabout just enough time for the cyclist to cross safety towards the inner ring.

In this case, there is no paved inner perimeter ring as was the case with the previous roundabout meaning it must be built which would increase the cost of execution.

Once again, we achieve a very safe alternative for cyclists, but at the cost of producing serious disturbances in the daily traffic at the intersection. Therefore, it is necessary to decide whether priority should be given to cyclist traffic or vehicle traffic considering the serious circulation problems that would occur on intense traffic days (weekends, football matches, etc.).

What follows is a drawing of the alternative described as well as the results of the hazard index calculation tool and the cost of execution.

3.- Alternative No. 2. Implementation of specific warning lights:

The second alternative studied is also identical to the one used in the previous case. The idea is to add specific lighted signing to warn the rest of the vehicles of the presence of vulnerable elements (cyclists) inside the intersection so they can take extra precautions and be more aware than normal in view of any possible unforeseen circumstance.

We also believe that dynamic lighted signing, which is activated exclusively on demand, is much more effective than static signing always present whether or not there are any cyclists which undoubtedly brings down drivers' alertness.

As explained above, the proposal studied consists of high visibility lighted signing distributed at different points in the intersection so all vehicles will notice it; however, it has been designed on demand. When a cyclist enters the intersection, he/she can activate a push button that connects the circuit so the light signals go into operation and automatically turn off after a certain amount of time so as to warn drivers travelling alongside the cyclist.

The risk index spreadsheet for the roundabout under this alternative is shown below as well as the approximate cost of its execution and a descriptive drawing of the alternative.

4.- Alternative No. 3. Implementation of traditional horizontal and vertical lighted signing:

Again, we propose the same alternative as in the case above. This similarity in options chosen is not a coincidence as despite the enormous design and traffic differences, both roundabouts feature the same risks for cyclists which are a longitudinal slope that provokes abnormally low speeds for cyclists, on the one hand, and, on the other hand, excessive speed by vehicles entering the intersection due to the existing slope (in the case above, the excess speeds were produced inside the roundabout given the geometric characteristics as well as at the entrances).

In view of this problem, the only thing we can try to do is insist on the road signing so drivers moderate their speed or, in the extreme case of a very high number of accidents, security cameras could even be installed to achieve the desired effect.

Again, elements similar to the ones above have been chosen both as far as the vertical and horizontal signing. We basically refer to rumble strips at the entrances, cascaded lights in the inner ring, reflectors on the hard shoulder, the use of LEDs on the traditional vertical signing and pre-warning signs informing drivers of the habitual presence of cyclists in the intersection and limiting the maximum speed permitted to 30 km/h.

A descriptive drawing of the proposed alternative, the results of the spreadsheet as well as the approximate financial cost of implementing this alternative are shown below.

5.- CONCLUSIONS:

In summary, the decrease in the risk index of the roundabout in comparison with the original risk index as well as the cost are indicated below for each one of the three alternatives studied. We have also included an assessment of the effect on the surrounding traffic for each one of the options because, as already indicated, this is an essential factor when deciding upon on option or another.

INTERSECTION ROUNDABOUT HOUSING DEVELOPMENT ROAD - NUEVA CONDOMINA ENTRANCE

	% Decrease in risk index	Financial cost of implementation	Effect on traffic and other users
Alternative No. 1	58.41 %	€68,018.09	Very high
Alternative No. 2	12.00 %	€40,531.76	Unnoticeable
Alternative No. 3	14.42 %	€29,521.31	Unnoticeable

In view of these data, **we have chosen alternative three**. The cost is the least of all of them, but we believe it is important to keep in mind the high longitudinal slope factor.

If we were to propose the second alternative (lighted signing activated by push buttons), the cyclists have to stop before entering the roundabout, activate the push button and start back up. Due to the existing slope, this re-start would be excessively slow and we might add a risk in the attempt to eliminate another so this factor makes us choose the third alternative and propose intensified lighted signing.

Alternative one is rejectable given the high costs and excessive effect at times with the most intense traffic.

INTERSECTION ROUNDABOUT AVENIDA RONDA SUR - AVENIDA DE LOS DOLORES

1.- Current situation.

It is a large roundabout, situated in the intersection of two of the main avenues in the urban area which are avenida Ronda Sur and avenida de Los Dolores. One of the entry slip roads (from Ronda Sur) creates a rather high slope which means many vehicles enter at an excessive speed. The other entry slip roads from Ronda Sur and avenida de Los Dolores feature a normal longitudinal slope although the number of lanes and turning radiuses at the entrances also generate confidence in drivers which can likewise cause excess speeds at the entrances.

It is a completely urban intersection with the resulting characteristics of the existence of pavements, traffic lights, pedestrian crossings and very intense traffic throughout the entire day with occasional much more intense peak hours. There are five driving lanes and five entry slip roads, some of them very close together. The roundabout features an adequate longitudinal and cross-slope and very good visibility. The state of conservation and maintenance is also adequate as well as the signing.

The confluence of important roads is such that there are no predominant movements; they are all constantly used at the same time. This situation generates a large number of inner crossings to such extent that channelling was created inside the roundabout to separate some movements from others.

There are some disadvantages from a cyclist safety perspective which are basically the excess speed mentioned above (when a vehicle enters the roundabout when the light is green) and the constant vehicle movements on the inside. There is also another circumstance due to slip roads that are very close together. The traffic lights occasionally produce an accumulation of vehicles stopped on the inside waiting for the green traffic light that affects all of the other movements.

It is possible for cyclists to cross safety in any direction because of the traffic lights and there are also pedestrian crossings on all of the slip roads, but this does not prevent the constant and equally dangerous interferences which would best be avoided.

The tool designed was applied to the current reality of the intersection in order to analyse the real risk situation posed by travelling through it with the following results:

2.- Alternative No. 1. Construction of a segregated bike lane:

The first option studied was to separate cyclists from all of the other vehicles, just as in the rest of the cases. Despite having space inside the central ring to create a perimeter bike lane, this is not considered appropriate given the added difficulty for the traffic if cyclists were to cross to the inside.

In this case, since it is an urban area there is enough space on the outer perimeter to include a bike lane, but there is not enough space for it to be segregated (where it does not interfere with either vehicles or pedestrians). Even still, it is considered an acceptable option given the characteristics of the roundabout which would improve the existing situation as analysed.

The bike lane proposed partly runs over pavements and partly over landscaped areas next to the intersection. It also includes a small stretch of bike lane segregated by the current hard shoulder of the roundabout which would be separated from traffic with adequate protective elements (bollards, humps, etc.).

The layout is quite irregular and rather inconvenient for cyclists, but it is also very safe and does not affect the traffic at all as the cyclist crossings coincide with the pedestrian crossing periods.

The alternative studied is shown on the drawing below as well as the approximate budget and the risk index for cyclists if it were implemented.

3.- Alternative No. 2. Complete intersection remodelling:

This is a very complicated option and would involve a very high financial cost. It is proposed anyway even in the knowledge that the final result does make any improvement over the above option from a cyclist safety perspective but it is a good example of an action that would singularly improve the safety of cyclists and the surrounding vehicles which is a situation that could occur in many other intersections that may have to be analysed.

In general, the existing inner separation is eliminated which provides for a total of five lanes. The triangular islets at the entrances have been remodelled to free up more space and some pedestrian pavements have been modified. Enough space is obtained with all of these actions to build a segregated bike lane along the hard shoulder for the entire roundabout perimeter; but as can be seen in the drawings attached, the layout is very similar and the slip road crossings are in the same location as the pedestrian crossings as before which is why the risk index is identical.

The risk index spreadsheet for the roundabout under this alternative is shown below as well as the approximate cost of its implementation.

4.- Alternative No. 3. Implementation of traditional horizontal and vertical lighted signing:

Given that once again one of the fundamental safety problems is the excessive speed at which some vehicles enter the intersection when the lights are green, it seems appropriate once again to insist on signing and reduce the maximum permitted speed.

We use lighted signing because we believe it will have a more intense effect on users since it is novelty so once again we propose similar measures as above in relation to the vertical signing: Speed limits of 30 km/h implemented with LEDs to increase the effectiveness as well as the replacement of the existing roundabout warning signs for others that are also lighted up by LEDs. It has been considered appropriate to include information signing prior to the intersection at all entrance slip roads informing users that they are approaching a roundabout habitually used by cyclists.

With respect to the horizontal signing, the proposal is to situate sequential cascaded lights on the inner edge of the roundabout as well as install reflectors on the outer hard shoulder to make it more visible at night. Speed humps were also installed at the entrances where excessive speeds may occur which are the abovementioned avenida Ronda Sur and the avenida de los Dolores.

A descriptive drawing of the alternative studied, the results of the spreadsheet as well as the approximate financial cost of implementing this alternative are shown below.

5.- CONCLUSIONS:

In summary, the decrease in the risk index of the roundabout in comparison with the original risk index as well as the cost are indicated below for each one of the three alternatives studied. We have also included an assessment of the effect on the surrounding traffic for each one of the options because, as already indicated, this is an essential factor when deciding upon on option or another.

INTERSECTION ROUNDABOUT AV. RONDA SUR – AVENIDA DE LOS DOLORES

	% Decrease in risk index	Financial cost of implementation	Effect on traffic and other users
Alternative No. 1	33.38 %	€18,487.30	Moderate
Alternative No. 2	33.38 %	€139,903.55	Low
Alternative No. 3	10.58 %	€30,616.76	Unnoticeable

In this case, it seems clear that the most desirable solution is the second alternative which separates the bicycles from the surrounding traffic and from pedestrians, but the implementation involves a very high cost.

The third alternative is also quite recommendable, improves road safety as a whole and has a moderate cost, but it does not decrease the risk index for cyclists much.

Therefore, we propose the first alternative for this intersection due to the risk index - cost ratio as it also separates cyclists from the surrounding traffic which seems to be the most recommendable for this intersection without a doubt.

6.- FINAL CONCLUSIONS:

We believe it is appropriate to provide some conclusions after having completed this study.

First of all, we believe the tool designed is versatile enough that it can be used at roundabout intersections of very different types. It is important to note that **the risk indices** assigned to each one of the concepts are subjective and have been chosen by the author of this study meaning they **are completely disputable**. Given the format chosen for the spreadsheet design (.xls), it is very easy to modify and adapt to any need. Each index is a percentage meaning the ones deemed appropriate just need to be increased all while decreasing the others so the sum continues to be 100%. Thus, we believe it is best for each user to revise the percentages and be able to adjust them to their own understanding of the risks studied. The same is true for the concepts themselves. The list of **thirty-seven risk factors** at an intersection is completely **open to dispute**. New ones may be added or some of the existing ones may be eliminated meaning the tool is easily modifiable and therefore, we also recommend a critical analysis of the concepts to make any modifications deemed appropriate for the user.

Furthermore, this study shows several alternatives for the current situation of each one of the three intersections studied. Said alternatives are some of the possibilities, but not the only possibilities. Other possibilities may be studied such as creating overpasses in problematic situations, segregating bike lanes on the outside or on the inside of roundabouts, reserving inner lanes of the roundabout for the exclusive use of bicycles, searching for alternative itineraries, colouring specific lanes for cyclists, channelling the cyclist layouts with lighted signals (LEDs) built into the paved surface, the possibility of changing the push buttons proposed for automatically-activated lighted devices with localisers on the bicycles (GPS) or a combination of all of these.

Finally, the budgets shown are approximate. If any of the alternatives contained in this studied are proposed, it would be best to create a detailed budget for the alternative prior to any decision making.

Murcia, 27 September 2012