

Road Safety for Cyclists in London

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Aim

The aim of this project is to use imagery to estimate safety on the roads of London, from a cyclist's perspective. After a brief introduction to the most important road safety indicators, I compiled an ordered list with several risk factors. The next step will be to determine the most appropriate pre-trained models to capture them in the images already available on the Imperial servers.

Cycling Benefits

Cycling comprehends multiple benefits to society. They can be categorized in 5 main domains: Safety, Economy, Environment, Equity and Health [1].

The main cause of death in the USA in youngsters was traffic accidents. Accounting for 41% of the total number of deaths in the age group 15 to 24 [CDC]. In the European Union, in the past 10 years, deaths among cyclists remained constant, while for car drivers and passengers had decreased 24%. Among pedestrians fell by 19% (Figure 1). UK was one of the only 3 EU nations which fatality rate among pedestrians increased, 1.3% a year. On average, it fell 2.6% in EU per year. For cyclists, in the UK, the number of fatalities decreased 1.3%, with the 13th-best average annual drop. Given that 99% of the pedestrians killed were struck by motor vehicles and 1% by bikes, it is evident the necessity of promoting cyclists' safety and increase their number in the streets. In parallel, this promotes *safety in numbers*: cyclists are safer if their number increases. The awareness drivers develop by contacting more frequently with cyclists is one of the main causes.

Many economic benefits for individuals, companies and communities are known from promoting walking and cycling as alternative ways of transportation (Figure 2). According to 2015 Urban Mobility Scorecard, the cost of congestion for the US in 2014 was 160 billion dollars. For an individual was estimated to be 960 dollars each year. These values account for time and fuel expenses. While the cost of having a car in the USA in 2018 was calculated to be 8849 dollars, for a bike was 308 dollars and walking was considered free. 2018 Benchmarking Report adds that bike tourism has a positive economic impact in multiple regions worldwide. Protected Bike Lanes Mean Business Report shows the positive impact cycling may have in business. It was found that workers doing their commutes cycling, on average, spent more time and travelled more often to their companies, then car drivers. Moreover, in a 2011 study, the Political Economy Research Institute found that 11.41 jobs were on average created when investing 1 million pounds in bicycle-only projects, comparing to 7.75 jobs while investing the same amount in road-only projects.

Reducing the dependency on non-renewable sources, it is also one of the positive aspects of cycling. It was estimated by the United States Environmental Protection Agency that the transportation sector was responsible by the largest share of greenhouse gas emissions – 28% (in the USA). From those, passenger vehicles and light-duty trucks account for most of the overall transport sector – 60%. Moreover, it is also known that structures such as roads and parking lots increase significantly the probability of urban flooding, stormwater runoff and urban heat island effect (due to the lack of shadows and exposed land in the cities, they often register higher temperatures than the surroundings, resultant from the low levels of air humidity). Promoting cycling will reduce the need of the previous infrastructures and mitigate some of the consequences.

Promoting cycling among the population of a country promotes equity. Due to the high cost of car ownership, when a city prioritizes road infrastructure for these vehicles, it puts in higher risk low-income families that cannot afford it. This is particularly important in low-income communities where a brief from Bridging the Gap estimated that only 50% of the roads have sidewalks, comparing to 90% in high-income

homologous. This results in higher threat for pedestrians and cyclists. The New Majority: Pedalling Towards Equity reported that 26% of people of colour would like to cycle but do not do it due to safety concerns, comparing to 19% in white respondents.

Physical activity, such as cycling and walking, has numerous benefits to physical and mental health (Figure 3). Centre for Disease Control and Prevention reported that 1 in 10 premature deaths, 1 in 8 breast cancers, 1 in 8 cases of colorectal cancer, 1 in 12 people suffering from diabetes and 1 in 15 cases of heart disease could be prevented if citizens became more active. It can also reduce the risk for coronary heart disease, stroke and many respiratory chronic diseases, which are intimately related to air quality. 2018 State of the Air report states over 133.9 million Americans live in counties with unhealthy levels of ozone and/or particle pollution. A factor that is highly influenced by the transportation patterns inside a community. Vehicles are one of the main contributors accordingly to the United States Environmental Protection Agency. Due to all these benefits, it becomes evident the importance of promoting a less sedentary lifestyle among the population.

For this reason, by promoting cyclists' safety, the whole society will benefit. Cyclists and pedestrians will be safer. Drivers will reduce their commute times and translate that into society gains such as lower levels of pollution and economic losses.



REDUCTION IN ROAD DEATHS SINCE 2010:

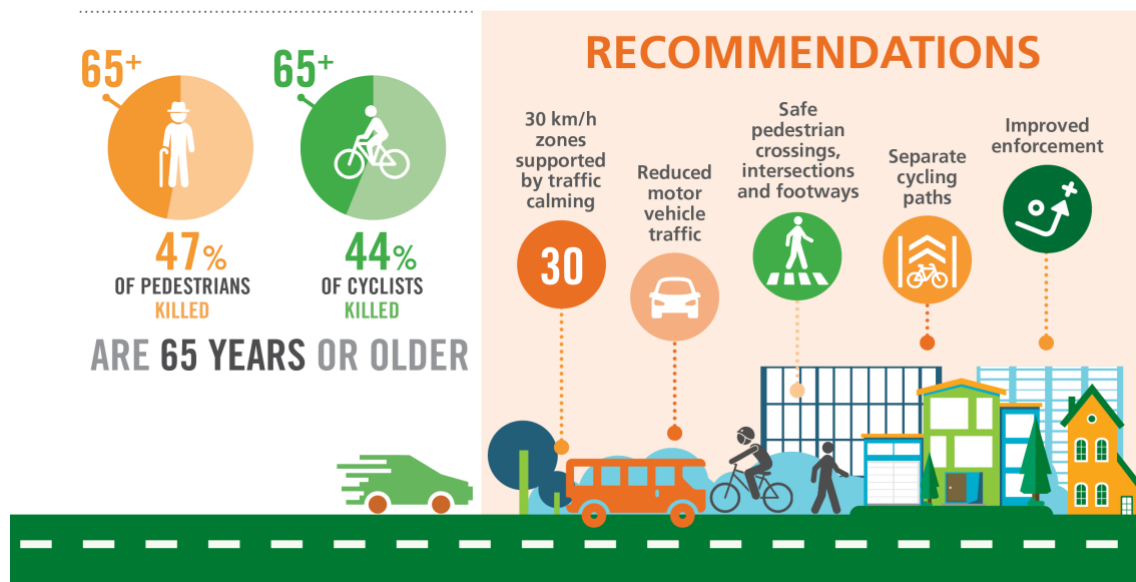
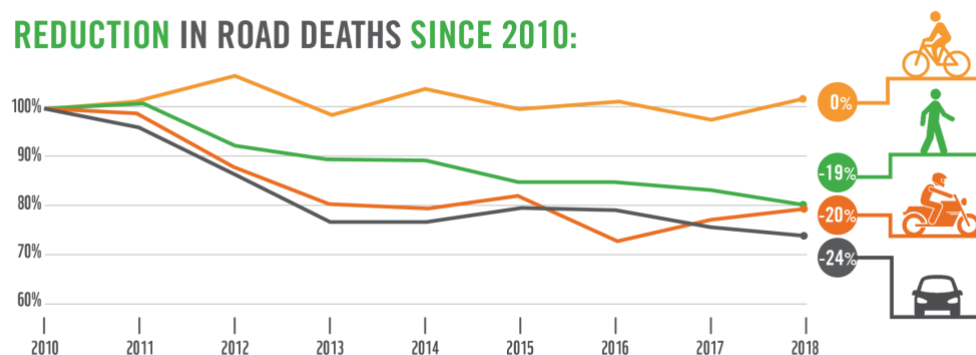


Figure 1 Road safety in EU countries. Accounting for the fact pedestrians and cyclists are the 2 most vulnerable elements on the roads (upper right corner), new safety measures should focus on them. [2]



Figure 2 Sedentarism increases the chance of developing chronic diseases (top). There is a high burden associated with the lack of physical activity (bottom). Adapted from [3].



Figure 3 Impact of physical activity in the risk of premature death (top). Benefits of maintaining an active lifestyle in different stages of life (middle). In a higher scale, communities also benefit from having physically active citizens (bottom). [3]

Road Safety Indicators

Road safety indicators are essential for policy making. According to the European Road Safety Charter, they allow us to assess the current situation of the roads, observe the impact on accident rates after an intervention, monitor its progress over time and predict further evolutions.

To be useful, road safety indicators should comply with several criteria:

1. Relate to some aspect of road safety, such as the causes or consequences of a road accident.
2. Be Measurable in a reliable way.
3. Be Monitorable over time.
4. Allow road safety engineers or public health experts to set targets.
5. Be Useful for establishing comparisons and benchmarking different safety performances.

There are 6 dimensions common to all indicators: geographical scope, time span, numerical format, representation/visualization, reliability, accuracy, representativeness and a specific “level” of road safety. The first encompasses where the measurement takes place: organisation, city, region, country, Europe or global. The second relates to the time frame comprehensive to the analysis: day, week, month, quarter, year, decade or longer. The units of the measure are represented by the third feature. They can be a proportion, a percentage or some other well-defined ratio. Representation described the way in which data is presented, e.g. in the form of a map, graph or table. Reliability, accuracy and representativeness are linked to the design and implementation of the measurement system. Finally, the “level” of the indicator differs on whether it considers one of the following: impact of the crashes, post-crash response, crash outcomes, crash causes and predictors, road safety policy and measures, or safety culture and safety systems. Crash outcomes, including indicators such as mortality, severely/slightly injured and accident rates, were the ones considered while selecting the risk factors presented in the next section.

Risk Factors

14 cyclist risk factors were identified on the roads of London. Table 1 lists them, along with an estimated score proportional to their suitability to be captured using image segmentation and object detection deep learning models. Google Street View images are used for the project. Different tiles were previously prepared to guarantee visual uniformity.

Risk Factor	Street View Imagery Suitability	References
Cycle Lane	★★★★★	[4] [5]
Street Light	★★★★★	[6]
Pedestrians (e.g.: children near schools)	★★★★★	[7]
Water Drainers	★	[7]
Tram/Train Rails	★	[8] [9]

Number Intersections	★★★	[7]
Intersections Visibility	★	[5]
Bends Visibility	★	[5]
Vehicle Speed	★★★★	[4] [7]
Parked Cars	★★★★★	[5] [8] [7]
Lorries and other Large Vehicles	★★★	[8] [7]
Road Width	★★★★	[8]
Pavement Quality (Pits, Trenches, Tree Root Encroachments)	★	[5] [7] [9]
Advanced Stop Line	★	[8] [7]

In an attempt to list and order the most relevant risk factors while cycling in London, I considered the accident, injury and fatality rates. In London, the fatality rate for cyclists is relatively low, consequently, priority was given to the other two more discriminative ones (accident and injury rates). This way, a comparable quantity was used to order all risk factors when designing Figure 4 diagram. Note there is also a strong qualitative and experience-based component inherent to the same rankings.

The top 3 most relevant factors identified to influence cyclists' safety were the presence of a cycle lane, road speed limits and road lane width. Next, statistical data that supports the rankings defined in Figure 4 will be provided. Note that only a small number of accidents involving cyclists are reported [10], consequently, the statistics presented in the next paragraphs may not totally reflect a real-life scenario.

Cycle Lane and Parked Cars

Cycle lanes can be physically separated or located on the road. Depending on the situation, one can be more beneficial than the other.

Physically separated lanes reduce the probability of crash when a car tries to overtake a cyclist or, in the case of fall, to be hit. One of the main causes of injury among cyclists are falls caused by bad pavement quality [5] [7] [9]. With no cars parked in the surroundings, these lanes reduce the risk of injury among cyclists by half. [11] For all these reasons, risks specifically associated to high road speed limits, narrow bicycle lane widths, road pavement quality and parked cars were not considered.

In the case of an on-road cycle lane, vehicular speeds tend to be lower and there are less interactions between these and the cyclists, when comparing to no lane. [12] Near intersections and in roundabouts, some studies suggest these lanes can be safer than physically separated ones. Although, the former can still perform better than the latter if built following specific criteria to make clearly visible the cyclists.

This makes the first scenario the safest, followed by on-road and no cycle lane.

The presence of a cycle lane was considered the most decisive factor by preventing many of the previously identified risks. It was considered the number one in the rankings of risk factors.

Vehicle Speed

Speed was found to be one of the major contributing factors in around 10% of all accidents and 30% of the fatal ones. Speed of vehicles involved in a crash is the single most important factor in determining the severity of injuries. [13]

There are 2 distinct factors when considering speed. Not only higher speeds are known to be responsible for an increased rate of accidents, injuries and deaths, but also large speed differences. Roads with high speed variance are more unpredictable, once they favour the number of encounters and an increased number of overtaking manoeuvres. Consequently, reducing speed limits sometimes may only result in the decrease of the vehicles' average speed and not its variance. [14]

In the core of the danger posed by vehicles' high speeds are the increase in the braking distance and kinetic energy that is transferred from the vehicle to the cyclist. Once both increase with the square of the velocity, the possibility of avoiding or surviving a crash decreases faster than linearly. [14]

In a biological perspective, it is known the human body can only resist the transference of a limited amount of kinetic energy in a crash. [15] This amount varies for different body parts, age groups and gender. Considering the best-designed car, if the vehicle exceeds 30 km/h, this limit can be exceeded. [16] Studies also show if a car travels at a speed lower than 30 km/h, the probability for a pedestrian to survive a crash is higher than 90%. When hit by a car at 45 km/h, the chance of surviving decreases to 50%. [17] Or, as the speed of a car rises from 30 km/h to 50 km/h, the probability of surviving a crash decreases by a factor of 8. [18] In the driver's perspective, the best-designed car provides protection until 70 km/h in frontal collisions where all passengers are wearing belts. [16] For side impacts, the maximum supported velocity is 50 km/h. [16]

In a road safety scope and based on a work done by Nilsson in Sweden, a change in the average speed of 1% for a 120 km/h road would imply a 2% increase in the accident numbers. At 50 km/h, this accident rate would increase instead 4%. In the United Kingdom, in urban roads, an increase of 1 km/h in speed was shown to raise the number the number of accidents by 1 to 4%, depending on the quality of the road. [14] This was considered the second most relevant factor. In the case of an on-road cycle lane next to a low-speed limit road, the risk factors related to parallel traffic were considered negligible, regardless of the width of the lane.

Lane Width

In the United Kingdom, recommended cycle lane width is 2 meters. Minimum required is 1.5 meters. All values below 1.5 m are considered too narrow, allowing little room to manoeuvre around obstacles, such as: debris, potholes and water drainers. It is frequently referred it is safer not having a bicycle lane, than one that is too narrow, once motorists tend to drive right up to the line and cyclists too close to the kerb.

After the road speed limits, cycle lane width was considered the following most important factor. Whenever it is considered wide, traffic risk factors were not considered. Regardless of the width of an on-road cycle lane, low-speed limits were enough to discard all traffic related risk factors.

Street Light

After the top 3, street light was considered the most relevant criterion in determining road safety. It is known to affect drivers and cyclists' reaction time and make cyclists unnoticeable particularly when not using any reflective or luminous gear. Moreover, in the cyclists' perspective, they are less aware of other road risks associated for example to the quality of the pavement. It is not expected to encounter many significantly under illuminated roads in London, consequently, it was placed in fourth place of the ranking.

Pavement Quality, Tram/Train Rails and Water Drainers

As frequently referred in the literature, pavement quality is a crucial factor to consider when evaluating safety. [5] [7] [9] Pavement quality refers to the quality of the road when there is no cycle lane or to the cycle lane itself, when it is present. Along with the presence of water drainers and trails, these were the following most important risk factors. This was placed under street light once with enough luminosity and circulating at a moderate velocity, it may not pose a significant threat.

Number Intersections and Intersections Visibility

The majority of bike and car crashes occur in intersections. In [19], the reported percentage was 60% over the total number of crashes. Additionally, as part of the same study, intersections where streets do not meet at right angles, posed an additional danger to cyclists. Crashes at these areas were 31% more likely to cause serious injury to the cyclist. The main reason is the decreased intersection visibility.

Lorries and other Large Vehicles

In the last years, economic development and consumer demand have been increasing, and so as the number of trucks in the cities. [20] [21] While cycling has following the same trend, the number of encounters among them has significantly increased. As an example, in New York City, 15% of bicycle networks overlap with 11% of truck networks. [22] The increased number of encounters has contributed to a higher accident and mortality rates involving trucks. Truck-bicycle accidents have usually more severe consequences than any other type of accidents. [23] [24] [25] [26] In some EU countries, 30% of all cycling fatalities are associated to trucks. [27] Studies in the past 2 decades have identified trucks as the most common vehicle category involved in cyclist deaths, in London. [24] [28] [29]

Advanced Stop Line

These lines present in several European countries such as Belgium, Denmark and United Kingdom, allow a head start to certain types of vehicles (namely, bicycles) when the traffic signal changes from red to green. This has several advantages. First, drivers behind the line can clearly realize the presence of cyclists around

them and take the right precautions to avoid danger manoeuvres. Second, it becomes safer for a cyclist to turn to the left avoiding a crash with the cars that are behind. In terms of statistical data on accident, injury and mortality rate, there is few available.

Bend Visibility

Several sources identify bends as a risk factor. Bends and intersections are often jointly considered as posing similar risks to the cyclist. Namely, low visibility in the cyclist's perspective, make several situations risky that usually are not (sudden appearance of pedestrians or intrusive vegetation). In the driver's perspective, it can be harder to notice cyclist's presence and, consequently, collide against them. [5]

Nevertheless, there is no clear statistical data showing how bends affect cyclists' accident, injury or fatality rates.

Pedestrians

Among all age-groups, pedestrian fatalities most often occur in children younger than 14 years old, when comparing with adults aged between 15 and 64 or 65 or more. In terms of gender, men are at a greater risk than women. [30] For these reasons, locations with higher concentration of people satisfying these criteria (e.g., school areas) are an additional risk. Nevertheless, in car-free zones, accidents between pedestrians and cyclists are extremely rare and almost never serious. [31] Thus, this was considered the least important of the risk factors.

General Overview

Generally, from the left to the right of the diagram the number of risk factors decreases. The most unsafe situation was considered to be no cycle lane. Secondly, high speed limits with a narrow lane in an on-road scenario. Thirdly, high-speed limits but with a wider lane. Fourthly, low-speed limits regardless of the presence of a narrow or wide on-road lane. Finally, a physically separated lane was considered the safest scenario. In red are highlighted the top 3 most relevant factors for each of the different scenarios.

Datasets

Two object detection and two image/semantic segmentation training datasets were compared in terms of their discriminative power to identify cyclist’s risk factors identified in Table __. Some were directly extracted from the Google Street View images of London, others were indirectly inferred. Features in Table _ with an asterisk are dynamic. Consequently, in the same location, they are expected to vary in number over time. Below, four state-of-the-art datasets are compared before choosing the most suitable pre-trained deep learning models.

	Object Detection		Image Segmentation	
Risk Factor	MS Coco	Open Images V6	Cityscapes	ADE20K
Cycle Lane	-	-	Sidewalk*	-
Streetlight	-	Streetlight*	-	Streetlight* Street Lamp*
Pedestrians (e.g.: children near schools)	People	Girl Man Person	Person	Person Individual Someone Somebody Mortal
Water Drainers	-	-	-	-
Tram/Train Rails	Train	Train	-	-
Number Intersections	-	-	Sidewalk* Road	Sidewalk* Pavement*
Intersections Visibility	-	-	Sidewalk* Road	Sidewalk* Pavement*
Bends Visibility	-	-	-	-
Vehicle Speed	Stop Sign* Traffic Light*	Stop Sign* Traffic Light* Traffic Sign*	Traffic Light* Traffic Sign*	Traffic Light* Traffic Signal* Stoplight*
Parked Cars	Car Parking Meter*	Car Taxi Vehicle	Parking*	Car Auto Automobile Machine Motorcar
Lorries and other Large Vehicles	Bus Train Truck	Bus Train Van	Bus Truck On Rails Caravan	Truck Motortruck Van
Road Width	-	-	Road*	Road* Route*
Pavement Quality (Pits, Trenches, Tree Root Encroachments)	-	-	-	-
Advanced Stop Line	-	-	-	-

As mentioned above, some risk factors can be captured directly, while others require an indirect approach. None of these datasets contains labelled cycle lanes. Although, Cityscapes is able to identify physically separated ones along with sidewalks, as part of the same category.

Open Images and ADE20K contain in their dataset the specific category of objects streetlight.

For the presence of pedestrians, all datasets contain various elements that let us infer about how crowded a given road might be.

None of the 4 datasets contain images with labels for features present on the ground. This include water drainers, rails, pavement quality or road lines (such as advanced stop line).

One way to indirectly capture tram rails would be to infer them by the presence of trams. Both MS Coco and Open Images datasets contain this element.

Number of intersections can be calculated by the number of interruptions in the sidewalk or the presence of perpendicular roads. Both situations can be captured using the image segmentation datasets.

Lack of visibility in intersections can be inferred by the presence of non 90 degrees road connections.

In terms of bend visibility, there are no clear elements in any of the 4 datasets that can be easily used to capture this.

Traffic calming signs are known to slowdown vehicle speed. Datasets contain labels to detect traffic lights, stop signs, stop lights and other traffic signs.

Parked cars to be detected looking for the presence of parking meters and parking areas delimited by the respective lines.

Lorries and large vehicles to be detected on the road. All datasets contain labels for these types of vehicles.

Finally, image segmentation will be used to calculate road width.

Microsoft Coco Dataset

Number of images:

Classes:

Cityscapes Dataset

Number of images:

Classes:

Pre-Trained Models

Two pre-trained models will be used to perform object detection and image segmentation in the street view images of London.

For the object detection, it will be used YOLOv4 pre-trained in the Coco dataset. This project uses static images to identify cyclist risk factors. In the future, this technique may allow us to use video sources instead and obtain more detail on the risk factor affecting cyclist's safety. This can be particularly relevant in the case of dynamic features like the ones included in Table _ with no asterisk.

Image segmentation will be performed using a pre-trained model with Cityscapes dataset. This method will not only allow to detect the presence of several objects in the images, but also to consider their sizes and shapes. Important factors to consider when trying to calculate road widths.

Risk Factors

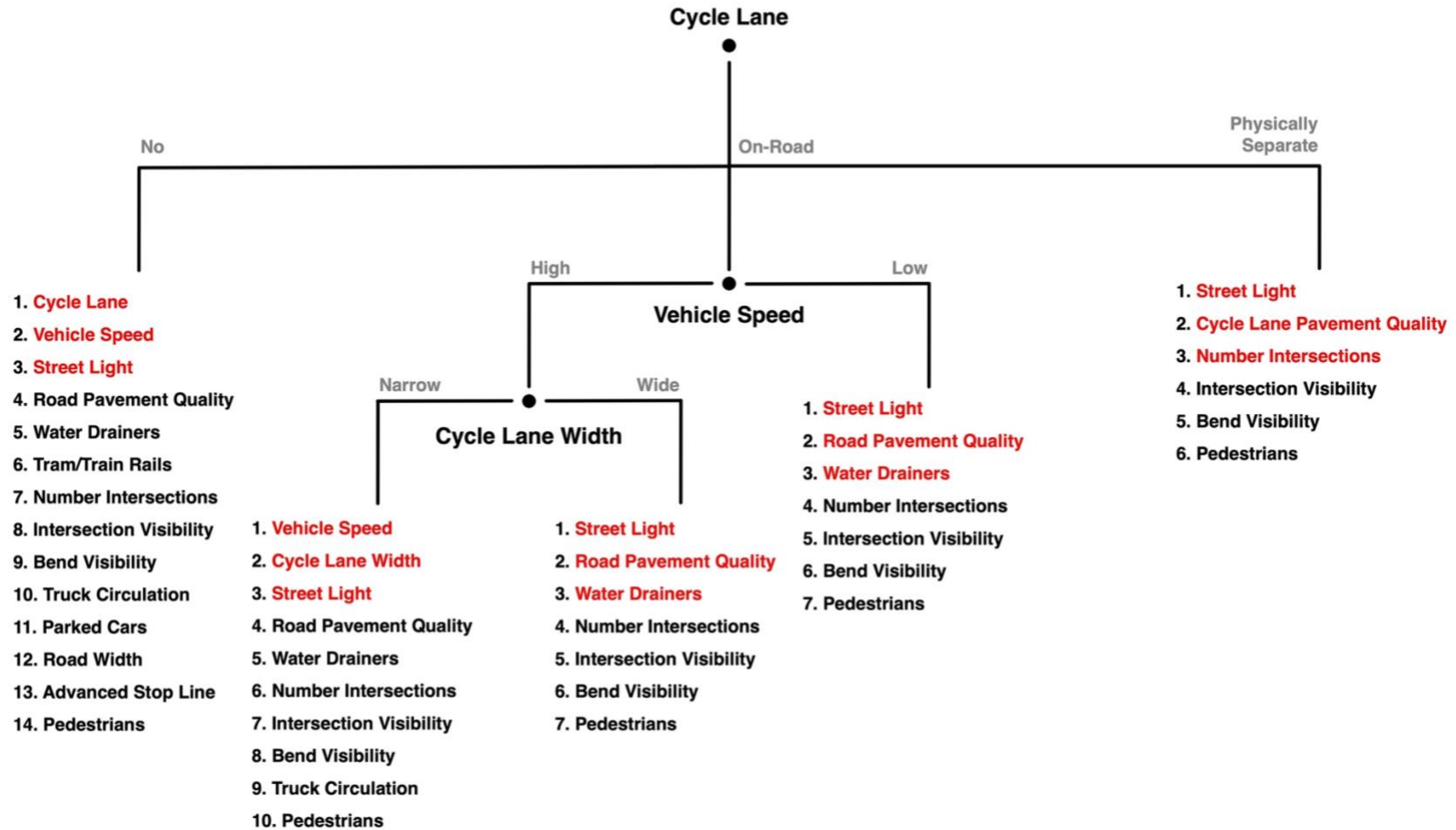


Figure 4 Identified cyclists' risk factors in 5 scenarios on the roads of London.

Top 3

Cycle Lane
Vehicle Speed
Cycle Lane Width

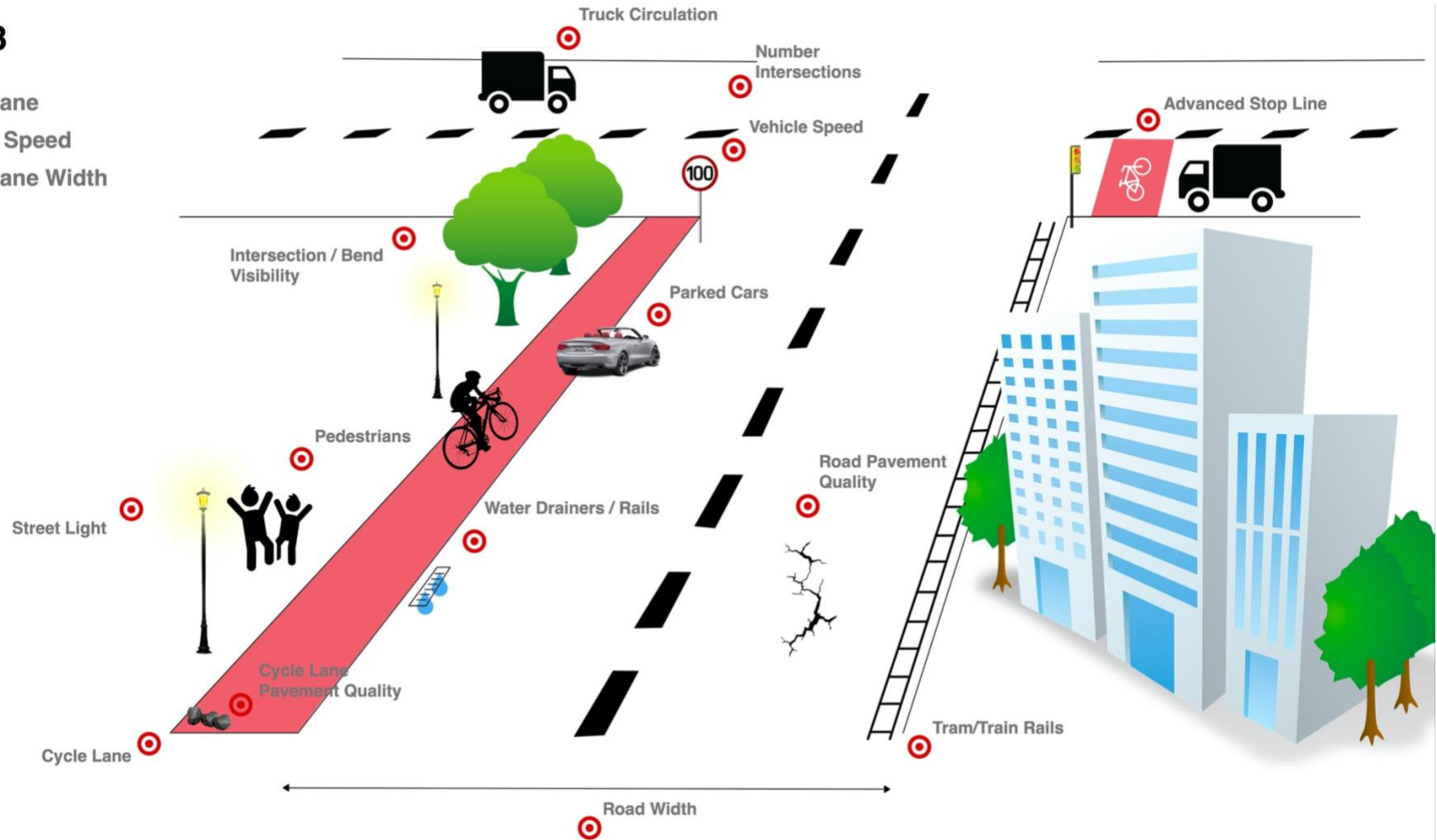


Figure 5 Cyclists' risk factors identified on the roads of London and depicted in a simulated scenario.

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