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Executive summary

Traffic safety as a challenge to reduce accidents, injuries and fatalities is still an important social problem in spite of the wide introduction of sophisticated safety measures to the road user, the vehicle and the infrastructure. One of many factors that are likely to contribute to an increase in road transport safety risks includes the increasing number of vulnerable road users, such as motorcyclists.

The aim of the reported work within the 2-BE-SAFE project, WP1, was to highlight the potential influence of the road infrastructure characteristics on the motorcycle accident risk.

As a usual starting point of many research works, a literature review to specify the actual **State of the Art**, took place. The results have shown that a lot of questions are not completely answered – especially the influence of specific road condition parameters together with alignment types and road geometry on powered two-wheelers (PTW) accident types. A comparison of country specific analyses has not been found. Most of the results who define the State of the Art are very general, but gave fruitful hints for the design of the studies conducted and reported on the following pages.

The first step of investigation was the **macroscopic analysis** of each single partner (country). Results from each participant country (Greece, Spain, Italy, Great Britain) on risk factors regarding the junction types, the road area types, the most critical accident types share many common points and are often comparable. Other potential risk factors show trends, which differ in each country – like the basic accident data itself. This unique comparison of possible infrastructure risk assessment also reflects also an obviously differing rider's philosophy (different motives to ride a motorcycle – urban/interurban rate of mileage, motorcycling for fun and to substitute the passenger car).

In the final stage of the project, a more in-depth view on the PTW accident event and the road section, where cashes occurred, has been accomplished. **Microscopic analyses** on specific physical values of road condition characteristics as well as detailed information on the trace parameters were correlated with PTW accidents. Parameters measured by special devices and/or in-depth accident data of the accidents are used to fulfil the aim finding risk factors regarding the road infrastructure. Unique data correlations show trends of potentially risky crash circumstances regarding the surface characteristic and e.g. curve radii classes. In-depth analyses reveal the negative effects of impacting a road restraint system. Participating countries are Spain, Germany and Austria.

Even similarities in risk factors and obvious trends of critical road infrastructure are explored in that European survey; it also proves that the issue of motorcycle is much more complex than often thought. European wide solutions to decrease PTW accidents by making the road infrastructure "motorcycle friendly", self-explaining and forgiving needs an in-depth understanding of the vehicle-road-interaction and its dynamics. A strong connection of road types, the mileage per year and the purposes of the rides are also feasible, in order to understand the motives of motorcyclists using a specific route. Especially the microscopic analyses of specific road sections has shown a strong need for further research regarding the interaction between motorcycle tyres and road surface condition.

Characteristics of PTW accidents spots are in some points comparable within the European context, but other black spots specifications are even in one country unique – statistically insignificant, but highly dangerous.

With that kind of studies within that task a unique comparison of risk factors depending on road infrastructure factors could be shown.

1. Introduction and Methodology

Motorcycle safety and accidentology needs an overall view on all possible crash-causal factors. Within this activity of WP1 in the 2-BE-SAFE project, one specific issue is addressed – the possible correlation of infrastructure (risk) factors and PTW accidents.

Do road surface characteristics, condition, alignment parameters, as well as road installations influence the PTW crash risk?

Literature reviews and the identification of the State of the Art, together with in-depth accident analyses and further investigation tools (risk assessment software) are done in order to verify potential infrastructure risk factors.

Three main sub activities can be identified:

- Within the first sub activity, a selective overview of the existing (or under examination) PTW safety guidelines and their influences on road design will take place, and links with other projects will be identified, as well as relevant documents produced by related working groups (e.g., at EU/CEN level) will also be considered. This analysis will define the current trends on road infrastructure issues in the PTW domain.
- The second sub activity involves a macro-analysis of the role of the road infrastructure (type of area or road, junction type, curvature etc) on PTW accidents. Data extracted from national accident databases (Greece, Spain, United Kingdom, Italy) will be analysed to identify the accident causation factors and potentially review accident site characteristics (primary road infrastructure parameters).
- Within the third sub activity, analysis at a micro-level will be performed to identify the critical characteristics of road infrastructure that constitute PTW risk factors. Data from accident databases and road geometry data (Austria, Germany and Spain) and appropriate software tools (MARVin, RoadVIEW) will be employed to conduct this detailed analysis. Similarities of road design elements and surface conditions (various curve radii, curvature, crossfall in road sections, type of pavement, skid resistance, texture etc.) and the combination of these data at accident locations will be determined as well as typical crash-causal-combinations.

2. State of the Art

The main objective of 2-BE-SAFE WP1, Task 1.2 is to investigate which road infrastructure elements (road design elements and road surface parameters) have an influence on PTW accidents. Within the first activity, a selective overview of the existing PTW safety guidelines, projects and papers and their influence on road design is required. The consulted sources vary from public studies performed by governments to reports of different European research studies.

2.1. Main PTW accident factors regarding infrastructure

2.1.1. Type of area

A significant number of projects and papers related to the influence of infrastructure elements to the PTWs behaviour can be traced in literature. However, the papers concerning PTW safety are much fewer. One of the major influential characteristics of PTW accidents interaction to infrastructure is the type of area. MAIDS (ACEM, 2003) reports that most of the accidents (72%) take place in an urban area and approximately 25% take place in a rural area. Pearson and Whittington (2001) also state that approximately 70% of motorcycle injuries occur on local area roads in Australia.

ASSING (2002), a German study on the general development of accidents involving motorcycles using individual data of the official accident statistics concerning accidents involving injury to persons in which at least one motorcycle (lights motorcycle, motorcycle or moped) was involved, reveal that **the highest degree of seriousness is to be found on roads outside built-up areas**.
Furthermore, the crash severity depends on the location. Because most crashes at intersections happen inside urban areas where the speed is generally lower than outside urban areas, the crash severity is also much lower at these locations (ASSING, 2002). By contrast the percentage of crashes in curves is much higher outside urban areas.

Bridges can be problematic for motorcyclists. Issues develop if they are placed on bends or if they have a surface friction lower than that of the approach road (e.g. concrete or wood after an asphalt road) (NPRA, 2004).

SPORNER (2006) analyses the main aspects and the particular risks for accidents on rural roads in cooperation with TÜV Bayern and some police stations within the federal states of Bavaria and North Rhine Westphalia. For the first time a global view on vehicle/driving behaviour and layout of roads is presented: If only one of the derived risk elements appears it may be harmless, but in combination with others it can finally cause an accident. The study includes analytical investigated samples concerning the focal reasons that caused the accident, as well as a list of typical distinctive features due to the layout of the roads.

2.1.2. Road geometry and roadside installations

A serious consideration in PTW safety is the influence of road geometry, roadside installations, such as barriers, posts and so on, as well as the markings. Miller (1997) reports that graveled (rather than sealed) road shoulders, slippery road markings, slippery manhole covers/steel plates and uneven road surfaces are considered a danger to motorcyclists. Miller (1997) suggests that kerbs should be marked or painted with fluorescent material to ensure that they are more conspicuous in low light conditions.

According to an in-depth study concerning safety situations in Germany, **crests** in **the vicinity of curves** and intersections, a **high bendiness** and **high gradients** are characteristics of roads with a high proportion of motorcycle crashes (Kühn, 2008)

Gerlach (2007), analyzed data for road sections in which accidents occurred and compared with sections where no accidents happened. This analysis by comparison provided the most important results of the project. It was possible to show that at road sections in which a) the angle changing throughout the entire section is more than 200gon/km, b) a maximum of 15 changes in the road direction per km occur, c) at least 50% of the roads are straight and d) the road section is longer than

2.0km there is a higher risk potential for motorcyclists compared to the average potential for risk on comparative road sections.

Gerlach (2007) also emphasizes that 18% out of 595 motorcycle crashes (only crash type: driving accident) occurred at crash sites, where the crossfall did not match the requirement of driving dynamics (superelevation in the inner curve). However, these “negative” crossfalls mostly had a superelevation much below 2.5%. Furthermore it could be shown, that the recommended maximum crossfall of 8.0% was exceeded in some cases.

One particular analysis concerning the gradient comes up with the following result: the number of motorcycle casualties on road sections with a descending gradient between 4.0% and 10.0% is higher than on road sections with an ascending gradient lower than 4.0%. Accordingly a descending gradient has a strong effect on motorcycle safety (Gerlach, 2007).

An analysis which combines the effects of crossfall, gradient and direction of curve pointed out, that most motorcycles crashes happen **in left curves with descending gradient followed by right curves with descending gradient**. Furthermore it could be found, that especially in left curves with descending gradient, a negative crossfall is a major problem (Gerlach, 2007).

Due to the fact, that 78% of the investigated motorcycles crashes happen on roads with a bendiness of more than 200gon/km (60% of investigated routes), it could be proven, that **the bendiness of a road** is a very important criterion from the safety point of view (Gerlach, 2007).

MAIDS report (ACEM, 2003) identified the contributing factors for each accident case study reported. Considering a roadway design defect as a condition which presented a danger for PTW riders (such as failure to install signs, built-in obstructions, curve with decreasing radius or inadequate distance to merge lines), data indicated that roadway design defects were present in 57 cases (6,2%) along the PTW pre-crash path, but did not contribute to the causation of the accident in 47% of those cases.

A roadway maintenance defect was reported in 146 cases (15,8%), being a primary or contributing factor in 25 cases (17,1% of cases involving a roadway maintenance defect). **Weather made no contribution to the accident causation** in 92,7% of the total number of cases, while there were 18 cases (2%) in which weather was identified as the primary contributing factor and weather was also reported to contribute to accident causation in 42 cases (4,6% of all cases).

Motorcycle Action Group - MAG (2005) underlines that the major cause of injury when a rider comes into contact with a crash barrier is **exposed posts**. Several solutions have been developed; one system most widely used today involves the fitment of a secondary rail to the existing barrier. Following several motorcycle accidents (including fatalities) at the A2070 Cloverleaf Junction in Kent, the Highways Agency identified the German ‘BikeGuard’ system as best suited to improve rider safety. Analysis of accident statistics since this was introduced has shown that “no personal injury accidents have occurred”.

In relation to infrastructure elements, Elliot et al. (2003) made the following points:

- Parallel longitudinal grooves in the road surface (for example, to avoid aquaplaning) can also induce instability.
- While travelling on a road with markings on the path of travel, a potential leaning angle of 45 degrees on dry tarmac can be reduced to 40 degrees on dry road markings, and reduced further to 25 degrees on wet markings.
- Crossing profiled (markings running in a direction other than parallel to the direction of travel) road markings causes “strong steering impulses leading to deviations of about 100mm” from the motorcycle’s track. Furthermore, road markings cause surface water retention, and can increase the possibility of aquaplaning.

Road markings, manholes and cattle grids can be more slippery than the road surface, especially when wet (NPRA 2004). Moreover, riding is affected by the presence of surveillance cameras; not-at-fault crash involvement at intersection is reduced in such a setting (Haque et al., 2009).

Some concern has been expressed over the potential for Vehicle Restraint Systems (VRS) to cause injury to motorcyclists. The following assertions are made (MacDonald, 2002):

- The current standards and specifications for roadside hardware, and the systems themselves, are not designed to take into account impact by motorcyclists.

- The current European Standard is not necessarily applied to minor roads;
- There is a distinction between a safety fence and a safety barrier. The former consists of poles supporting one or more horizontal elements, whereas the latter tend to have a continuous surface.
- Safety barriers are generally not considered to present the same type of hazard to motorcyclists as fences.

Gibson and Benetatos (2000) examined New South Wales fatal motorcycle crash records from 1998/1999, identifying three crash scenarios involving crash barriers:

- Motorcyclist is thrown into the air prior to impacting with the barrier;
- Motorcyclist separates from their bike and slides along the road before striking the barrier;
- Motorcyclist strikes the barrier whilst still on the bike.

They also concluded that **the majority of fatal impacts were at a relatively shallow angle** (<45°). The perceived risk of impacting a concrete barrier is less within this angle range compared to an impact with a barrier post from a w-beam or wire rope barrier. Morgan and Ogden (1999) suggest that impact forces are not as severe when colliding with a large surface area at a shallow attack angle. Gibson and Benetatos (2000) and Duncan et al., (2000) therefore argue that **hitting an exposed post** can result in more severe injuries. Impacts with guardrail posts reportedly cause injuries that are five times more severe than those from an average motorcycle accident.

ATSB (2000) examined any evidence or information regarding the safety implications of wire rope safety barriers. Concerning the use of road safety barrier systems, the study underlines that road safety barriers are an important and effective road safety measure. Motorcycle representatives argue that **little consideration is given to the installation of barriers which are safe for all road users**, and that the needs of motorcyclists are “largely ignored” in this matter. As accident reporting is not detailed enough to quantify the safety issue, they claim wire rope fences result in “unquantified trauma”. ATSB (2000) recommended concrete barriers, and argued that when maintenance costs are taken into account, these can be a more economically viable option. Furthermore, they recommend that vehicle rollovers can be prevented by the use of ‘F profile’ concrete barriers, providing an overall beneficial solution. On the other hand, the ATSB’s view was that wire rope safety barriers are “not currently a motorcycle safety problem”, given only one recorded motorcycle casualty and no fatalities involving a wire rope safety barrier. Furthermore, they state that although motorcycle riders only make up 0.5% of road traffic, that the authorities do have an obligation to address their safety issues. However, without evidence, they could not remove a measure which has safety benefits for other road users.

In view of APROSYS (2006) task concerning of impacts of motorcyclists into infrastructure, a review of existing literature on motorcycle-infrastructure interaction showed that collisions with an obstacle occur in 4,2% to 19,7% of motorcycle accidents depending on the area. Roadside barriers are involved in 2,4% to 4% of all PTW fatalities, constituting a particular hazard to PTW riders. **The typical barrier impact location is a curve, and in about half of the cases the rider impacts in upright position**. In spite of this fact, research is mainly focused on the other half, involving a sliding impact position. Several countermeasures have been developed to reduce the injuries of the riders involved in this sliding impact position, such as a continuous additional rail mounted on roadside barriers.

As a result of an in-depth databases analysis it was concluded that roadside barriers impact occurred under small angles at high speeds, mostly causing injuries to head and lower extremities (APROSYS, 2006). Considering metal barrier impacts, the rail seems to be hit more often than the post. Trees and poles impacts are at least equally hazardous to PTW riders than barrier impacts. MAG’s position in relation to safety barriers in the UK is summarized below (Motorcycle Action Group - MAG 2006):

- In 2003, there were 109 slight, serious or fatal motorcycle casualties where the rider hit the central barrier.

- There were 144 collisions where the rider struck the near or offside crash barrier.
- From 1999 to 2003, there were 1271 motorcycle casualties involving a collision with a central, near or offside barrier. These collisions resulted in 142 fatalities.
- In 2003, 5.2% of all fatalities were crash barrier impacts.

The paper points towards computer simulations and tests which reportedly indicate that "injuries will be severe if a rider hits the cables or exposed supporting posts of vehicle restraint systems" (MAG, 2006). MAG's position in the paper is that vehicle restraint systems are designed with the majority of road users in mind, and that motorcyclists "are not given sufficient consideration". MAG suggests that vehicle restraint systems should be designed and tested for motorcycle safety, as well as for the safety of other road users.

When striking barriers, studies indicated that the dummy experienced more rapid deceleration/load when colliding with a steel barrier than a concrete barrier. Nevertheless, the research suggests that the deceleration during both would have resulted in severe or life threatening injuries (Berg et al., 2005). When the rider impacted with a steel barrier in an upright position, the crash tests showed that the dummy slid alongside and onto the barrier. Contact and snagging with parts of the barrier would have led to severe injuries in this instance. The rider was not decelerated by the concrete barrier, and although the measured dummy loads did not indicate a risk of life-threatening injury. Kinetic energy was not dissipated, and this increases the risk of being deflected into oncoming traffic (Berg et al., 2005).

The results obtained from the simulated concrete barrier tests indicate that motorcyclists impacting in an upright position will experience low deceleration and sustain survivable injuries, unless they are catapulted over the barrier and strike the objects around which the barriers were built (Berg et al., 2005).

The results on the simulated wire rope barrier tests showed that (Berg et al., 2005):

- Riders are unlikely to clear these types of barriers. They are likely to get caught and decelerate very quickly;
- The wires are likely to guide the motorcycle into posts and lead to heavy impacts, increasing the risk of severe injury to the rider.

Impact with crash barriers/safety fences can result in serious injures for motorcyclists. There are today several means for improving the safety performance of existing barriers/fences in order to make them friendlier for motorcyclists. In particular, crash barriers which allow the rider to slide along the surface of the barrier without hitting any objects that concentrate the collision energy seem to lessen the risk of injury. Although, at the moment, it is not possible to estimate how large the reduction in injury severity will be when crash barriers are modified, it is no doubt that this measure will result in some reduction of injury severity. It is recommended that effort made to improve barriers/fences located on sharp curves or on motorcycle accident black spots should be given priority. Finally Ulleberg (2003) conclude that it is also important to focus on the road side area on locations where there are no fences/barriers, particularly by removing objects in the road side area which the motorcyclists may hit in run-off-road accidents.

Regarding guardrail crashes, Gabler (2007) examined the Fatality Analysis Reporting System (FARS) database to identify guardrail crash trends in cases where a fatality has occurred. The primary results of the study were as follows:

- In 2005, for the first time, the number of motorcycles suffered more fatalities than car passengers or any other vehicle type involved in a collision with a guardrail;
- Motorcycles compose only 2% of the vehicle fleet in the US, but account for 42% of fatalities involving a guardrail;
- Over two thirds of motorcyclists fatally injured in guardrail crashes were wearing a helmet;

- Approximately one in eight motorcyclists who were struck by a guardrail were fatally injured; a fatality risk over 80 times higher than for car occupants involved in a collision with a guardrail.

In Germany, in 1986 and 1987, 15% of motorcycle fatalities involved crashes with guardrails (Koch and Brendicke, 1988). The solutions proposed by Brailly (1998) were the use of a shield on barriers to protect the rider from the upright sections of barrier. The study suggested introducing a 'safety zone' on barriers using this method of 'modesty rails', particularly on curves with a radius of less than 250m. The German solution has been to re-design the post and use an energy absorbing material.

2.1.3. Lighting and Visibility

A significant concern in PTW safety is visibility. **Poor visibility** (horizontal curvature, vertical curvature, darkness) is responsible for increased motorcycle injury severity (Savolainen and Mannering, 2007). Poor sightline visibility and rider/bike conspicuity are likely to contribute to motorcycle accidents at intersections (NPRA 2004). Moreover, riding in darkness without street lighting was related to severe motorcyclists' injury (de Lapparent, 2006, Pai and Saleh, 2007, 2008).

Motorcyclists are found to be more **vulnerable during night time** at both intersections and expressways (Haque et al. 2009). Injuries resulting from early morning riding, in general, appear to be the most severe, especially in junctions controlled by stop, and give-way signs and markings (Pai and Saleh 2007).

DGT (2007) aimed to obtain the main PTW accident scenarios and to identify their causes and consequences in a well-defined sampling area, i.e. the non-urban roads of the Spanish road network. The study focused on fatal accidents involving at least one motorcycle (rider or the occupant killed as a result of the accident) during the year 2007. The study shows that most of the accidents occur with enough lighting, good weather conditions and good roadway surface condition. Approximately three out four fatal accidents are located in conventional roads. Run-off accidents were reported in 60% of all cases, being the most frequent type of fatal accident. Roadside elements were found to be particularly hazards to motorcycle riders, since these elements were impacted in approximately 35% of all fatal accidents. Within accidents including roadside elements, metal barrier collisions were reported in 18% of all cases.

Motorcyclists often experience **reduced visibility** when wearing glasses, visors or wind shields (NPRA, 2004). Dew can build up quickly on motorcyclists' visors, windshields and glasses when entering a tunnel.

2.1.4. Type of collision

Concerning the type of collision, a French study (Brailly, 1998) concluded that the **rate of fatal injuries per collision is five times higher than the national average if the rider strikes a barrier**. Collisions with barriers account for 8% of all motorcycle fatalities and 13% of fatalities on rural roads.

At-fault crashes on expressways are found to increase when **riding in the median lane**, with higher engine capacity and when riding with a pillion passenger (Haque et al., 2009).

Head-on collisions with other vehicles while negotiating a curve make up 6% of person injury accidents, and 13% of fatal accidents (NPRA 2004). **Collisions with stationary objects result in more severe injuries** (Quddus et al., 2002; Lin et al., 2003; Keng, 2005; Savolaine and Mannering, 2007). Motorcyclists were more injurious while motorcycles were overtaking their collision partners and while vehicles made a turn (Pai and Saleh, 2008).

For collisions at intersections between cars and motorcycles the car drivers are usually at fault. A possible explanation for this is that the car drivers do not "see" motorcycles, either because the shape and colour of motorcycles make them blend with the background and hard to see or the car drivers have a strong set to just notice other cars making them overlook motorcycles even though they are clearly visible (Glad, 2001).

2.1.5. Junction Type

Junction type is a significant influential factor of PTW safety. Hurt et al. (1981) and de Lapparent (2006) note that the probability that a severe/fatal accident occurs at intersections is higher than the same probability at non intersections. The most common of accident has been found to be the right of way violation (ROWV), where a vehicle pulls out from a side road onto a main carriageway into the path of an approaching motorcycle (Hurt et al., 1981; Haworth et al., 2005; de Lapparent, 2006; Crundall et al., 2008).

Pai and Saleh (2007, 2008) provide an extensive study on the interaction of junction type and motorcycle injury severity. In brief, the influential factors to motorcyclist injury severity at uncontrolled junctions are: elderly rider, greater engine size of motorcycle, riding in early morning, on weekend and under fine weather; street lights unlit; riding on uncongested road; collisions with bus/coach or HGV. In the case of signalized intersection, identified critical parameters are the following: heavier engine size of motorcycle; collisions with bus/coach or HGV; riding under fine weather and on non built-up road; and type of collision.

Regarding interactions of junction type with gender and age, it has been reported that **male riders**, given an accident has occurred, were more likely to be severely injured at signalized than at unsignalized junctions (Pai and Saleh, 2007). Moreover, teenaged riders were more prone to be severely injured than those aged 20–59 in accidents where stop, give-way signs or markings controlled the junctions, in contrast to findings regarding accidents at uncontrolled junctions (Pai and Saleh 2007). Collisions where older driver vehicles were making a turn and colliding with motorcycles appeared mostly in unsignalized junctions (Pai and Saleh, 2008).

Intersection accidents account for 30% of person injury accidents, and 17% of fatal accidents. These types of accidents are more prevalent in ‘moped’ users. In 87% of such accidents it was the motorists’ obligation to give way, whereas in 13%, it was the motorcyclist who should have yielded. This would suggest that **driver behaviour is the main factor in intersection accidents** (NPRA, 2004).

Unsafe speed greatly affects injury severity (Branas and Knudson, 2001; Savolainen and Mannering, 2007); the effect of speeding is intensified at unsignalized junctions (Pai and Saleh, 2007).

More than half of motorcycle crashes with personal injury occur at intersections respectively t-junctions including entrances and exits (ASSING, 2002). However, these crashes are characterised by a relatively low severity (ASSING, 2002). The crash severity is much higher for crashes in curves, especially in combination with slopes.

2.1.6. Pavement surface condition

On the pavement surface conditions, Shankar et al. (1996) emphasize on pavement surface and type of highway impact on sideswipe collisions between motorcycles and other motorized vehicles at junctions. **Wet pavement surface** is found to cause at-fault motorcycle accidents at non-intersections (Haque et al., 2009). However, Savolainen and Mannering (2007) suggest that in certain circumstances, risks could be mitigated by motorcyclists; for example, riding on wet pavement conditions, near intersections.

ASSING (2002) reports that in Germany during 1999, 83% of all motorcycle crashes occurred on dry road surfaces. In comparison the percentage of all crashes with personal injury on dry road surfaces was only 66%. This difference could be explained by the fact that most motorcyclists use their bikes only during fair weather conditions

In the PTW accident analysis conducted in MAIDS (ACEM, 2003), roadway was found to be dry and free of defect in 84,7% of all accidents, while roadway was found to be wet in 7,9% in all collected cases. Road surface defects were present in 30% of cases.

Bitumen used in the repair of road surfaces have much lower skid resistance than for wet tarmac causing steering problems when riders cross wet bitumen, particularly whilst leaning or braking in an upright position Elliot et al. (2003).

A well known problem caused by an insufficient stiffness of a motorcycle frame is **deterioration of the stability** (Brorsson and Ifver, 1984). Serious injuries have been reported caused by motorcycles which suddenly begin to wobble or weave. Road surface actively contributed to 15% of crashes examined by the Victorian Motorcycle case control study (Haworth et al., 1997). The authors suggested that the important factors in these collisions were:

- Surface grip;
- Surface irregularities and potholes;
- Loose materials;
- Patch repairs;
- Road markings.

Pearson and Whittington (2001), state that motorcycles are very sensitive to **changes in friction** level between the road surface and tires.

2.1.7. Type of vehicle and vehicle characteristics

Type of vehicle and vehicle characteristics has an important role on PTW accidents. Greater motorcycle engine size and motorcycle speed resulted in higher injury severity levels regardless of the control measure adopted (Shankar et al., 1996; Quddus et al., 2002; Langley et al., 2000; Lin et al., 2003; Harrison and Christie, 2005; de Lapparent, 2006; Pai and Saleh, 2007). Moreover, **collisions with heavier vehicles result in more severe injuries** (Quddus et al., 2002; Lin et al., 2003; Keng, 2005; Pai and Saleh, 2007).

Ulleberg (2003) conclude that **there are no studies based on real accidents estimating the preventive effect of ABS-brakes on motorcycles**. Moreover, studies demonstrate that the use of daytime running lights reduces the number of accidents which involve a collision with another vehicle. It is expected that additional measures improve motorcycle conspicuity (e.g. fluorescents clothing, additional beams or the use of high beam in daylight) can result in a further reduction in daytime collision accidents. There is, however, a need for further studies in order to estimate the effects of such additional measures. Collision tests indicate that leg protectors may reduce the severity of leg injuries, but increase the risk of head, chest and neck injuries. Tests demonstrate that an airbag can be effective, especially in cases where the motorcycle collides into the side of a car. The airbag may, however, increase the risk of head injuries in some cases. It is uncertain whether the airbag can cause neck injuries while inflating.

2.2. Summary of Findings

The main objective of the Sate of the Art report is to highlight which road infrastructure elements (road design elements, road surface parameters, roadside obstacles, road furniture,…) have an influence on PTW accidents. A selective overview of the existing PTW safety guidelines, projects and papers and their influence on road design has been done.

The consulted sources vary from public studies performed by governments to reports of different European research studies.

Even most of the PTW accidents occur with enough lighting, good weather conditions and good roadway surface condition the summary of all cited reports, project papers and guidelines give an overview on road infrastructure related risk factors. From the literature overview, the most relevant risk factors are:

- Roadway design defects (e.g. failure in road construction, disharmonic trace geometry, curvature, unevenness, potholes);
- Roadway maintenance defects;
- Road surface condition (e.g. problems on wet roads, slippery bitumen on hot asphalt, poor skid resistance);
- Collision with road side barriers in a run-off accident (very high fatality rate);
- Critical curve radii (curve radii relations);
- “Negative” crossfall (crossfall does not match the requirement of driving dynamics);
- Combined effect of crossfall, gradient and direction of curve (most motorcycles crashes happen in left curves with descending gradient followed by right curves with descending gradient; in left curves with descending gradient, a negative crossfall is a major problem);
- Intersections (poor sightline visibility and rider/bike conspicuity are likely to contribute to motorcycle accidents at intersections);
- Road markings, manhole covers and cattle guards;
- Poor visibility and speeding are a common multiplicator of infrastructure related accident risk.

A core problem of identifying significant correlations between road infrastructure parameters and accident information is the lack of relevant data. Another reason of not having more detailed investigations on this research question is that official motorcycle accident reports - and the media coverage of motorcycle accidents - do not always give all the facts. When a motorist violates a give way sign and hits a motorcyclist, a common explanation is that the rider was speeding, or that the rider was impossible to see, which is now recognised as ‘inattentional blindness’, while in single vehicle crashes, when a rider loses control on a curve, a common explanation is that he was speeding. In-depth studies or specific accident simulations including the road infrastructure (virtual road) are very rare.

3. Macroscopic Analysis

3.1. Introduction

Most European countries have experienced a systematic increase in the diffusion of Powered Two-Wheelers (PTWs) as an alternative or complementary mean of undertaking personal transport. Scooters, mopeds and motorbikes are now a common sight on all categories of roads, their popularity having considerably increased, especially within the urban environment, due to a number of factors.

The popularity of PTWs requires that infrastructure needs to be built, maintained and upgraded taking into consideration the different needs of these types of users. The often terrible consequences of accidents involving PTWs are a constant reminder that, much too often, infrastructure is not designed to ensure the maximum possible levels of safety for motorcycle and moped riders.

The 2-BE-SAFE project and its work package 1 intend to provide an understanding of the link between riders or drivers and road environment characteristics (road infrastructure and weather conditions) that constitute risk to PTWs, on road safety.

Activity 1.2 within WP1 has been planned to specifically identify the influence of road infrastructure elements on PTW accidents, using accident statistics from national databases for macro-analyses and specific software-tools and in-depth data for micro-analyses. The aim is to identify the influence of road infrastructure characteristics (e.g. road types, junction types, road surface condition, road geometry, etc.) that constitute risk factors for PTWs.

This report refers to the first level of analysis that encompasses the macroscopic analysis of the interactions between mopeds and motorcycles and road infrastructure characteristics using data from the Greek, Spanish, British and Italian accident database. Data extracted from national accident databases have been analysed to identify the accident causation factors and potentially review accident site characteristics (primary road infrastructure parameters). The results are promising and useful for the other 2-BE-SAFE work packages to focus on their objectives, although the differences in the national databases are evident (but they cannot be eliminated).

This report provides the deliverable in respect of this activity and is structured as follows: each country's analysis is a single part of the report, the first chapter of each national report briefly describes the methodology and data specifications utilized in the analyses of PTW accident data, followed by the specific analyses and queries.

The basic sets of queries are in all single report parts (for each country) similar and comparable, even though the layout and wording is slightly different. Due to the different analyses tools and especially of the different data sets. All partners involved in the macro-analyses work used moped und motorcycle accidents in the surveys, the Greek queries are presented separately for each mode whereas the other partners provided them together as PTW accidents.

Regarding the identification of real risk factors (risk assessments) a critical point is that there is no exposure data for any of the data bases. In order to use the absolute accident numbers to assess risk trends, some weighting factors are included in the analyses. For example the query of the road condition was compared with the ratio of rainy days in the specific country.

Each partner delivered also some specific queries and data comparisons within their data analysis in order to figure out some "extra benefits" to fulfill the requested task.

Each country's part closes with a list of key findings – which is finally summarized at the end of the report as a merged conclusion.

3.2. Interaction between Powered Two-Wheeler Accidents and Infrastructure in Greece

3.2.1. Methodology – Greek Data Base and Available Data

Data from the Greek National database with disaggregate road accident data are used in this research. Information for each accident is collected by the Police and coded by the National Statistical Service of Greece. The System for ANalysis of TRaffic Accidents (SANTRA) developed by NTUA uses this national data file (DTPE 2002). This database contains all injury accidents, the related casualties, and the drivers involved for the period 1985 - 2007 (466.912 Injury Accidents and 1.073.162 Persons). The dataset used in this research includes all mopeds and motorcycle accidents reported for the period 2005 -2007 that account for 49.858% of the total accidents (24.147 of 48.432), cross-classified by type of area (inside and outside urban areas), junction type and other variables (SANTRA, 2007).

Further analyses will focus on both mopeds and motorcycles, as well as inside and outside urban areas in order to reveal differences and similarities between different types of PTW.

3.2.2. Interaction between Moped Accidents and Infrastructure in Greece

During the period 2005-2007, 2.421 moped accidents and 21.897 motorcycle accidents were observed. PTW accidents accounted for 51% of the total accidents observed in Greece. The following sections are dedicated to interactions between mopeds and road infrastructure with respect to accident type, area type, carriageway type, junction type, collision type, road geometry characteristics, pavement state and conditions, as well as combinations of the above. The next chapter refers to similar analysis of motorcycle accidents. Finally, moped and motorcycle fatalities are contrasted in a comparative framework with respect to carriageway type, junction type and road geometry.

3.2.2.1. Type of Accident by Carriageway type

Three types of moped accidents are considered:

- Accident between moped and other moving vehicles (mopeds, motorcycles, passenger cars and so on)
- Accident between moped and a pedestrian
- Accident between moped and a stationary vehicle or other object

The above accident types are examined with respect to the number of ways (directions) and carriageways; based on Greece national accident datasets three categories are identified:

- One way (one carriageway): One-way carriageways with one or more lanes. Entrance/exit roads also are considered.
- One way (two carriageways): Dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median.
- Two ways: Single carriageway with at least one lane in each way (direction).

Four types of collision are considered: (a) Head-on, (b) Lateral (Head-on side), (c) At angle (Side) and (d) Rear end (Nose to tail). Table 1 provides the number and percentage of the total number of moped accidents with moving vehicles with respect to the collision type, as well as the carriageway type. As can be observed more than 1.500 moped accidents with other moving vehicles inside urban areas were observed in Greece, and this accounts for the 88% of the total number of moped accidents with moving vehicles observed in Greece (Table 1).

Most accidents occur on single carriageways with at least one lane in each way (direction) on both urban and interurban area (Table 1). On single carriageways with at least one lane in each way (direction), 70% of the accidents observed inside urban areas are lateral collisions, while, on one-way carriageways with one or more lanes, lateral crashes account for the 73% of the accidents in urban areas. For accidents outside urban areas, the percentages for lateral collisions in single carriages with at least one lane in each way and one-way carriageways with one or more lanes are 48% and 75% respectively. In total, lateral collisions account for 68% of crashes inside urban areas and the 47% of crashes outside urban areas. The proportion of rear end and head-on collisions outside urban areas is around twice the proportion inside urban areas. At angle crashes account for 20% and 26% in dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median, inside and outside urban areas respectively.

Table 1: Accidents between mopeds and moving vehicles with respect to carriageway and collision type, Greece 2005-2007.

	Carriageway Type	Collision Type				Total
		Head-on	Lateral	At angle	Rear end	
inside urban area	ONE (one carriage way)	1%	73%	17%	9%	300
	ONE (two carriage way)	3%	59%	20%	17%	297
	TWO	11%	70%	12%	8%	934
	Total	7%	68%	14%	10%	1.531
Outside urban area	ONE (one carriage way)	0%	75%	0%	25%	4
	ONE (two carriage way)	5%	37%	26%	32%	19
	TWO	16%	48%	10%	27%	179
	Total	14%	47%	11%	27%	202
Total		142	1142	240	208	1.733

Table 2 depicts the accidents between mopeds and pedestrians with respect to carriageway type. It is observed that, inside urban areas, 57% of crashes occur on single carriageways with at least one lane in each way (direction); outside urban areas, this percentage rises to 88% (although the numbers are small). Moreover, in one-way carriageways with one or more lanes, 24% of accidents account for accident between mopeds and pedestrians; no pedestrian accidents were reported outside urban areas on one-way carriageways with one or more lanes between 2005 and 2007.

Table 2: Accidents between mopeds and pedestrians with respect to carriageway type, Greece 2005-2007.

	Carriageway	Accidents	%
inside urban area	ONE (one carriage way)	45	24%
	ONE (two carriage way)	35	19%
	TWO	106	57%
	Total	186	
outside urban area	ONE (one carriage way)	0	0%
	ONE (two carriage way)	1	12%
	TWO	7	88%
	Total	8	
Total		388	

In Table 3, accidents and percentages of accidents between mopeds and stationary objects are presented considering both collision type and carriageway type. As can be observed, in total 46% of the accidents between stationary objects and mopeds are in urban areas, while the same type of accident with stationary element account for the 87% of the total accidents with stationary elements observed outside urban areas. Moreover, a high percentage of accidents in urban areas refer to collision with a parked vehicle (33%). Outside urban areas, the majority of moped accidents occur with an obstacle. The percentage of collisions with slow moving vehicles is around 6% in outside urban areas.

A more thorough look at the figures in Table 3 shows that in urban areas, 34% of accidents that occur on one-way carriageways with one or more lanes are collisions with a vehicle slowing/stopping/stationary, while the proportion is 33% on dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median. Collision with an obstacle account for 32%

of accidents with stationary elements in one-way carriageways with one or more lanes and the 43% in dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median.

On single carriageway with at least one lane in each way (direction), 53% of accidents observed inside urban areas are related to collisions with an obstacle, while the same percentage rises to 87% for crashes observed outside urban areas.

Table 3: Accidents between mopeds and stationary vehicles or obstacles with respect to carriageway and collision with stationary object type, Greece 2005-2007.

	Carriageway Type	Collision with a vehicle slowing/stopping/stationary	Collision with a parked vehicle	Collision with an obstacle	Collision with a train	Total
inside urban area	ONE (one carriage way)	34%	34%	32%	0%	38
	ONE (two carriage way)	33%	24%	43%	0%	21
	TWO	10%	35%	53%	2%	91
	Total	19%	33%	46%	1%	150
outside urban area	ONE (one carriage way)	0%	0%	0%	0%	0
	ONE (two carriage way)	0%	0%	100%	0%	1
	TWO	7%	7%	87%	0%	15
	Total	6%	6%	88%	0%	16
Total		30	51	83	2	166

Moreover, in outside urban areas no accidents with stationary objects were observed in the period 2005-2007 in one-way carriageways with one or more lanes. On dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median, the only accident was a collision with an obstacle.

Table 4 depicts the number of moped accidents occurring without any kind of collision with respect to the carriageway type. Skidding is separated out in the tables as it is systematically observed in moped accidents both inside and outside urban areas. These accidents are much more frequent in single carriageway with at least one lane in each way (direction) [TWO] than on other road types.

Table 4: Mopeds accidents (single vehicle accidents) with respect to carriageway, Greece 2005-2007.

	Carriageway	Running off-road (skidding)	%	Other	Total
inside urban area	ONE (one carriage way)	33	87%	5	38
	ONE (two carriage way)	39	100%	0	39
	TWO	140	91%	14	154
	Total	212	92%	19	231
outside urban area	ONE (one carriage way)	5	100%	0	5
	ONE (two carriage way)	2	68%	1	3
	TWO	86	98%	2	88
	Total	93	97%	3	96
Total		305		22	327

3.2.2.2. Type of Accident by Junction type

In total, most accidents between mopeds and moving vehicles are observed inside urban areas and at police controlled junctions (Table 5); high percentage of moped accidents are also observed in uncontrolled junctions, whereas in junctions controlled by traffic lights, accidents volume is much lower. Outside urban areas, the number of accidents between mopeds and moving vehicles is significantly lower when compared to those observed in urban areas and occur in junctions that are not controlled. Both inside and outside urban areas, a very high percentage of accidents between moving vehicles and mopeds are lateral collision at junctions controlled by warden. Lateral collisions are also commonly observed in accidents between moving vehicles and mopeds in junctions controlled by traffic lights.

Table 5: Accidents between mopeds and moving vehicles with respect to carriageway and junction type, Greece 2005-2007.

	Junction Type	Head-on	Lateral	At angle	Rear end	Total
Inside urban area	Junction with traffic lights	1%	73%	13%	14%	197
	Junction - police controlled	2%	90%	6%	1%	409
	Junction not controlled	8%	70%	14%	8%	347
	Other	6%	84%	6%	3%	31
Outside urban area	Junction with traffic lights	0%	100%	0%	0%	8
	Junction - police controlled	11%	68%	21%	0%	19
	Junction not controlled	6%	74%	6%	15%	34
	Other	33%	33%	33%	0%	3
Total		45	828	110	65	1.048

As indicated in Table 6, 43% of the accidents between a moped and a pedestrian are observed in junctions that are not controlled. Moreover, a high accident percentage is also observed in junctions controlled by traffic lights.

Table 6: Accidents between mopeds and pedestrians with respect to junction type, Greece 2005-2007.

	Junction Type	Accident between a moped and a pedestrian	%
Inside urban area	Junction with traffic lights	18	39
	Junction - police controlled	5	11
	Junction not controlled	20	43
	Other	3	7
outside urban area	Junction with traffic lights	0	0
	Junction - police controlled	0	0
	Junction not controlled	0	0
	Other	0	0
Total		46	

Most moped collisions with an obstacle are observed at uncontrolled junctions inside urban areas (Table 7). Interestingly, only one moped accident with stationary objects outside urban areas was observed in the period 2005-2007 in Greece.

Table 7: Percentage of accidents between mopeds and stationary objects with respect to junction and collision type, Greece 2005-2007.

	Junction Type	Collision with Stationary Element				Total
		Collision with a vehicle slowing/stopping/ stationary	Collision with a parked vehicle	Collision with an obstacle	Collision with a train	
Inside urban area	Junction with traffic lights	33%	33%	33%	0%	6
	Junction - police controlled	50%	25%	25%	0%	8
	Junction not controlled	9%	36%	55%	0%	22
	Other	0%	100%	0%	0%	1
Outside urban area	Junction with traffic lights	0%	0%	0%	0%	0
	Junction - police controlled	0%	0%	0%	0%	0
	Junction not controlled	0%	0%	100%	0%	1
	Other	0%	0%	0%	0%	0
Total		8	13	17	0	38

As can be observed in Table 8, running off road single moped accidents are mostly observed in urban areas at uncontrolled junctions. Moreover, as seen in Table 9, a higher proportion of younger moped users between 15 and 34 years were involved in moped accidents. Outside urban areas, 50% of accidents involving mopeds involve persons of age between 25 and 34 years old at junctions controlled by traffic lights.

Table 8: Single moped accidents with respect to junction type, Greece 2005-2007.

	Junction Type	Running off-road (skidding)	other	Total
Inside urban area	Junction with traffic lights	100%	0%	7
	Junction - police controlled	100%	0%	7
	Junction not controlled	93%	7%	29
	Other	100%	0%	2
outside urban area	Junction with traffic lights	0%	100%	4
	Junction - police controlled	0%	100%	0
	Junction not controlled	14%	86%	7
	Other	0%	100%	7
Total				49

Table 9: Mopeds accidents with respect to junction type and age of persons in moped, Greece 2005-2007.

	Junction Type	Age of Persons on Moped							
		Unknown	15-24	25-34	35-44	45-54	55-64	65+	Total
Inside urban area	Junction with traffic lights	7%	26%	24%	17%	12%	7%	6%	164
	Junction - police controlled	7%	27%	20%	16%	12%	7%	11%	330
	Junction not controlled	9%	28%	23%	17%	9%	8%	7%	310
	Other	7%	17%	23%	23%	10%	7%	13%	30
outside urban area	Junction with traffic lights	8%	17%	50%	8%	17%	0%	0%	12
	Junction - police controlled	0%	20%	20%	30%	5%	0%	25%	20
	Junction not controlled	6%	26%	17%	23%	6%	6%	17%	35
	Other	0%	29%	29%	0%	29%	14%	0%	7
Total		68	240	201	157	95	63	84	908

3.2.2.3. Type of Accident by Road Geometry

By road geometry, four characteristics are observed in the Greek accident database: (a) straight road, (b) bend, (c) narrow passage and (d) slope. Table 10 summarizes the interactions between collision type and road geometry in accidents involving mopeds and other moving vehicles. Lateral collisions inside urban areas are mostly observed in straight roads. Significant number of accidents is also observed in bends and slopes. As for accidents observed outside urban areas, a similar pattern with accidents inside urban areas is observed. A high proportion of narrow passage accidents between mopeds and moving vehicles inside urban areas are head-on collisions. In areas outside urban environments, narrow passages are exclusively related to lateral collisions. A large proportion of accidents outside urban areas are rear-end collisions.

Table 10: Mopeds accidents with other moving vehicles with respect to collision type, Greece 2005-2007.

	Road Geometry*	Head-on	Lateral	At angle	Rear end	Total
Inside urban area	Straight road	11%	49%	22%	18%	488
	Bend	31%	43%	16%	10%	129
	Narrow passage	57%	24%	0%	19%	21
	Slope	16%	50%	17%	16%	153
outside urban area	Straight road	14%	31%	15%	40%	110
	Bend	32%	47%	0%	21%	66
	Narrow passage	0%	100%	0%	0%	7
	Slope	22%	41%	4%	33%	54
Total		178	473	171	206	1028

*some variables are not mutually exclusive

Table 11 shows that the majority of accidents involving mopeds and pedestrians occur in straight roads and are significantly more frequent inside urban areas. In Table 12 it is observed that most of the accidents with stationary elements observed in straight roads inside urban areas refer to collisions with a parked vehicle or an obstacle. Furthermore, 60% of accidents with stationary elements on slopes inside urban areas refer to collisions with an obstacle. Collisions with an obstacle are almost exclusively causing accidents with stationary elements outside urban areas. Inside urban areas, accidents without collision in straight roads, slopes and bends are exclusively skidding accidents. This does not apply to accidents observed outside urban areas (Table 13).

Table 11: Moped accidents between mopeds and pedestrians with respect to road geometry characteristics, Greece 2005-2007.

	Road Geometry*	Accident between a moped and a pedestrian	%
Inside urban area	Straight road	132	86%
	Bend	9	6%
	Narrow passage	2	1%
	Slope	10	7%
outside urban area	Straight road	8	89%
	Bend	0	0%
	Narrow passage	0	0%
	Slope	1	11%
Total		162	

*some variables are not mutually exclusive

Table 12: Percentage of accidents between mopeds and stationary vehicles or obstacles with respect to collision type at different road geometry characteristics, Greece 2005-2007.

	Road Geometry*	Collision with Stationary Element				Total
		Collision with a vehicle slowing/stopping/ stationary	Collision with a parked vehicle	Collision with an obstacle	Collision with a train	
Inside urban area	Straight road	23%	36%	38%	2%	99
	Bend	0%	0%	100%	0%	17
	Narrow passage	25%	38%	38%	0%	8
	Slope	12%	28%	60%	0%	25
outside urban area	Straight road	9%	9%	82%	0%	11
	Bend	0%	0%	100%	0%	6
	Narrow passage	0%	0%	0%	0%	0
	Slope	0%	0%	100%	0%	6
Total		29	47	94	2	172

*some variables are not mutually exclusive

Table 13: Single mopeds accidents with respect to road geometry characteristics, Greece 2005-2007.

	Road Geometry*	running off-road (skidding)	other	total
Inside urban area	Straight road	100%	0%	7
	Bend	100%	0%	7
	Narrow passage	93%	7%	29
	Slope	100%	0%	2
outside urban area	Straight road	0%	100%	4
	Bend	0%	100%	0
	Narrow passage	14%	86%	7
	Slope	0%	100%	7
Total		356	24	380

*some variables are not mutually exclusive

Moreover, the majority of running-off accidents in urban areas is observed in narrow passages (Table 13). Outside urban areas, the largest proportion of running-off accidents is observed in both narrow passages and slopes.

3.2.2.4. Type of Accident by Pavement Conditions

In Greece, for the period of 2005-2007, rainy days account for 18% of the total number of days in a year. The pavement conditions considered are: (a) dry, (b) wet, (c) slippery, (d) icy, (e) snow-clad, and (f) other. Almost all fatalities and injuries (95%) observed between 2005 and 2007 occurred in accidents under dry pavement conditions in both urban and interurban areas (Table 14). Asphalt is the most frequently observed pavement type in moped accidents in both inside and outside urban areas (Table 15).

Table 14: Mopeds accidents with respect to pavement conditions, Greece 2005-2007.

	Pavement Condition	Fatalities (Killed at 30)	% Fatalities	Injuries	Total
Inside urban area	Dry	95	4%	2.135	2.230
	Wet	5	5%	97	102
	Slippery	0	0%	12	12
	Icy	0	0%	2	2
	Snow-clad	0	0%	3	3
	Other	1	14%	6	7
Outside urban area	Dry	63	16%	324	387
	Wet	2	13%	13	15
	Slippery	0	0%	3	3
	Icy	1	50%	1	2
	Snow-clad	0	0%	0	0
	Other	0	0%	0	0
	Total	167		2.596	2.763

Table 15: Mopeds accidents with respect to pavement conditions and pavement type, Greece 2005-2007.

	Pavement Condition	Fatalities (Killed at 30)				Injuries				Total
		Asphalt	Concrete	Other	Total	Asphalt	Concrete	Other	Total	
Inside urban area	Dry	97%	2%	1%	95	100%	0%	0%	2.127	2.222
	Wet	100%	0%	0%	5	100%	0%	0%	97	102
	Slippery	0%	0%	0%	0	100%	0%	0%	12	12
	Icy	0%	0%	0%	0	100%	0%	0%	2	2
	Snow-clad	0%	0%	0%	0	100%	0%	0%	3	3
	Other	0%	0%	100%	1	67%	67%	0%	3	4
Outside urban area	Dry	98%	0%	2%	63	100%	0%	1%	322	385
	Wet	100%	0%	0%	2	100%	0%	0%	13	15
	Slippery	0%	0%	0%	0	100%	0%	0%	3	3
	Icy	100%	0%	0%	1	100%	0%	0%	1	2
	Snow-clad	0%	0%	0%	0	0%	0%	0%	0	0
	Other	0%	0%	0%	0	0%	0%	0%	0	0
	Total	162	2	3	167	2.578	3	13	2.583	2.750

3.2.3. Interaction between Motorcycle Accidents and Infrastructure in Greece

3.2.3.1. Type of Accident by Carriageway type

Table 16 provides the percentage of the total number of motorcycle accidents with moving vehicles with respect to the collision type, as well as the carriageway type. As can be observed, more than 14.500 motorcycle accidents with other moving vehicles inside urban areas were observed in Greece and that accounts for 90% of the total number of motorcycle accidents with moving vehicles observed in Greece (Table 16).

From the total number of accidents, more than 9% of accidents on single carriageway with at least one lane in each way (direction) are head on collisions, regardless of the type of area (Table 16). In single carriageways with at least one lane in each way (direction), 68% of the accidents observed inside urban areas are lateral collisions, while 69% of the accidents are observed in one-way carriageways with one or more lanes. For accidents outside urban areas, the percentages for lateral collisions in single carriages with at least one lane in each way and one-way carriageways with one or more lanes are 46% and 43% respectively. Moreover, the proportions of rear end and head-on collisions are significantly greater outside urban areas when compared to accidents inside urban areas. Angle crashes make up the 25% and 29% of accidents on dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median inside and outside urban areas respectively.

In total, lateral collisions account for the 65% of crashes inside urban areas and the 45% of crashes outside urban areas. These figures are lower than the case of moped accidents with moving vehicles.

Table 16: Accidents between motorcycles and moving vehicles with respect to carriageway and collision type, Greece 2005-2007.

	Carriageway Type	Collision Type				Total
		Head-on	Lateral	At angle	Rear end	
inside urban area	ONE (one carriage way)	3%	69%	19%	9%	2.949
	ONE (two carriage way)	2%	56%	25%	17%	3.958
	TWO	9%	68%	14%	8%	7.635
	Total	6%	65%	18%	11%	14.542
Outside urban area	ONE (one carriage way)	23%	43%	20%	14%	35
	ONE (two carriage way)	3%	42%	29%	26%	198
	TWO	13%	46%	17%	24%	1.313
	Total	12%	45%	19%	24%	1.546
Total		1.011	10.165	2.958	1.954	16.088

Table 17 depicts the accidents between motorcycles and pedestrians with respect to carriageway and collision type. It is observed that, inside urban areas, 46% of crashes occur on single carriageways with at least one lane in each way (direction); outside urban areas, this percentage rises to 84%.

Moreover, 22% of accidents on one-way carriageways with one or more lanes account for accident between motorcycles and pedestrians; a small percent of pedestrian accidents are observed outside urban areas in one-way carriageways with one or more lanes.

Table 17: Accidents between motorcycles and pedestrians with respect to carriageway type, Greece 2005-2007.

	Carriageway Type	Accidents	%
inside urban area	ONE (one carriage way)	445	22%
	ONE (two carriage way)	645	32%
	TWO	941	46%
	total	2.031	
outside urban area	ONE (one carriage way)	1	2%
	ONE (two carriage way)	8	15%
	TWO	46	84%
	Total	55	
Total		2.086	

In Table 18, accidents and percentages of accidents between motorcycles and stationary elements (objects or other vehicles) are presented considering both collision type and carriageway type. In total, most accidents are observed with stationary objects (collision with an obstacle).The percentage of motorcycle accidents with stationary object rises to 50% from 46% in the case of mopeds, for urban areas. Outside urban areas, the same percentage equals to 76%, whereas in the case of mopeds, the same percentage is 88%. Moreover, a high percentage of accidents in urban areas refer to collision with a parked vehicle (23%). Outside urban areas, the majority of motorcycle accidents occur with an obstacle. The percentage of collisions outside urban areas with slow moving vehicles is 14%.

On single carriageway with at least one lane in each way (direction), 54% of accidents are observed between stationary objects (collision with an obstacle) and motorcycles in urban areas, while the same type of accident with stationary element account for the 70% of the total accidents with stationary elements observed outside urban areas. Compared to moped accidents, similar percentages are observed in urban areas, whereas outside urban areas moped accident percentage is much higher (87%). In urban areas, 39% of accidents that occur in one-way carriageways with one or more lanes account for collisions with a parked vehicle and this percentage drops to 15% of dual-carriageway road collisions with a minimum of two lanes in each direction, often separated by a median. Collisions with an obstacle make up the 35% of the total accidents with stationary elements on one-way carriageways with one or more lanes and the 55% in dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median.

Table 18: Accidents between motorcycles and stationary vehicles or obstacles with respect to carriageway and collision type, Greece 2005-2007.

	Carriageway Type	Collision with a vehicle slowing/stopping/stationary	Collision with a parked vehicle	Collision with an obstacle	Collision with a train	Total
inside urban area	ONE (one carriage way)	25%	39%	35%	1%	244
	ONE (two carriage way)	30%	15%	55%	0%	301
	TWO	19%	27%	54%	0%	550
	Total	23%	27%	50%	0%	1.095
outside urban area	ONE (one carriage way)	0%	0%	100%	0%	11
	ONE (two carriage way)	15%	15%	70%	0%	27
	TWO	15%	10%	75%	0%	162
	Total	14%	11%	76%	0%	200
Total		281	312	700	2	1.295

Moreover, outside urban areas, in dual-carriageway roads with a minimum of two lanes in each direction, often separated by a median, 70% of accidents are collisions with obstacles. A similar percentage is observed in single carriageways with at least one lane in each way (direction).

Table 19 depicts the number of motorcycle accidents occurring without any kind of collision with respect to the carriageway type. As in mopeds, skidding is commonly observed in motorcycle accidents both inside and outside urban areas. The high number of PTW crashes inside urban areas is explained by the fact that there is a higher proportion of PTW traffic in the cities. These accidents are proportionately more frequent in single carriageways with at least one lane in each way (direction).

Table 19: Motorcycles accidents (without collision) with respect to carriageway type, Greece 2005-2007.

	Carriageway	Running off-road (skidding)	% skidding	Other	Total
inside urban area	ONE (one carriage way)	469	92%	43	512
	ONE (two carriage way)	424	94%	26	450
	TWO	835	92%	76	911
	Total	1.728	92%	145	1.873
outside urban area	ONE (one carriage way)	24	100%	0	24
	ONE (two carriage way)	52	95%	3	55
	TWO	601	97%	16	617
	Total	677	97%	19	696
Total		2.405		164	2.569

3.2.3.2. Type of Accident by Junction type

In total, a majority of accidents between motorcycles and moving vehicles, as in the case of mopeds, are observed inside urban areas and at police controlled or not controlled junctions (Table 20). Outside urban areas the number of accidents involving motorcycles is significantly lower and they occur at junctions that are not controlled. Both inside and outside urban areas, a very high percentage of accidents between moving vehicles and motorcycles refer to lateral collisions at police controlled junctions. Lateral collisions are frequently observed in accidents between moving vehicles and motorcycles in junctions controlled by traffic lights and other situations.

Inside urban areas, as indicated in Table 21, 54% of the accidents between a motorcycle and a pedestrian are observed in junctions that are not controlled. A high accident percentage is also observed in junctions controlled by traffic lights. Outside urban areas, accidents between a motorcycle and a pedestrian are observed in junctions that are not controlled account for the 86% of the total accidents observed between motorcycles and pedestrians (Table 21) although the total number of accidents between pedestrians outside urban areas is small.

Table 20: Accidents between motorcycles and moving vehicles with respect to junction type and collision type, Greece 2005-2007.

	Junction Type	Head-on	Lateral	At angle	Rear end	Total
Inside urban area	Junction with traffic lights	3%	70%	19%	9%	2.374
	Junction - police controlled	2%	88%	8%	2%	3.152
	Junction not controlled	6%	67%	18%	9%	3.100
	Other	7%	73%	12%	7%	181
outside urban area	Junction with traffic lights	5%	64%	16%	15%	55
	Junction - police controlled	2%	87%	7%	4%	92
	Junction not controlled	8%	64%	17%	11%	158
	Other	4%	70%	4%	22%	23
Total		337	6.876	1.323	599	9.135

Table 21: Accidents between motorcycles and pedestrians with respect to junction type, Greece 2005-2007.

	Junction Type	accident between a moped and a pedestrian	%
Inside urban area	Junction with traffic lights	251	39%
	Junction - police controlled	26	4%
	Junction not controlled	347	54%
	Other	16	3%
outside urban area	Junction with traffic lights	1	14%
	Junction - police controlled	0	0%
	Junction not controlled	6	86%
	Other	0	0%
Total		647	

Most motorcycle accidents accounting for collisions with an obstacle are observed in uncontrolled junctions inside urban areas (Table 22). The number of motorcycle accidents with stationary elements outside urban areas is significantly lower than accidents occurring inside urban areas for the period 2005-2007 in Greece.

As can be observed in Table 23 as in the case of mopeds, the majority of single motorcycle accident inside urban areas are running off road accidents. The opposite occurs outside urban areas.

Table 22: Percentage of accidents between motorcycles and stationary vehicles or obstacles with respect to junction and collision type, Greece 2005-2007.

	Junction Type	Collision with Stationary Element				Total
		collision with a vehicle slowing/stopping/ stationary	collision with a parked vehicle	collision with an obstacle	collision with a train	
Inside urban area	Junction with traffic lights	58%	11%	31%	0%	62
	Junction - police controlled	44%	38%	18%	0%	39
	Junction not controlled	25%	33%	41%	0%	150
	Other	0%	29%	43%	29%	7
outside urban area	Junction with traffic lights	100%	0%	0%	0%	2
	Junction - police controlled	67%	0%	33%	0%	3
	Junction not controlled	33%	33%	33%	0%	9
	Other	50%	0%	50%	0%	2
Total		99	77	96	2	274

Table 23: Single motorcycle accidents with respect to junction type, Greece 2005-2007.

	Junction Type	running off-road (skidding)	Other	Total
Inside urban area	Junction with traffic lights	90%	10%	82
	Junction - police controlled	93%	7%	69
	Junction not controlled	90%	10%	244
	Other	87%	13%	15
outside urban area	Junction with traffic lights	0%	100%	0
	Junction - police controlled	4%	96%	4
	Junction not controlled	8%	92%	20
	Other	27%	73%	4
Total		397	41	438

Moreover, as seen in Table 24, a high proportion of younger motorcycle users between 25 and 34 years old, as in the case of moped accidents, were involved in motorcycle accidents. Outside urban areas, 36% of accidents involving motorcycles involve persons of age between 25 and 34 years old at police controlled junctions.

Table 24: Motorcycles accidents with respect to junction type and age of persons in moped, Greece 2005-2007.

	Junction Type	Age of Persons in Moped							
		Unknown	15-24	25-34	35-44	45-54	55-64	65+	Total
Inside urban area	Junction with traffic lights	7%	20%	35%	20%	10%	6%	2%	2.121
	Junction - police controlled	6%	23%	29%	19%	10%	7%	5%	1.736
	Junction not controlled	9%	27%	29%	17%	10%	5%	3%	2.768
	Other	8%	19%	36%	19%	9%	4%	5%	169
outside urban area	Junction with traffic lights	4%	25%	29%	18%	14%	7%	4%	28
	Junction - police controlled	1%	23%	36%	19%	6%	7%	7%	69
	Junction not controlled	1%	24%	31%	18%	9%	9%	8%	170
	Other	0%	19%	31%	23%	8%	12%	8%	26
Total		517	1.660	2.221	1.315	712	408	254	7.087

3.2.3.3. Type of Accident by Road Geometry

Table 25 summarizes the interactions between collision type and road geometry in accidents involving motorcycles and other moving vehicles. Inside urban areas, on straight roads, the majority of collisions are lateral ones. Lateral collisions inside urban areas are mostly observed in straight roads; in urban areas lateral collisions account for the 50% of the total accidents observed in straight roads. Significant number of accidents is also observed in bends and slopes. As for accidents observed outside urban areas, a similar pattern with accidents inside urban areas is observed. Moreover, 28% of narrow passage accidents between motorcycles and moving vehicles inside urban areas are head-on collision. In areas outside urban environments, narrow passages are also strongly related to lateral collisions.

Table 25: Motorcycles accidents with other moving vehicles with respect to collision type and road geometry characteristics, Greece 2005-2007.

	Road Geometry*	Head-on	Lateral	At angle	Rear end	Total
Inside urban area	Straight road	8%	50%	24%	18%	5.183
	Bend	20%	43%	25%	11%	541
	Narrow passage	28%	42%	18%	12%	93
	Slope	15%	51%	19%	15%	583
outside urban area	Straight road	9%	37%	21%	33%	881
	Bend	26%	42%	18%	14%	333
	Narrow passage	38%	43%	10%	10%	21
	Slope	15%	38%	24%	22%	221

*some variables are not mutually exclusive

Table 26 shows that the majority of accidents involving motorcycles and pedestrians occur in straight roads and are significantly more frequent inside urban areas. In both areas, apart from straight roads, significant percentages of accidents are traced in road bends and slopes.

In Table 27 it is observed that most of the accidents with stationary elements observed in straight roads inside urban areas refer to collisions with an obstacle. 61% of accidents with stationary elements at slopes inside urban areas refer to collisions with an obstacle. Many of the accidents with stationary elements, outside urban areas are collisions with an obstacle. Skidding is almost exclusively observed in accidents without collision regardless of geometry. This applies to accidents observed both inside and outside urban areas (Table 28). Motorcycle accidents without collision, outside urban areas, differ from those of mopeds, in that the latter are not related to skidding.

Table 26: Motorcycles accidents between motorcycles and pedestrians with respect to road geometry characteristics, Greece 2005-2007.

	Road Geometry*	Accident between a motorcycles and a pedestrians	%
Inside urban area	Straight road	1.339	89%
	Bend	51	3%
	Narrow passage	12	1%
	Slope	105	7%
outside urban area	Straight road	40	69%
	Bend	8	14%
	Narrow passage	1	2%
	Slope	9	16%
Total		1.565	

*some variables are not mutually exclusive

Table 27: Percentage of accidents between motorcycles and stationary vehicles or obstacles with respect to collision type at different road geometry characteristics, Greece 2005-2007.

	Road Geometry*	Collision with Stationary Element				total
		Collision with a vehicle slowing/stopping/ stationary	Collision with a parked vehicle	Collision with an obstacle	Collision with a train	
Inside urban area	Straight road	24%	29%	48%	0%	645
	Bend	4%	17%	79%	0%	192
	Narrow passage	9%	18%	73%	0%	22
	Slope	18%	20%	61%	0%	98
outside urban area	Straight road	20%	14%	67%	0%	87
	Bend	3%	6%	90%	0%	94
	Narrow passage	0%	0%	0%	0%	4
	Slope	7%	11%	83%	0%	46
Total		205	264	719	0	1.188

*some variables are not mutually exclusive

Table 28: Motorcycles accidents (without collision) with respect to road geometry characteristics, Greece 2005-2007.

	Road Geometry*	Running off-road (skidding)	Other	Total
Inside urban area	Straight road	90%	10%	966
	Bend	97%	3%	345
	Narrow passage	93%	7%	28
	Slope	94%	6%	195
outside urban area	Straight road	98%	2%	330
	Bend	92%	8%	346
	Narrow passage	100%	0%	21
	Slope	97%	3%	202
Total		2.295	138	2.433

*some variables are not mutually exclusive

3.2.3.4. Type of Accident by Pavement Conditions

As can be observed in Table 29, the majority of fatalities observed between 2005 and 2007 occurred in accidents under dry pavement conditions, as in the case of mopeds. The same applies to injuries.

In Table 30, it can be seen that asphalt is the most frequently observed pavement type in motorcycle accidents in both inside and outside urban areas, as expected.

Table 29: Motorcycle accidents with respect to pavement conditions, Greece 2005-2007.

	Pavement Condition	Fatalities (Killed at 30)	% Fatalities	Injuries	Total
Inside urban area	Dry	775	4%	19.493	20.268
	Wet	25	3%	766	791
	Slippery	1	1%	72	73
	Icy	0	0%	14	14
	Snow-clad	2	5%	35	37
	Other	3	7%	41	44
outside urban area	Dry	460	15%	2.537	2.997
	Wet	21	19%	91	112
	Slippery	0	0%	9	9
	Icy	0	0%	3	3
	Snow-clad	0	0%	8	8
	Other	5	0%	8	13
Total		1.287		23.061	

Table 30: Motorcycle accidents with respect to pavement conditions and pavement type, Greece 2005-2007.

	Pavement Condition	Fatalities (Killed at 30)				Injuries				Total
		Asphalt	Concrete	Other	Total	Asphalt	Concrete	Other	Total	
Inside urban area	Dry	769	3	3	775	19.422	17	594	19.428	20.203
	Wet	25	0	0	25	762	2	2	762	787
	Slippery	1	0	0	1	70	1	1	70	71
	Icy	0	0	0	0	14	0	0	14	14
	Snow-clad	2	0	0	2	35	0	0	35	37
	Other	1	0	2	3	37	0	4	39	42
outside urban area	Dry	290	0	6	296	2.524	0	13	2.530	2.826
	Wet	13	0	0	13	89	0	2	89	102
	Slippery	0	0	0	0	7	0	2	7	7
	Icy	0	0	0	0	3	0	0	3	3
	Snow-clad	0	0	0	0	8	0	0	8	8
	Other	2	0	0	2	6	0	2	6	8
Total		1.103	3	11	1.117	775	20	620	22.991	24.108

3.2.4. Comparison of Moped and Motorcycle Accidents in Greece

Absolute figures of moped and motorcycle accidents are contrasted. As illustrated in Figure 1, the magnitude of motorcycle fatalities is significantly greater than the magnitude of moped fatalities. Motorcycle accidents in single carriageway with at least one lane in each way (direction) are significantly higher compared to the other types of carriageway in both areas.

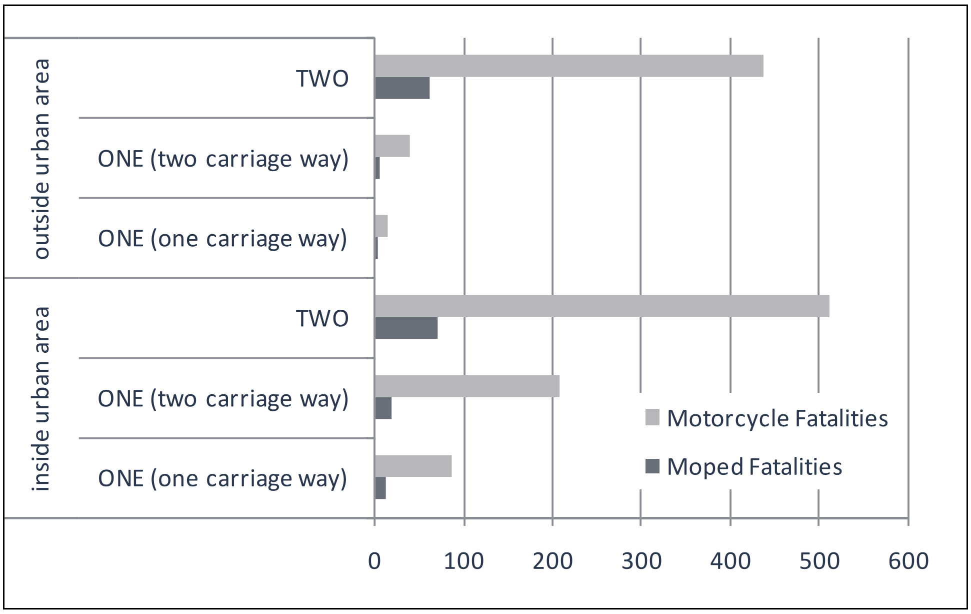


Figure 1: Moped and motorcycle fatalities with respect to area and carriageway type, Greece 2005-2007.

However, as seen in Table 31, the distribution of moped fatalities per carriageway type follow similar pattern as in the case of motorcycle accidents.

Table 31: Moped and Motorcycle total fatalities and injuries with respect to carriageway type, Greece 2005-2007.

	Carriageway Type	Mopeds			Motorcycles			Total
		% Fatalities	% Injuries	Total Fatalities and Injuries	% Fatalities	% Injuries	Total Fatalities and Injuries	
Inside urban area	ONE (one carriage way)	2%	98%	450	2%	98%	4.239	4.689
	ONE (two carriage way)	4%	96%	432	4%	97%	5.888	6.320
	TWO	5%	95%	1474	5%	95%	11.106	12.580
	Total	4%	96%	2356	4%	96%	21.231	23.587
Outside urban area	ONE (one carriage way)	17%	83%	12	14%	87%	95	107
	ONE (two carriage way)	13%	87%	31	11%	89%	342	373
	TWO	17%	84%	364	16%	84%	2.707	3.071
	Total	16%	84%	407	16%	85%	3.143	3.550
Total		159	2.604	2.763	1.352	23.053	24.374	27.137

Regarding accidents with respect to junction type, absolute figures of moped and motorcycle accidents are also diverse. As seen in Figure 2, the magnitude of motorcycle fatalities is significantly greater than the magnitude of moped fatalities, while absolute figures of motorcycle accidents inside urban areas are significantly higher than the same figures outside urban areas. Moreover, motorcycle accidents in single carriageway with at least one lane in each way (direction) are significantly higher compared to the other types of carriageway in areas outside urban environment.

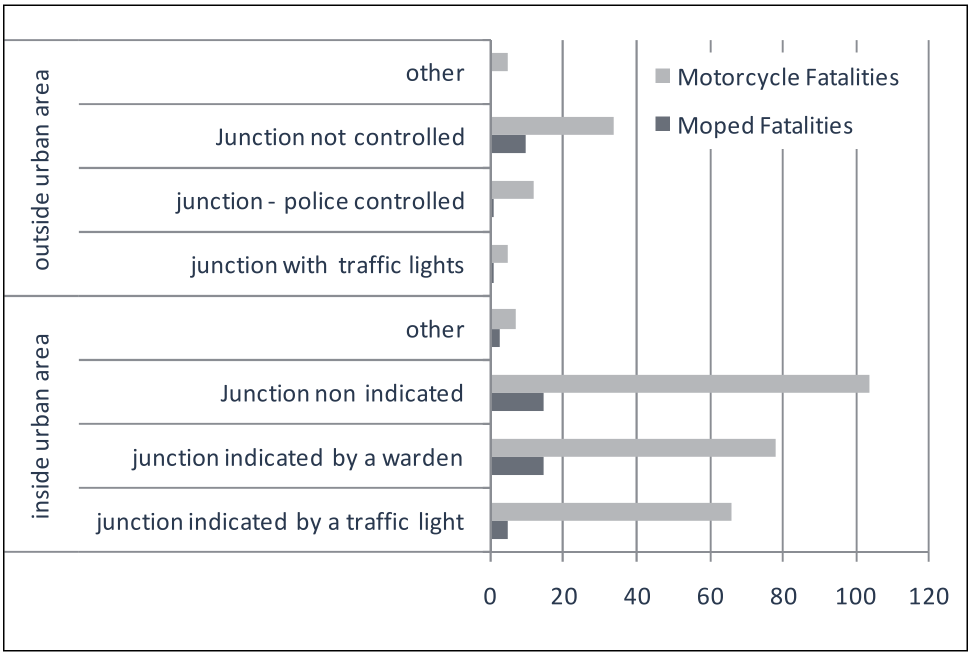


Figure 2: Moped and motorcycle fatalities with respect to area and junction type, Greece 2005-2007.

Moreover, at not controlled junctions outside urban areas, similar percentages for fatalities and injuries are observed for motorcycles and mopeds; the accident severity is similar for mopeds and motorcycles at junctions outside urban areas that are not controlled (Table 32).

Table 32: Moped and Motorcycle total fatalities and injuries with respect to junction type, Greece 2005-2007.

	Junction Type	Mopeds			Motorcycles			Total
		% Fatalities	% Injuries	Total Fatalities and Injuries	% Fatalities	% Injuries	Total Fatalities and Injuries	
Inside urban area	Junction with traffic lights	2%	98%	248	2%	98%	3.123	3.371
	Junction - police controlled	3%	97%	501	2%	98%	3.840	4.341
	Junction not controlled	3%	97%	477	3%	97%	4.145	4.622
	Other	6%	94%	51	3%	97%	256	307
Outside urban area	Junction with traffic lights	8%	92%	12	8%	92%	70	82
	Junction - police controlled	4%	96%	23	10%	90%	129	152
	Junction not controlled	20%	80%	49	17%	84%	240	289
	Other	0%	100%	4	16%	84%	36	40
Total		50	1.315	1.365	311	11.528	11.839	13.204

The magnitude of motorcycle fatalities is significantly greater than the magnitude of moped fatalities in hump or narrow passages in both urban and outside urban areas. Motorcycle fatalities are greater in bends inside urban areas when compared to moped fatalities (Figure 3).

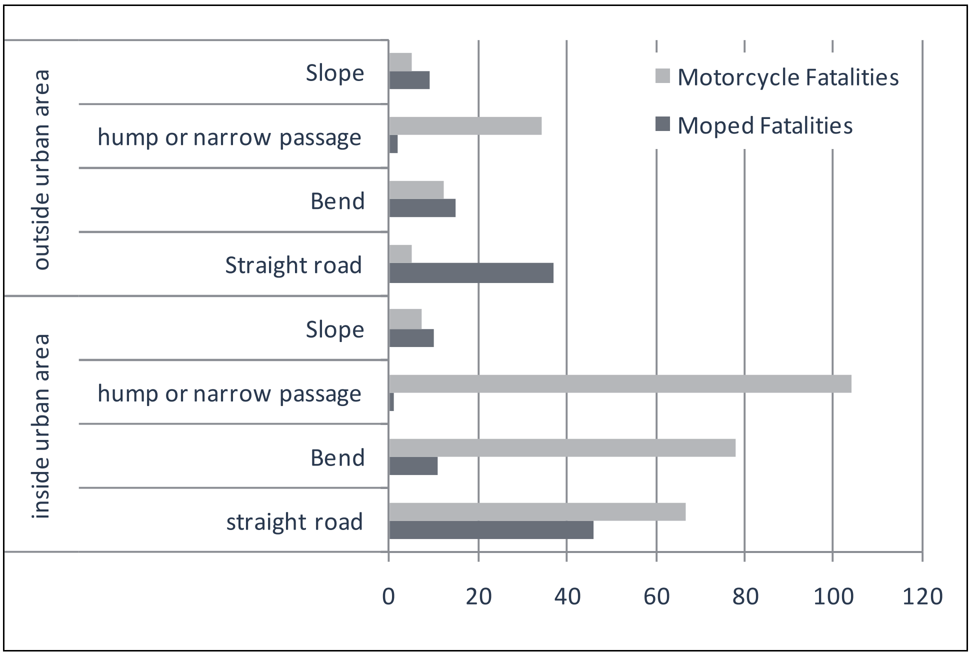


Figure 3: Moped and motorcycle fatalities with respect to area and road geometry, Greece 2005-2007.

The percentage of motorcycle fatalities at straight road and slopes are significantly low in both urban and interurban environment (Table 33). Moreover, narrow roads are critical for motorcycles regardless of the area type. Increased moped fatalities percentages are observed outside urban areas, especially narrow passages.

Table 33: Moped and Motorcycle total fatalities and injuries with respect to road geometry, Greece 2005-2007.

	Road Geometry*	Mopeds			Motorcycles			Total
		% Fatalities	% Injuries	Total Fatalities and Injuries	% Fatalities	% Injuries	Total Fatalities and Injuries	
Inside urban area	Straight road	6%	94%	793	1%	99%	8.490	9.283
	Bend	7%	93%	153	6%	94%	1.358	1.511
	Narrow passage	5%	95%	20	65%	35%	169	189
	Slope	6%	94%	155	1%	99%	1.094	1.249
Outside urban area	Straight road	19%	81%	192	0%	100%	1.638	1.830
	Bend	17%	83%	86	1%	99%	1.023	1.109
	Narrow passage	20%	80%	10	77%	23%	63	73
	Slope	13%	87%	71	1%	99%	591	662
Total		131	1.349	1.480	1.169	13.257	14.426	15.906

*some variables are not mutually exclusive

Moreover, inside urban areas, motorcycle fatalities in narrow passages account for the 65% of total motorcycle accidents observed, whereas the same percentage drops to 5% for mopeds. Slope outside urban areas seems to be more critical in moped accidents comparing to motorcycle accidents.

3.2.5. Summary of Findings - Greece

More than 1.500 moped accidents with other moving vehicles inside urban areas were observed in Greece that account for the 88% of the total number of moped accidents with moving vehicles observed in Greece. The most prevailing remarks are the following:

- Lateral collisions account for the 68% of crashes inside urban areas and the 47% of crashes outside urban areas. Rear end and head-on collisions are proportionately twice as common outside urban areas when compared to accidents inside urban areas.
- For collisions between mopeds and pedestrians, inside urban areas, 57% of crashes occur is single carriageways with at least one lane in each way (direction); for outside urban areas, this percentage rises to 88% (although the numbers are small).
- In total, 46% of accidents between stationary objects and mopeds in urban areas are collisions with an obstacle, similarly for outside urban areas the majority of moped accidents occur with an obstacle.
- In total, most accidents between mopeds and moving vehicles are observed inside urban areas and at junctions controlled by police. Outside urban areas, the number of accidents between mopeds and moving vehicles is significantly lower and the majority occurs at junctions that are not controlled.
- Most moped collisions with an obstacle are observed in uncontrolled junctions inside urban areas.
- Proportionately more of younger moped users between 15 and 34 years old are involved in accidents than other age groups. Outside urban areas, 50% of accidents at junctions with traffic lights involving mopeds involve persons of age between 25 and 34 years old.
- Lateral collisions inside and outside urban areas are mostly observed in straight roads. In areas outside urban environments, narrow passages are exclusively related to lateral collisions.
- 60% of accidents with stationary objects/vehicles at slopes inside urban areas refer to collisions with an obstacle.

Regarding motorcycles in Greece, more than 14.500 motorcycle accidents with other moving vehicles inside urban areas were observed accounting for the 90% of the total number of motorcycle accidents with moving vehicles observed in Greece. Some remarks made are the following:

- Inside urban areas on single carriageways with at least one lane in each way (direction), 69% of the accidents are lateral collisions, while 68% of the motorcycle accidents on one-way carriageways with one or more lanes are lateral collisions.
- Rear end and head-on collisions are proportionately more common outside urban areas when compared to accidents inside urban areas.
- Lateral collisions account for 65% of motorcycle crashes inside urban areas and 45% of crashes outside urban areas. Lateral collisions are frequently observed in accidents between moving vehicles and motorcycles in junctions controlled by traffic lights.
- The majority of motorcycle accidents with a stationary element occur with an obstacle. In urban areas, 39% of accidents on one-way carriageways with one or more lanes account for collisions with a parked vehicle. Most motorcycle accidents which are collisions with an obstacle are observed in uncontrolled junctions inside urban areas.
- Most accidents between motorcycles and moving vehicles are observed inside urban areas and at junctions controlled by police. Outside urban areas, the number of accidents between motorcycles and moving vehicles is significantly lower and occur more often on junctions that are not controlled.
- 54% of the accidents inside urban areas between a motorcycle and a pedestrian are observed in junctions that are not controlled. The majority of accidents involving motorcycles and pedestrians occur in straight roads and are significantly more frequent inside urban areas.

- A higher number of younger motorcycle users between 25 and 34 years old are involved in accidents. Outside urban areas, 36% of accidents involving motorcycles at junctions controlled by warden involve persons of age between 25 and 34 years old.
- Accidents are mostly observed on straight roads regardless of the road geometry. Moreover, critical factors seem to be bends and slopes.
- Over a quarter of narrow passage accidents inside urban areas between motorcycles and moving vehicles are head-on collisions.
- Most of the motorcycle accidents in straight roads and at slope, at a bend and in narrow passage inside urban areas refer to collisions with an obstacle.

Finally, by contrasting moped and motorcycles accidents, the following are revealed:

- The magnitude of motorcycle fatalities is significantly greater than the magnitude of moped fatalities.
- The percentage of moped fatalities per carriageway type follow similar pattern to motorcycle fatalities.
- The percentage of motorcycle fatalities at junctions controlled by police are more than double comparing to similar moped accidents outside urban areas.
- The percentage of motorcycle fatalities at straight road and slopes are low in both urban and interurban environment and lower than the moped fatalities.
- Narrow roads are significantly more critical for motorcycles than mopeds regardless of the area type.
- Injuries and fatalities in accidents involving a PTW are mostly observed in dry weather conditions
- Skidding is systematically observed in PTW accidents both inside and outside urban areas

3.3. Interaction between Powered Two-Wheeler Accidents and Infrastructure in Spain

3.3.1. Methodology – Spanish Data Base and Available Data

In Spain traffic accidents are documented by the police. Accidents occurring on a public roadway, involving at least one vehicle and having caused at least one *victim* (i.e., a person killed outright or whose condition will require hospitalization or at least basic medical care) are recorded in the Spanish Road Accident Database. The Spanish database consists of approximately 90.000 accidents per year.

For this macro-analysis, a three-year period (2005-2007) has been considered and approximately 97.600 accidents involving at least one PTW (mopeds (53.1%) and motorcycles (46.2%)) have been included.

It is necessary to remark that exposure data is not available and therefore not included, since this macro analysis is descriptive and does not intend to calculate the risk associated to certain factors.

3.3.2. Overview of Interaction between PTW Accidents and Infrastructure in Spain

Motorcyclists form one of the most vulnerable groups of road users. In these accidents, fatalities account for 2% of the total number of injured motorcyclists, as shown in Figure 4.

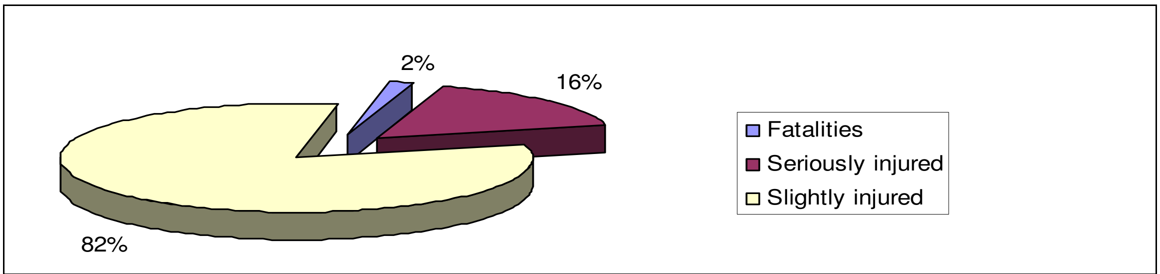


Figure 4: PTW accident victims (n=157.169 injured motorcyclists), Spain 2005-2007.

Sampling (accidents involving one PTW) took place in regions consisting of both urban (73,5%) and rural areas (26,5%). The majority of accidents, however, happened in an urban setting. Approximately three-quarters (71751) of all accidents occurred within city limits. Accidents involving PTW type < 50 cm^3 (mopeds) (60%) in urban areas outnumbered the accidents involving PTW >50 cm^3 (40%).

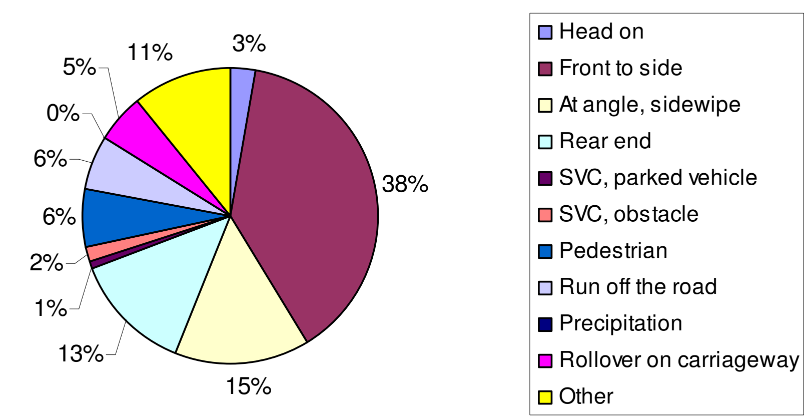
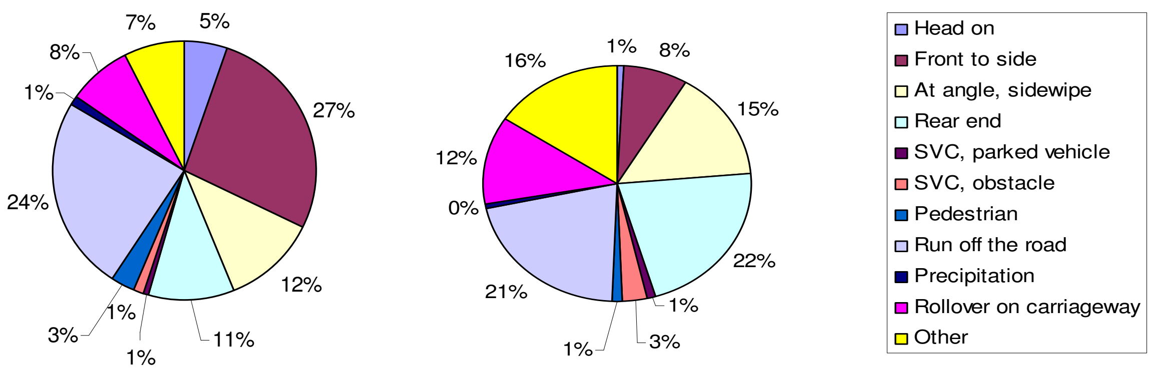


Figure 5: Type of collision. Inside urban area (n=71.751), Spain 2005-2007.

Analysing inside urban accidents' typology, front to side is the most frequent type of collision accounting for almost 40% of all accidents (see Figure 5).

Considering only outside urban accidents and differentiating between motorways and express roads, the following figures are obtained:



Type of collision. Express roads. (n=21809)

Type of collision. Motorways. (n=4042)

Figure 6: Type of collisions on express roads and motorways, Spain 2005-2007.

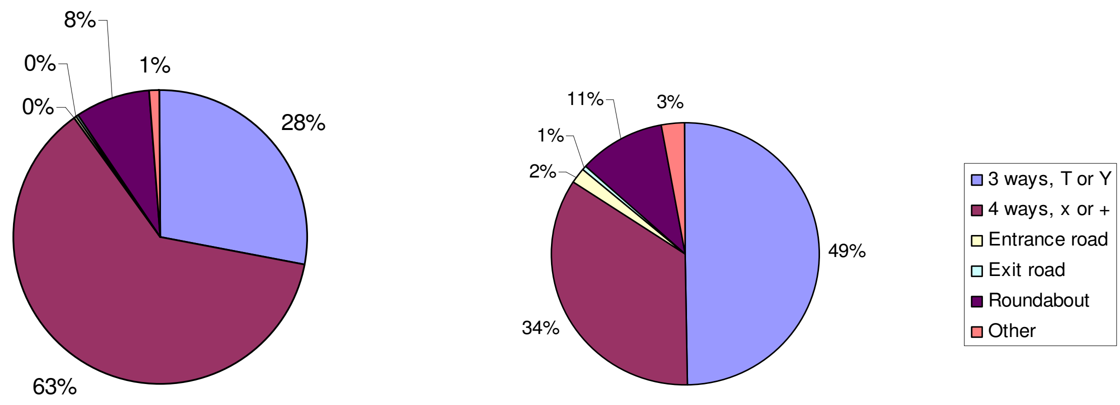
As the figures show (Figure 6), run-off-road and front-to-side accounted for half of the accidents in express roads, while rear-end and run-off-road are the most frequent type of collisions in motorways (43%).

Front to side, run-off-road and rear-end were the most frequent type of collisions representing almost 60% of the accidents. For this reason, the macro-analysis will be focused on these accident types.

3.3.3. Analysis of the most frequent type of collisions

3.3.3.1. Front-to-side accidents

Most of the front-to-side accidents occurred at intersections. Thus Figure 7 displays results of the type of intersections in which these accidents took place, differentiating between inside urban intersections and junctions located on express roads.

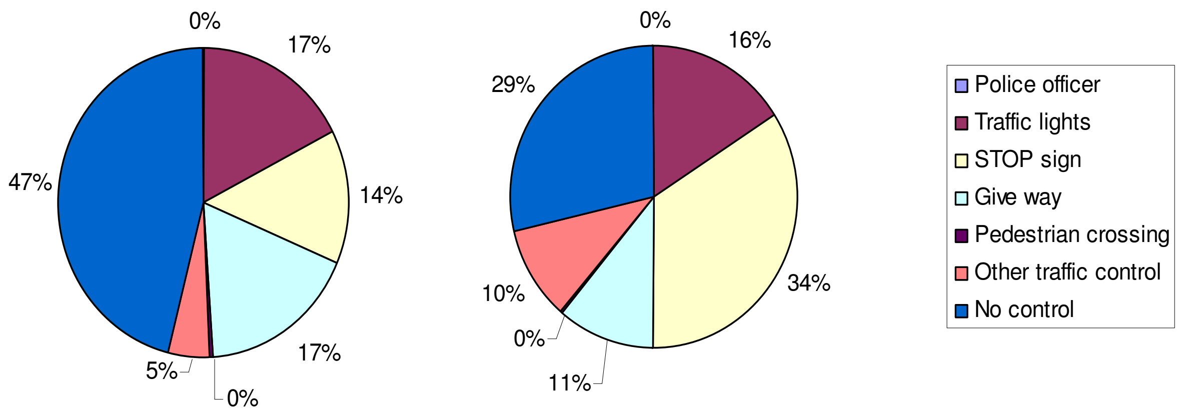


Type of junction. Inside urban. (n=19492) Type of junction. Express roads (n=4545)

Figure 7: Front-to-side accidents, Type of junction inside urban areas and on express roads, Spain 2005-2007.

For both inside and outside areas (express roads), the most common type of intersection where accidents happened is the 3-ways or 4-ways junction (Figure 7).

Regarding traffic control in these junctions, there is no traffic control in almost half of inside urban accidents and most of the front-to-side collisions in express roads are controlled by a STOP sign, as shown in Figure 8.



Traffic control. Inside urban. (n=16929) Traffic control. Express roads (n=4466)

Figure 8: Front-to-side accidents, Traffic control in junctions inside urban areas and on express roads, Spain 2005-2007.

Moreover, nearly 70% of both inside urban and express roads accidents happen during daylight.

3.3.3.2. Run-off-road accidents

Run-off-road is the most frequent type of collision of the outside urban accidents. More than one third of these accidents took place on straight roads (Figure 9).

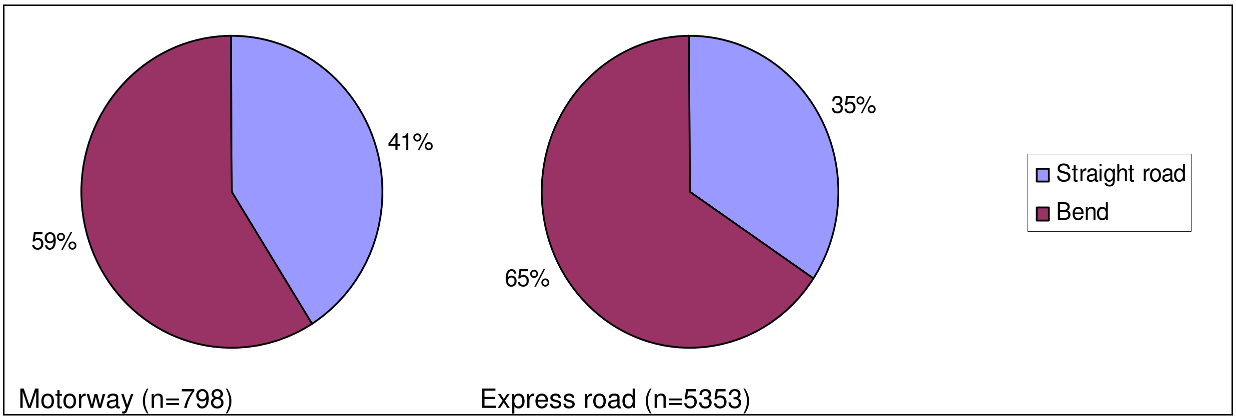


Figure 9: Run-off-road accidents, road design, Spain 2005-2007.

There is neither data regarding the orientation of the bends nor data about bend radius.

Although road surface condition could be a contributing factor especially for PTW vehicles, the road surface was dry in more than 90% of all run-off-road accidents (Figure 10).

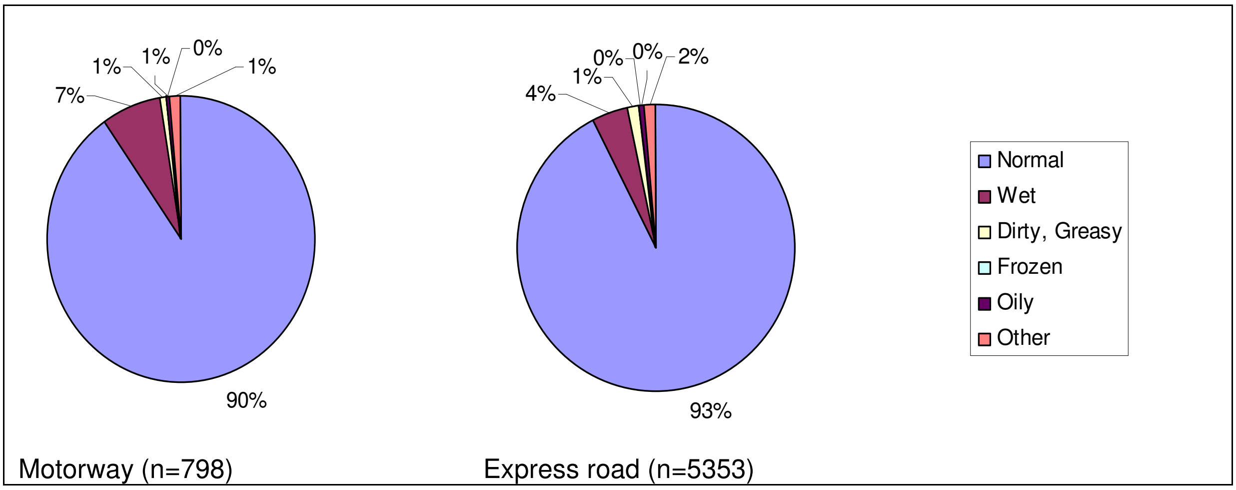


Figure 10: Run-off-road accidents, road surface condition, Spain 2005-2007.

Like front-to-side accidents, more than 70% run-off-road accidents happening both on motorways and express roads occurred during daylight.

Increasing carriageway and shoulder width could be a recommendable counter measure to minimise the effects of a possible loss of control of a vehicle. Thus, it is interesting to analyse these widths in express roads where there is more variability than in motorways.

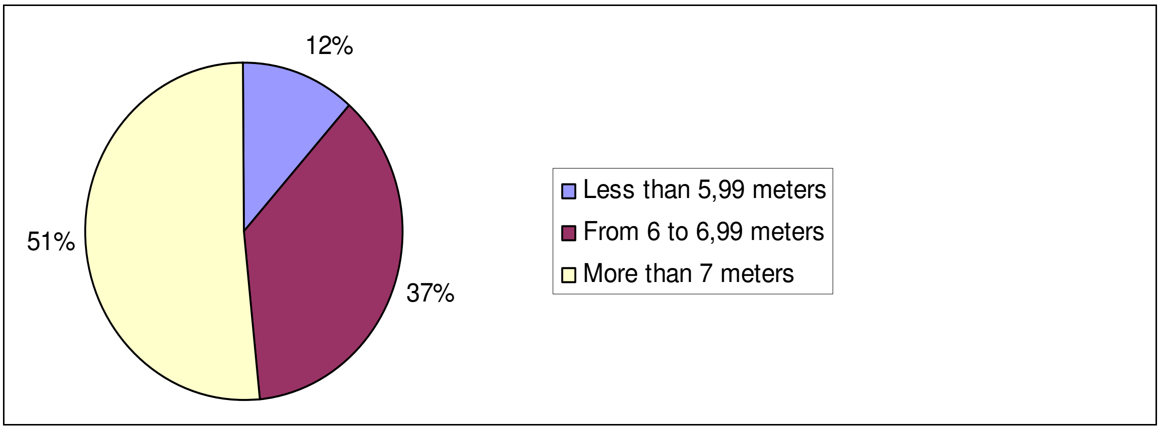


Figure 11: Run-off-road accidents, carriageway width on express roads (n=5353), Spain 2005-2007.

Half of the carriageways of express roads where run-off accidents happen are more than 7 meters wide (Figure 11), and most of them lack hard-shoulder or have one less than 1.5 meters wide (Figure 12).

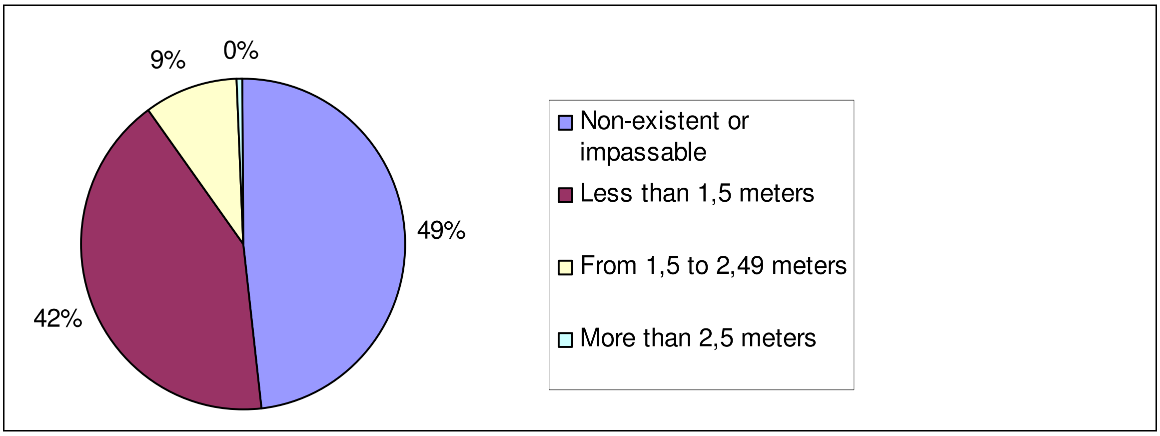


Figure 12: Run-off-road accidents, shoulder width on express roads (n=5353), Spain 2005-2007.

3.3.3.3. Rear-end accidents

Regarding the accident location, approximately 30% of both inside and outside urban rear-end collisions occurred at intersections (Figure 13).

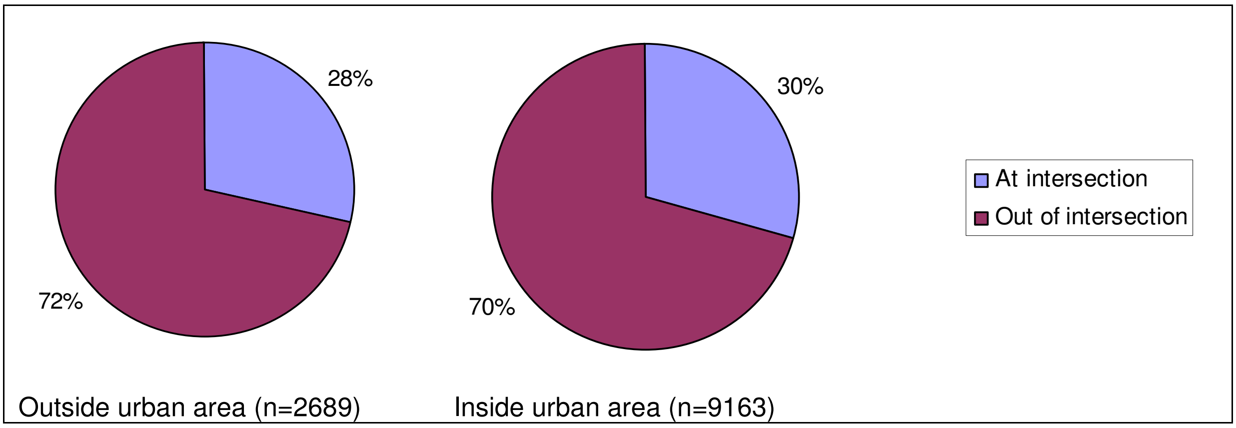


Figure 13: Rear-end accidents, inside and outside urban areas vs. intersections, Spain 2005-2007.

Analysing traffic control in these intersections, nearly 30% of inside urban rear-end accidents located at intersections are controlled by traffic lights, and half of them have no control. 40% of outside urban rear-end accidents that occurred at intersections are controlled by STOP or GIVE WAY signs (Figure 14).

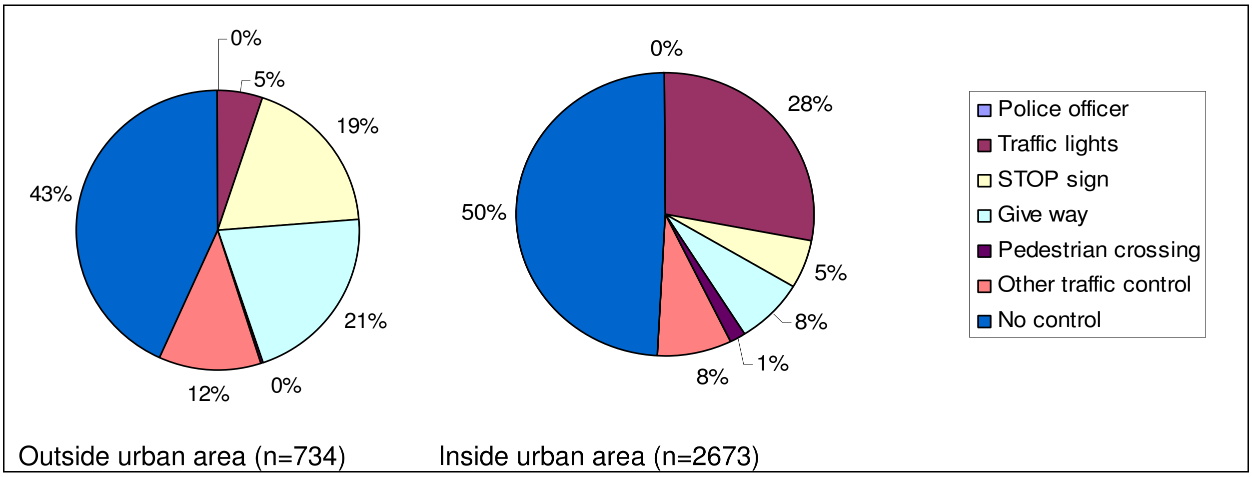


Figure 14: Rear-end accidents, inside and outside urban areas vs. traffic control, Spain 2005-2007.

3.3.4. Specific queries (Cross-tables between categories)

Also, some specific queries are presented in order to get a possible connection between PTW accidents and infrastructure parameters.

The following cross-tables (Table 34, Table 35 and Table 36) show where specific types of accidents occurred regarding the number of ways (directions) and carriageways. It is necessary to explain the criteria used to make the queries:

- One way (one carriageway): One-way carriageways with one or more lanes. Entrance/exit roads also are considered.
- One way (two carriageways): Dual-carriageway roads with a minimum of two lanes in each direction, frequently separated by a median.
- Two ways: Single carriageway with at least one lane in each way (direction).
- More: Rest of roads.

Table 34: Cross-table – accident type (between moving vehicles) vs. number of directions, Spain 2005-2007.

		accident type (between moving vehicles)			
		head-on	head-on side	side crash	nose to tail crash
Number of directions	ONE (one carriageway)	157 (0,16%)	3289 (3,37%)	1320 (1,35%)	945 (0,97%)
	ONE (two carriageway)	124 (0,13%)	2408 (2,47%)	1740 (1,78%)	2130 (2,18%)
	TWO	2902 (2,97%)	21435 (21,96%)	9510 (9,74%)	7241 (7,42%)
	MORE	281 (0,29%)	5984 (6,13%)	832 (0,85%)	1949 (2,00%)

Table 35: Cross-table – accident type (between moving vehicles and a pedestrian) vs. number of directions, Spain 2005-2007.

		accident type (between a moving vehicle and a pedestrian)
Number of directions	ONE (one carriageway)	602 (0,62%)
	ONE (two carriageway)	440 (0,45%)
	TWO	3218 (3,30%)
	MORE	759 (0,78%)

Table 36: Cross-table – accident type (between moving vehicles and a stationary one or other) vs. number of directions, Spain 2005-2007.

		accident type (between a moving vehicle and a stationary one or other)	
		Collision with a parked vehicle	Collision with an obstacle on carriageway
Number of directions	ONE (one carriageway)	137 (0,14%)	101 (0,10%)
	ONE (two carriageway)	133 (0,14%)	278 (0,28%)
	TWO	441 (0,45%)	908 (0,28%)
	MORE	64 (0,07%)	368 (0,38%)
		accident type (between a moving vehicle and a stationary one or other)	
		Running-off road (skidding)	Falling out of the vehicle
Number of directions	ONE (one carriageway)	559 (0,57%)	540 (0,55%)
	ONE (two carriageway)	1713 (1,76%)	1010 (1,03%)
	TWO	8757 (8,97%)	4445 (4,55%)
	MORE	729 (0,75%)	331 (0,34%)

Concerning the accident location, it is interesting to differentiate between accidents which occur at intersections and accidents which occur out of intersections (Table 37 to Table 40 and Table 41 to Table 44), analysing e.g. the type of junction and the traffic control (junctions), or the road alignment (non-junction).

Percentages are always over totals (accidents, casualties, fatalities) and two different baselines are used (regarding junction/not junction; number of carriageways and directions).

Table 37: Cross-table – accident type (between moving vehicles) vs. junction type, Spain 2005-2007.

		accident type (between moving vehicles)			
		head-on	head-on side	side crash	nose to tail crash
Junction	Cross road (X or +)	480 (0,49%)	13896 (14,24%)	3556 (3,64%)	1524 (1,56%)
	T or Y junction	773 (0,79%)	7919 (8,11%)	2055 (2,11%)	1251 (2,11%)
	Roundabout	51 (0,05%)	2146 (2,20%)	1009 (1,03%)	506 (0,52%)
		accident type (between moving vehicles)			
		head-on	head-on side	side crash	nose to tail crash
Junction	Junction indicated by a traffic light	184 (0,19%)	3789 (3,88%)	1349 (1,38%)	817 (0,84%)
	Junction indicated by a warden	4 (0,00%)	33 (0,03%)	11 (0,01%)	2 (<0,01%)
	Junction non indicated	607 (0,62%)	9201 (9,43%)	3480 (3,57%)	1674 (1,72%)

Table 38: Cross-table – accident type (between moving vehicles and a pedestrian) vs. junction type, Spain 2005-2007.

		accident type (between a moving vehicle and a pedestrian)
Junction	Cross road (X or +)	920 (0,94%)
	T or Y junction	415 (0,43%)
	Roundabout	72 (0,07%)
		accident type (between a moving vehicle and a pedestrian)
Junction	Junction indicated by a traffic light	377 (0,39%)
	Junction indicated by a warden	5 (0,00%)
	Junction non indicated	738 (0,76%)

Table 39: Cross-table – accident type (between moving vehicles and a stationary one or other) vs. junction type (part 1), Spain 2005-2007.

		accident type (between a moving vehicle and a stationary one or other)	
		Collision with a parked vehicle	Collision with an obstacle on carriageway
Junction	Cross road (X or +)	40 (0,04%)	119 (0,12%)
	T or Y junction	49 (0,05%)	107 (0,11%)
	Roundabout	14 (0,1%)	67 (0,07%)
		accident type (between a moving vehicle and a stationary one or other)	
		Collision with a parked vehicle	Collision with an obstacle on carriageway
Junction	Junction indicated by a traffic light	17 (0,02%)	36 (0,04%)
	Junction indicated by a warden	0	0
	Junction non indicated	55 (0,06%)	133 (0,14%)

Table 40: Cross-table – accident type (between moving vehicles and a stationary one or other) vs. junction type (part 2), Spain 2005-2007.

		accident type (between a moving vehicle and a stationary one or other)	
		Running-off road (skidding)	Falling out of the vehicle
Junction	Cross road (X or +)	801 (0,82%)	672 (0,69%)
	T or Y junction	656 (0,67%)	618 (0,63%)
	Roundabout	605 (0,62%)	676 (0,69%)
		accident type (between a moving vehicle and a stationary one or other)	
		Running-off road (skidding)	Falling out of the vehicle
Junction	Junction indicated by a traffic light	319 (0,33%)	267 (0,27%)
	Junction indicated by a warden	1 (0,00%)	4 (0,00%)
	Junction non indicated	2228 (2,28%)	870 (0,89%)

Table 41: Cross-table – accident type (between moving vehicles) vs. non-junction type, Spain 2005-2007.

		accident type (between moving vehicles)			
		head-on	head-on side	side crash	nose to tail crash
Non-Junction	Straight road	1104 (1,13%)	7531 (7,72%)	5616 (5,75%)	8031 (8,23%)
Non-Junction	Bend	994 (1,02%)	1032 (1,06%)	773 (0,79%)	647 (0,66%)
		head-on	head-on side	side crash	nose to tail crash
Non-Junction	Hump	29 (0,03%)	23 (0,02%)	12 (0,01%)	24 (0,02%)
Non-Junction	Narrow passage	22 (0,02%)	15 (0,02%)	16 (0,02%)	6 (0,01%)
Non-Junction	Slope	38 (0,04%)	38 (0,04%)	17 (0,02%)	13 (0,01%)

Table 42: Cross-table – accident type (between moving vehicles and a pedestrian) vs. non-junction type, Spain 2005-2007.

		accident type (between a moving vehicle and a pedestrian)
Non-Junction	Straight road	3311 (3,39%)
Non-Junction	Bend	218 (0,22%)
Non-Junction	Hump	4 (0,00%)
Non-Junction	Narrow passage	6 (0,01%)
Non-Junction	Slope	10 (0,01%)

Table 43: Cross-table – accident type (between moving vehicles and a stationary one or other) vs. non-junction type (part 1), Spain 2005-2007.

		accident type (between a moving vehicle and a stationary one or other)	
		Collision with a parked vehicle	Collision with an obstacle on carriageway
Non-Junction	Straight road	541 (0,55%)	1048 (1,07%)
	Bend	120 (0,12%)	270 (0,27%)
		Collision with a parked vehicle	Collision with an obstacle on carriageway
Non-Junction	Hump	4 (0,00%)	8 (0,01%)
	Narrow passage	4 (0,00%)	9 (0,01%)
	Slope	1 (0,00%)	17 (0,02%)

Table 44: Cross-table – accident type (between moving vehicles and a stationary one or other) vs. non-junction type (part 2), Spain 2005-2007.

		accident type (between a moving vehicle and a stationary one or other)	
		Running-off road (skidding)	Falling out of the vehicle
Non-Junction	Straight road	4340 (4,45%)	3147 (3,22%)
	Bend	4575 (4,68%)	1058 (1,08%)
		Running-off road (skidding)	Falling out of the vehicle
Non-Junction	Hump	26 (0,03%)	2 (0,00%)
	Narrow passage	49 (0,05%)	3 (0,00%)
	Slope	93 (0,1%)	3 (0,00%)

Finally, severity data for different situations are presented in the following table (Table 45):

Table 45: Cross-tables – severity data vs. junction type, non-junction type and number of directions, Spain 2005-2007.

		Summary involved in accident	
		Total of fatalities	Total injured people
Junction	Cross road (X or +)	226 (0,19%)	29172 (24,58%)
	T or Y junction	263 (0,22%)	17769 (14,97%)
	Roundabout	62 (0,05%)	6583 (5,55%)
		Summary involved in accident	
		Total of fatalities	Total injured people
Non-Junction	Straight road	690 (0,58%)	47842 (40,31%)
	Bend	818 (0,69%)	12765 (10,76%)
		Summary involved in accident	
		Total of fatalities	Total injured people
Number of directions	ONE (one carriageway)	63 (0,05%)	9813 (8,27%)
	ONE (two carriageway)	401 (0,34%)	13285 (11,19%)
	TWO	1481 (1,25%)	77529 (65,33%)
	MORE	191 (0,16%)	15912 (13,41%)

As general conclusions, accidents which happened in dual-carriageway roads were much more severe than the accidents which occurred in single carriageway roads with only one way of circulation, since the difference between the numbers of accidents in both roads is not proportional to the huge difference between the numbers of fatalities.

Front-to-side accidents generally took place at intersections. Considering just three types of junctions (Crossroads, T or Y junctions, and roundabout), front-to-side accidents happened more frequently at crossroads (58%), followed by “T or Y” junctions (33%) and finally by roundabouts (9%). The death toll associated to both type of 3-way junctions is similar, despite of the higher number of victims associated to crossroads.

Concerning out-of-intersection accidents, even though the number of accidents which occurred in straight section of roads was higher than the number of accidents which happened in bends, the first ones presented a lower number of fatalities.

3.3.5. Summary of Findings – Spain

- **Front-to side, run-off-road** and **rear-end** represent nearly **60%** of all accidents.
- **Inside urban accidents** account for three quarters of all accidents.
- **Road surface** is dry in more than 90% of run-off-road accidents.
- For front-to-side collisions, 3-ways intersections (**T or Y**) and 4-ways intersections (**X** or **+**) are the most frequent type of junctions in **outside urban** and **inside urban** areas respectively.
- Carriageways are wider than 7 meters in half of all run-off-road accidents.
- Carriageways lack hard shoulders in half of all run-off-road accidents.
- Approximately **30%** of rear-end accidents occur at **intersections**, mostly **without traffic control**.
- Accidents which happen in **dual carriageway roads are the most severe**, considering the number of fatalities with regard to the number of accidents.
- **Cross-roads are the most frequent type of intersection** where accidents occur and consequently account for the majority of victims registered at intersections.
- **Cross roads and “T or Y” junctions have a similar number of fatalities associated**, despite of the higher number of victims registered in crossroads.
- Even though the **number of accidents** which occur in **straight sections** of roads is **higher** than the number of accidents which happen in bends, the first ones present a **lower number of fatalities.**

3.4. Interaction between Powered Two-Wheeler Accidents and Infrastructure in Great Britain

3.4.1. Methodology – British Data Base and Available Data

This report provides the deliverable in respect of the activity 1.2, comprising the analysis of the GB road accident database, STATS19. The objective of this activity is to investigate which road infrastructure elements (road design elements and road surface parameters) have an influence on PTW accidents.

STATS19 (Department for Transport - DfT, 2008) contains details of all reported personal injury road accidents for GB. It incorporates huge amounts of data relating to multiple variables for each incident. All incidents relating to PTWs from years 2005-2007 were analysed with the aim of identifying accident trends with respect to infrastructure elements. There are incident records of 74.562 PTWs on the database within these years, which can be broken down further into motorbike types:

- 50cc and under 14737 (19.8%)
- Over 50cc and up to 125cc 20215 (27.1%)
- Over 125cc and up to 500cc 8183 (11.0%)
- Over 500cc 31427 (42.1%)

Firstly, relevant infrastructure-related data categories were identified from the STATS19 database. An initial high level analysis was conducted on each of these to identify which infrastructure elements are the most prevalent within the accident data.

The data categories were then analysed to a more in-depth level by cross-tabulating between various different factors to identify trends and relationships. For example, a table could be produced with 'types of junction' as row headers and 'objects hit in carriageway' as column headers. Each square within the table would show the number of cases fulfilling both criteria. This would therefore provide an indication of which combinations of these two factors were more prevalent in the accident statistics. A number of these cross-tables were produced, each intended to analyse different infrastructure-related elements.

3.4.2. Interaction between PTW Accidents and Infrastructure in Great Britain

3.4.2.1. Basic road network statistics

To provide a basis for drawing conclusions from the tables in the following sections, below is a basic summary of the UK road network (Table 46 - figures taken from Dft, 2009):

Table 46: Basic summary of the UK road network.

Road Class	Urban (km)	Rural (km)	Total (km)
Motorway & A(M)	-	3,559	3,559
A	11,106	35,586	46,692
B	5,476	24,685	30,161
C	10,992	73,582	84,574
Unclassified	114,450	115,032	229,482
Total	142,024	252,444	394,468

Glossary for Road Class

Motorway: Public road with dual carriageways and at least two lanes each way, though usually three and sometimes four. Interchanges are grade separated. The carriageways are separated by a central barrier or central reservation. No crossing is permitted and no stopping is permitted unless in an emergency (a hard shoulder is usually provided for this purpose). Entry is prohibited for pedestrians, animals, pedal cycles, mopeds, agricultural vehicles and learner drivers. The maximum permitted speed is 70 mph.

A(M) Road: As motorway

A Road: A roads are any other major routes not falling under Motorway classification. They will typically be single carriageway but not always and may sometimes reach motorway standard. Speed limits range from 30-70 mph. The key distinguishing feature from lower categories is their importance as a major travel corridor. Classification is however unrelated to road width or quality.

B Road: These are typically local routes with lower traffic densities than A roads and are typically not more than 15 miles long. Speed limits will typically range from 30-60 mph. Again, classification is unrelated to road width or quality.

C Road: C roads are generally minor local roads with low traffic densities relative to higher classifications, although in urban areas this may still represent high traffic flows. Speed limits will typically range from 20-60 mph.

Unclassified road: Any road not assigned a classification from the above listing.

3.4.2.2. Relevant STATS19 data categories

The following categories were identified as being relevant for the analysis (either by being directly related to infrastructure elements, or indirectly related - representing a potential influencing factor on rider interactions with infrastructure elements or measure of the accident type).

Reference numbers are taken directly from STATS19:

Attendant circumstances variables:

- 1.9 Time
- 1.12 Road class
- 1.14 Road type
- 1.15 Speed limit
- 1.16 Junction detail
- 1.21 Light conditions
- 1.22 Weather
- 1.23 Road surface conditions

Vehicle variables:

- 2.7 Manoeuvre
- 2.11 Skidding and overturning
- 2.12 Hit object in carriageway
- 2.14 Hit object off carriageway
- 2.16 First point of impact
- 2.22 Age of rider

Casualty variables:

- 3.9 Severity of casualty

3.4.2.3. Prevalence of specific elements within categories

It should be noted that the following tables are all compiled from the same data and should in theory all give the same total figure in terms of either vehicle count or incident count (74.562). In fact the totals vary to a slight degree due to some data being omitted. This is the case where the data was not recorded within the database or was entered as ‘unknown’. The discrepancies between the totals are however minimal and are not considered to have a significant effect on the validity of the figures. It will also be noted that each table has values highlighted in red, orange and yellow. This is simply intended to highlight the three highest incident/vehicle counts respectively.

Some data are also ‘greyed out’ in the tables. This is where data categories are non-descript and therefore do not tie in with the other categories for meaningful comparison. For example, categories of ‘other’ or ‘unknown’ are greyed out.

1.9) Time of day:

Table 47: Time of day query, UK 2005-2007.

Time period	Vehicle count	Percentage
00:00 - 02:59	1211	1.62
03:00 - 05:59	771	1.03
06:00 - 08:59	10448	14.01
09:00 - 11:59	9061	12.15
12:00 - 14:59	13442	18.03
15:00 - 17:59	20077	26.93
18:00 - 20:59	13713	18.39
21:00 - 23:59	5829	7.82

The time period '15:00-17:59' is shown to be the dominant time for PTW accidents (Table 47), followed by the pre and proceeding 3-hour periods. Although there is a slight peak around the morning rush-hour period, there are still far fewer vehicles involved in accidents than in the evening. It should be noted that this does not necessarily give an indication of increased rider risk however, as the figures do not account for the possibility of increased numbers of riders on the roads at these times due to these figures not being available.

1.12) Road Class

Table 48: Road class query, UK 2005-2007.

Road class	Incident count	Percentage	Incidents per 1000 km
Motorway & A(M)	1210	1.62	340.0
A	37148	49.82	795.6
B	9743	13.07	323.0
C	6383	8.56	75.5
Unclassified	20078	26.93	87.5

Class A roads are shown (Table 48) to be the dominant road type for PTW accidents, far outstripping any other road type, suggesting a clear need to focus on accidents on these roads. B roads should also be looked at as both absolute numbers and the relative risk (i.e. incidents per 1000km) are fairly high. The second most prevalent road class ('unclassified') has a high number of accidents, although the relative risk is low. For broad definitions of the different road classes, see the glossary in section 3.4.2.1 of this report.

1.14) Road type

Table 49: Road type query, UK 2005-2007.

Road type	Incident count	Percentage
Roundabout	5689	7.63
One way street	1297	1.74
Dual carriageway	7957	10.67
Single carriageway	58652	78.66
Slip road	533	0.71
Unknown	434	0.58

The figures (Table 49) show that single carriageway roads dominate the accident statistics and are by far the most common road type for PTW accidents. Note – a slip road is a short stretch of road that allows either entry or exit to/from a dual carriageway, without crossing any other traffic stream.

1.15) Speed limit

Table 50: Speed limit query, UK 2005-2007.

Speed limit	Incident count	Percentage
20	302	0.41
30	49434	66.30
40	6422	8.61
50	2098	2.81
60	13327	17.87
70	2978	3.99

Table 50 shows the high proportion of accidents in 30 mph areas shows that accidents are most likely to occur in built up areas. It would therefore be prudent to focus on accidents in these areas. Accidents on national speed limit roads are a distant second in terms of numbers, but still more than double the next category. An analysis of accident severity related to speed limit is provided in section 3.4.3 of the report.

1.16) Junction detail

Table 51: Junction detail query, UK 2005-2007.

Junction detail	Incident count	Percentage
Not at or within 20m of junction	25604	34.34
Roundabout	6579	8.82
Mini roundabout	650	0.87
T or staggered junction	26569	35.63
Slip road	822	1.10
Crossroads	6471	8.68
Multiple junction	1014	1.36
Using private drive or entrance	4123	5.53
Other junction	2730	3.66

It can be seen that there are more accidents at T-junctions (Table 51) than any other junction type. Interestingly, this even outstrips the number of accidents away from junctions. T-junctions would therefore seem to pose a risk to PTW riders. However, given the relative frequencies of junction types, roundabouts and crossroads also have high accident figures. It should be noted however that this assertion is based on intuitive estimates of the relative frequencies of such junction types, as actual numbers are not known.

1.21) Light conditions

Table 52: Light conditions query, UK 2005-2007.

Light conditions		Incident count	Percentage
daylight	Street lights present	40543	54.37
	No street lighting	14629	19.62
	Street lighting unknown	1785	2.39
darkness	Street lights present and lit	14745	19.78
	Street lights present but unlit	313	0.42
	No street lighting	2062	2.77
	Street lighting unknown	485	0.65

The vast majority of accidents occur during daylight hours (Table 52), likely to be an indication of generally higher traffic volumes during the day. The high number of accidents in areas where street lights are present is likely to be a further indicator of accidents tending to occur in built-up areas.

1.22) Weather

Table 53: Weather query, UK 2005-2007.

Weather	Incident count	Percentage
Fine without high winds	63076	84.60
Raining without high winds	7024	9.42
Snowing without high winds	182	0.24
Fine with high winds	842	1.13
Raining with high winds	632	0.85
Snowing with high winds	17	0.02
Fog or mist – if hazard	309	0.41
Other	1448	1.94
Unknown	1032	1.38

Despite adverse weather conditions being likely to result in degraded riding conditions, accidents during fine weather still dominate the accident figures (Table 53). This is a clear reflection of the large number of bikers who only use their motorcycles during fair weather conditions. Note that “other” and “unknown” have been greyed out as these are non-descript categories that offer little insight.

1.23) Road surface conditions

Table 54: Road surface conditions query, UK 2005-2007.

Road surface condition	Incident count	Percentage
Dry	56568	75.93
Wet/damp	17226	23.12
Snow	93	0.12
Frost/ice	579	0.78
Flood (water over 2cm deep)	37	0.05

As with those related to weather, dry road surface conditions dominate the accident figures (Table 54). However, wet/damp conditions are a much closer second. This could be an indication of riders going out after it has rained and crashing due to the slippery road, although this can only be speculated.

As a rough guide to these figures, the average number of days with over 1.0mm of rain ranges between about 110 and 220 in the UK, although the majority of the more populated areas within the UK average less than 150 days (Met Office, 2009). The more populated areas also experience on average between about 80 and 125 days of ground frost per year.

2.7) Manoeuvre

Table 55: Manoeuvre query, UK 2005-2007.

Manoeuvre	Vehicle count	Percentage
Reversing	80	0.11
Parked	233	0.31
Waiting to go ahead but held up	1881	2.52
Slowing or stopping	3383	4.54
Moving off	1204	1.62
U turn	211	0.28
Turning left	1654	2.22
Waiting to turn left	204	0.27
Turning right	2924	3.92
Waiting to turn right	461	0.62
Changing lane to left	326	0.44
Changing lane to right	404	0.54
Overtaking moving vehicle on its offside	6175	8.28
Overtaking stationary vehicle on its offside	3230	4.33
Overtaking on nearside	1293	1.73
Going ahead left hand bend	4644	6.23
Going ahead right hand bend	3969	5.32
Going ahead other	42265	56.70

'Going ahead other' is by far the dominant manoeuvre in the figures (Table 55). However, this is a non-descript category and may simply be an easy choice to default to at a scene. With this category removed, 'overtaking a moving vehicle' and 'going ahead on bends' stand out. These are higher speed manoeuvres.

2.11) Skidding and overturning

Table 56: Skidding and overturning query, UK 2005-2007.

Skidding and overturning	Vehicle count	Percentage
No skidding or overturning	54758	73.44
Skidded	15369	20.61
Skidded and overturned	2607	3.50
Overturned	1823	2.45

Table 56 shows that riders tend to remain upright, although these primarily represent the less serious accidents. A cross-tabulation of skidding/overturning with accident severity is included in the report.

2.12) Hit object in carriageway

Table 57: Hit object in carriageway query, UK 2005-2007.

Object hit in carriageway	Vehicle count	Percentage
None	70235	94.20
Previous accident	13	0.02
Roadworks	51	0.07
Parked vehicle	955	1.28
Bridge – roof	6	0.01
Bridge – side	17	0.02
Bollard/refuge	376	0.50
Open door of vehicle	109	0.15
Central island of roundabout	103	0.14
Kerb	1997	2.68
Other object	413	0.55
Any animal (except ridden horse)	283	0.38

In the vast majority of PTW accidents, riders avoid hitting carriageway objects (Table 57). Where an object is hit this is usually the kerb, with parked vehicles posing a stand-out hazard too. The number of accidents involving bollards or refuges is noticeably smaller, however the relatively low abundance of these (compared to kerbs or parked vehicles) suggest they may represent a greater hazard at any given location where they are present. Overall the low figures suggest that, whilst being a potentially important issue, it may not be practical to focus on objects in carriageway within the naturalistic riding study of the 2-BE-SAFE project.

2.14) Hit object off carriageway

Table 58: Hit object off carriageway query, UK 2005-2007.

Object hit off carriageway	Vehicle count	Percentage
None	69181	92.78
Road sign / traffic signal	530	0.71
Lamp post	381	0.51
Telegraph pole / electricity pole	101	0.14
Tree	462	0.62
Bus stop / bus shelter	29	0.04
Central crash barrier	320	0.43
Nearside or offside crash barrier	451	0.60
Completely submerged in water	5	0.01
Entered ditch	708	0.95
Other permanent object	2393	3.21

Once again, riders avoid hitting roadside objects the vast majority of the time (Table 58). Given the low numbers vehicles involved in accidents that do involve roadside objects, coupled with the fact that these objects are unlikely to be the cause of a crash, suggest that this is not a factor that would benefit from focussed attention for the purposes of this study, although there may well be significant value in addressing the issue in further studies or in work relating to accident blackspots.

2.16) First point of impact

Table 59: First point of impact query, UK 2005-2007.

First point of impact	Vehicle count	Percentage
Did not impact	6401	8.59
Front	42378	56.85
Back	4765	6.39
Offside	9391	12.60
Nearside	11606	15.57

Table 59 shows the dominance of the front as the first point of impact suggest that riders tend to hit rather than be hit by other vehicles in accidents (although a head-on collision could potentially be regarded as being hit depending on the circumstances). Where a rider is clearly hit (i.e. the other three categories) there is a dominance of side strikes, and within this a dominance of nearside collisions rather than offside collisions.

2.22) Age of rider

Table 60: Age of rider query, UK 2005-2007.

Age group	Vehicle count split				Total Count
	Up to 50cc	51-125cc	126-500cc	501cc & over	
16	5880	737	92	53	6762
17	2623	2431	287	148	5489
18	767	1875	358	238	3238
19	454	1410	289	345	2498
20	293	1080	300	400	2073
16-20	10017	7533	1326	1184	20060
21-25	935	3289	1090	3410	8724
26-30	663	2236	924	3852	7675
31-35	532	1739	873	4541	7685
36-40	455	1456	904	5390	8205
41-45	344	975	872	4854	7045
46-50	225	644	580	3242	4691
51-55	171	409	406	1982	2968
56-60	163	363	282	1268	2076
61+	198	359	331	787	1675
Unknown	1034	1212	595	917	3758

Young riders dominate the accident statistics (Table 60). Numbers clearly tend to reduce with age, although there is a slight peak at 36-40, possibly due to an increase in numbers of people taking up or coming back into motorcycling as they approach middle age. However, young riders are clearly the group most at risk.

3.9) Severity of casualty

Table 61: Severity of casualty query, UK 2005-2007.

Incident severity	Casualty count	Percentage
Fatal	1722	2.3
Severe	17457	23.4
Slight	49822	66.8
No injury	5561	7.5

Motorcycle accidents result in only slight injuries the majority of the time, but severe injuries still make up nearly a quarter of riders involved in incidents (Table 61).

3.4.3. Specific queries (Cross-tables between categories)

This section of the report aims to look deeper by producing cross tables between the proceeding individual data tables; thus revealing how such data categories relate to each other. However, cross table comparisons could be made between almost any two different factors, giving many possible combinations. The following are those considered to be (potentially) the most revealing. All comparisons involve an 'attendant circumstance variable' paired with a 'vehicle / casualty variable'.

The results from each cross-tabulation are presented in one or more of three possible ways:

1. A cross-table showing the actual count values of incidents falling into each category. In the interest of keeping the tables legible, rows or columns are sometimes omitted if they contain only low values.
2. A cross-table showing the count values converted into percentage. Percentages are in relation to columns rather than rows (thus the total percentages for each column will add up to 100). These tables therefore show the relative frequency of the row header categories within each column header category.
3. The same percentage data as 2 but in graph form.

All tables are colour-coded to the following format. Where a value (or values) clearly stand(s) out from the rest, this is shaded red. The next top 5 values are shaded orange and the remaining 5 from the top 10 are shaded yellow. Any values not relevant (i.e. representing a category such as 'other') are greyed out or the column / row omitted.

3.4.3.1. Junction detail vs. First point of impact

1.16 Junction detail

0. not at or within 20m of junction
1. roundabout
2. mini roundabout
3. T or staggered junction
5. slip road
6. crossroads
7. multiple junction
8. using private drive or entrance
9. other junction

Table 62: Junction detail vs. First point of impact (actual count values), UK 2005-2007.

	Junction detail								
First point of impact	0	1	2	3	5	6	7	8	9
Did not impact	2772	643	48	1865	89	467	76	200	241
Front	14140	2366	337	16402	344	3805	562	2840	1582
Back	1372	985	71	1386	81	412	92	151	215
Offside	3556	979	64	2925	158	890	129	374	316
Nearside	3757	1601	129	3985	150	895	155	558	376

Table 63: Junction detail vs. First point of impact (percentage), UK 2005-2007.

	Junction detail								
First point of impact	0	1	2	3	5	6	7	8	9
Did not impact	10.8	9.8	7.4	7.0	10.8	7.2	7.5	4.9	8.8
Front	55.2	36.0	51.9	61.7	41.8	58.8	55.4	68.9	57.9
Back	5.4	15.0	10.9	5.2	9.9	6.4	9.1	3.7	7.9
Offside	13.9	14.9	9.9	11.0	19.2	13.8	12.7	9.1	11.6
Nearside	14.7	24.4	19.9	15.0	18.2	13.8	15.3	13.5	13.8

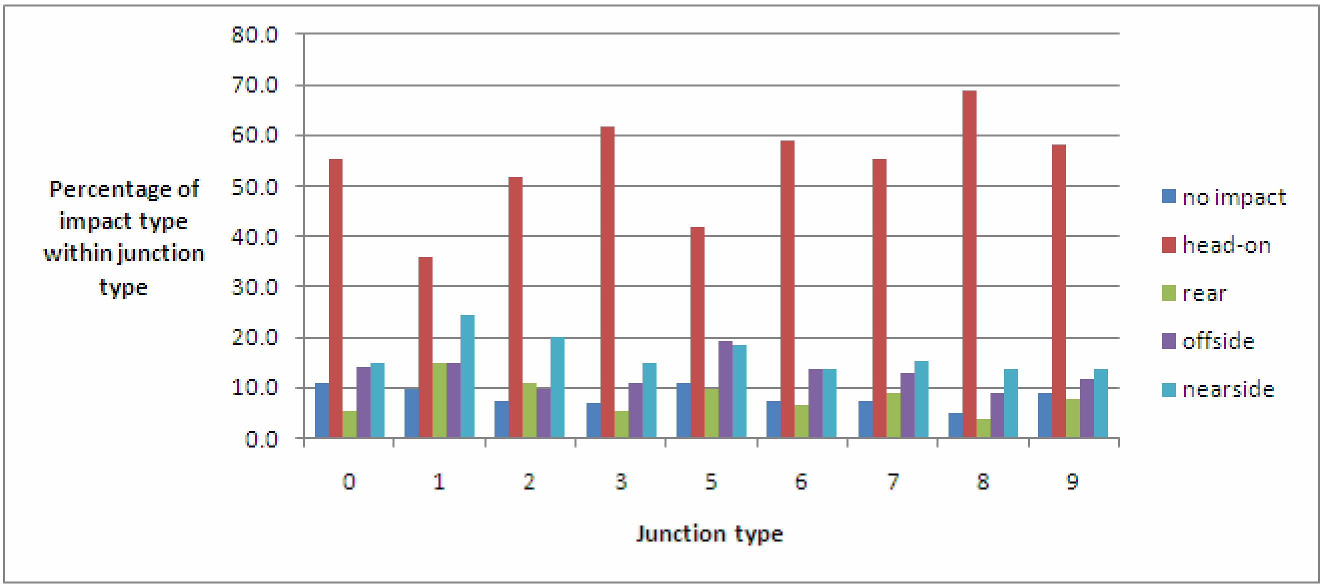


Figure 15: Junction detail vs. First point of impact (percentage figures in graph), UK 2005-2007.

It is likely that the first point of impact for a motorcyclist will be linked to the manoeuvre they are conducting at the time and their location. The above cross-tabs are intended to explore such a possible relationship (Table 62, Table 63 and Figure 15).

The percentage figures show that, proportionally:

- A head-on impact is more likely at a private drive or entrance or at a T-junction, and less likely at a roundabout or a slip road
- An off-side impact is more likely at a slip road and less likely at a private entrance or mini roundabout
- A nearside impact is more likely at a roundabout or mini roundabout and less likely at a crossroads or private drive

In absolute terms however, it is clear that the vast majority of accidents occur either at a T-junction or away from any kind of junction. Head-on collisions dominate the figures for both.

3.4.3.2. Junction detail vs. Manoeuvre

1.16 Junction detail

0. not at or within 20m of junction
1. roundabout
2. mini roundabout
3. T or staggered junction
5. slip road
6. crossroads
7. multiple junction
8. using private drive or entrance
9. other junction

2.7 Manoeuvre

1. reversing
2. parked
3. waiting to go ahead but held up
4. slowing or stopping
5. moving off
6. U turn
7. Turning left
8. Waiting to turn left
9. Turning right
10. Waiting to turn right
11. Changing lane to left
12. Changing lane to right
13. Overtaking moving vehicle on its offside
14. Overtaking stationary vehicle on its offside
15. Overtaking on nearside
16. Going ahead left hand bend
17. Going ahead right hand bend
18. Going ahead

Table 64: Junction detail vs. Manoeuvre (actual count values), UK 2005-2007.

	Manoeuvre																	
Junction Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	33	131	444	1284	230	112	73	5	113	36	123	209	2213	1072	426	3163	2488	*13439*
1	4	11	502	447	269	12	379	36	559	25	118	52	176	51	39	229	309	*3358*
2		1	26	47	16	3	18	4	122	8			17	8	3	8	12	*357*
3	20	60	529	1006	319	62	807	109	1419	266	40	62	2462	1386	505	789	805	*15919*
5	1	8	22	40	16	2	32	5	13	5	22	46	35	10	20	96	31	*418*
6	9	9	194	258	206	12	164	25	356	45	10	18	322	189	95	68	50	*4440*
7	1	1	41	61	53	1	31	2	65	6	2	6	40	25	19	43	43	*573*
8	9	3	35	107	43	2	83	8	167	34	2		664	357	118	122	96	*2273*
9	3	9	88	133	52	5	67	10	110	36	9	11	246	132	68	126	135	*1488*

Table 65: Junction detail vs. Manoeuvre (percentage), UK 2005-2007.

	Manoeuvre																	
Junction Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	41.3	56.2	23.6	38.0	19.1	53.1	4.4	2.5	3.9	7.8	37.7	51.7	35.8	33.2	32.9	68.1	62.7	*31.8*
1	5.0	4.7	26.7	13.2	22.3	5.7	22.9	17.6	19.1	5.4	36.2	12.9	2.9	1.6	3.0	4.9	7.8	*7.9*
2	0.0	0.4	1.4	1.4	1.3	1.4	1.1	2.0	4.2	1.7	0.0	0.0	0.3	0.2	0.2	0.2	0.3	*0.8*
3	25.0	25.8	28.1	29.7	26.5	29.4	48.8	53.4	48.5	57.7	12.3	15.3	39.9	42.9	39.1	17.0	20.3	*37.7*
5	1.3	3.4	1.2	1.2	1.3	0.9	1.9	2.5	0.4	1.1	6.7	11.4	0.6	0.3	1.5	2.1	0.8	*1.0*
6	11.3	3.9	10.3	7.6	17.1	5.7	9.9	12.3	12.2	9.8	3.1	4.5	5.2	5.9	7.3	1.5	1.3	*10.5*
7	1.3	0.4	2.2	1.8	4.4	0.5	1.9	1.0	2.2	1.3	0.6	1.5	0.6	0.8	1.5	0.9	1.1	*1.4*
8	11.3	1.3	1.9	3.2	3.6	0.9	5.0	3.9	5.7	7.4	0.6	0.0	10.8	11.1	9.1	2.6	2.4	*5.4*
9	3.8	3.9	4.7	3.9	4.3	2.4	4.1	4.9	3.8	7.8	2.8	2.7	4.0	4.1	5.3	2.7	3.4	*3.5*

Counts of accidents related to junction type (Table 64 and Table 65) show that, after 'not at a junction', the main types are T-junctions, roundabouts and cross-roads.

For these four categories the percentage figures show that, proportionally:

- Accidents away from junctions are, unsurprisingly, more likely if going ahead on a left or right hand bend, and less likely if turning left, waiting to turn left or turning right
- Accidents at T-junctions are more likely if waiting to turn left or right, and less likely if changing lane
- Accidents at roundabouts are more likely if changing lane to the left or if waiting to go ahead but held up
- Accidents at cross-roads are more likely if vehicle is moving off or waiting to turn left or turning right

In absolute terms however, the dominant accident types are:

1. Going ahead on a left hand bend, away from a junction
2. Going ahead on a right hand bend, away from a junction
3. Overtaking a moving vehicle on its offside, at a T-junction
4. Overtaking a moving vehicle on its offside, away from a junction

Note: This relates to UK roads where vehicles drive on the left hand side of the road

3.4.3.3. Road surface condition vs. Manoeuvre

1.23 Road surface condition

1. dry
2. wet/damp
3. snow
4. frost/ice
5. flood (water surface over 3 cm deep)

2.7 Manoeuvre

1. reversing
2. parked
3. waiting to go ahead but held up
4. slowing or stopping
5. moving off
6. U turn
7. Turning left
8. Waiting to turn left
9. Turning right
10. Waiting to turn right
11. Changing lane to left
12. Changing lane to right
13. Overtaking moving vehicle on its offside
14. Overtaking stationary vehicle on its offside
15. Overtaking on nearside
16. Going ahead left hand bend
17. Going ahead right hand bend
18. Going ahead other

Table 66: Road surface condition vs. Manoeuvre (actual count values), UK 2005-2007.

	Manoeuvre																	
Road surface condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	60	189	1460	2261	931	169	1233	151	2185	330	260	326	5051	2473	1059	3695	3039	31684
2	20	41	403	1052	263	41	395	51	695	128	64	75	1098	724	228	899	875	10166
3		1	1	7	1		4		6	1			3	3	1	1	5	59
4		2	10	56	8	1	20	2	30	1	2	2	21	23	4	40	46	311
5			1	5					2	1			1			4	2	21

Table 67: Road surface condition vs. Manoeuvre (percentage), UK 2005-2007.

	Manoeuvre																	
Road surface condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	75.0	81.1	77.9	66.9	77.4	80.1	74.6	74.0	74.9	71.6	79.8	80.9	81.8	76.7	82.0	79.7	76.6	75.0
2	25.0	17.6	21.5	31.1	21.9	19.4	23.9	25.0	23.8	27.8	19.6	18.6	17.8	22.5	17.6	19.4	22.1	24.1
3	0.0	0.4	0.1	0.2	0.1	0.0	0.2	0.0	0.2	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1
4	0.0	0.9	0.5	1.7	0.7	0.5	1.2	1.0	1.0	0.2	0.6	0.5	0.3	0.7	0.3	0.9	1.2	0.7
5	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0

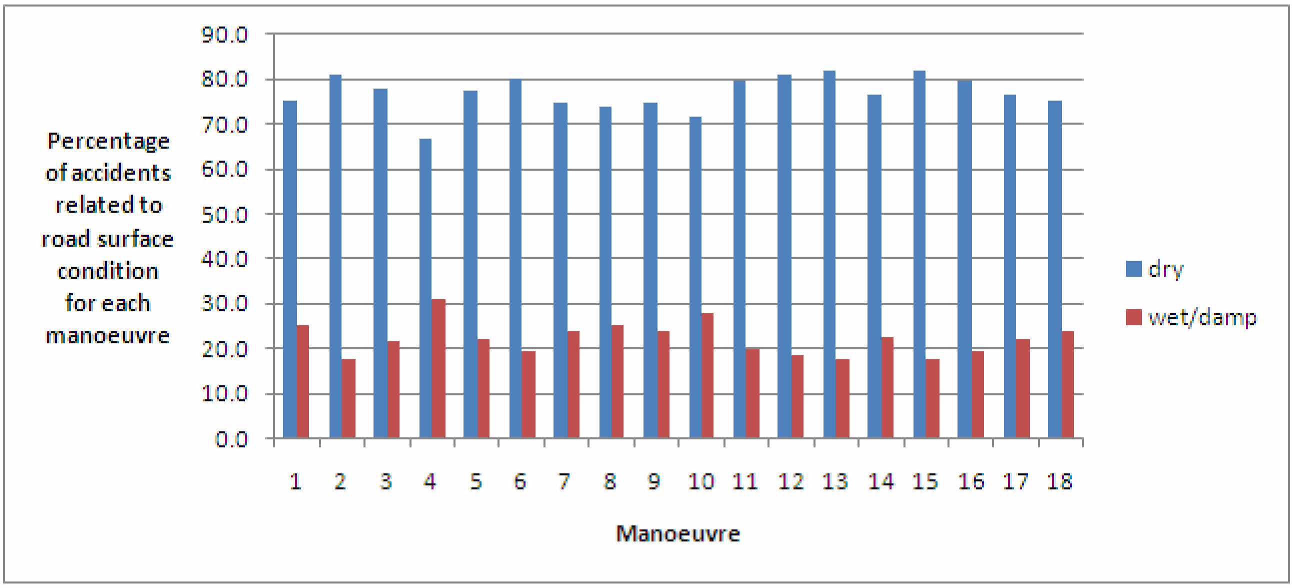


Figure 16: Road surface condition (dry, wet/damp) vs. Manoeuvre (percentage figures in graph), UK 2005-2007.

The percentage values show that snow, frost and flood conditions account for less than 1% of all accidents within each category of manoeuvre. The graph therefore ignores these conditions and shows only the percentages for dry and wet/damp conditions.

Notably, the figures (Table 66, Table 67 and Figure 16) show that certain manoeuvres are, proportionally, more likely to be linked to an accident when wet road conditions are present than dry road conditions. In descending order the top ones are:

1. Slowing or stopping
2. Waiting to turn right
3. Waiting to turn left
4. Reversing
5. Going ahead other
6. Turning left
7. Turning right

In absolute terms the dominant accident types are:

1. Going ahead other, dry conditions
2. Going ahead other, wet conditions
3. Overtaking moving vehicle on its offside, dry conditions
4. Going ahead left hand bend, dry conditions
5. Going ahead right hand bend, dry conditions
6. Overtaking stationary vehicle on its offside, dry conditions
7. Slowing or stopping, dry conditions
8. Turning right, dry conditions

3.4.3.4. Road surface condition vs. Skidding/Overturning

Table 68: Road surface condition vs. Skidding/overturning (actual count values), UK 2005-2007.

	Road surface condition				
Skidding / overturning	Dry	Wet/damp	Snow	Frost/ice	Flood (>3cm deep)
No skidding or overturning	43284	11108	48	245	23
Skidded	10005	5016	40	289	11
Skidded and overturned	1811	751	5	40	
Overturned	1463	351		5	3

Table 69: Road surface condition vs. Skidding/overturning (percentage), UK 2005-2007.

	Road surface condition				
Skidding / overturning	Dry	Wet/damp	Snow	Frost/ice	Flood (>3cm deep)
No skidding or overturning	76.5	64.5	51.6	42.3	62.2
Skidded	17.7	29.1	43.0	49.9	29.7
Skidded and overturned	3.2	4.4	5.4	6.9	0.0
Overturned	2.6	2.0	0.0	0.9	8.1

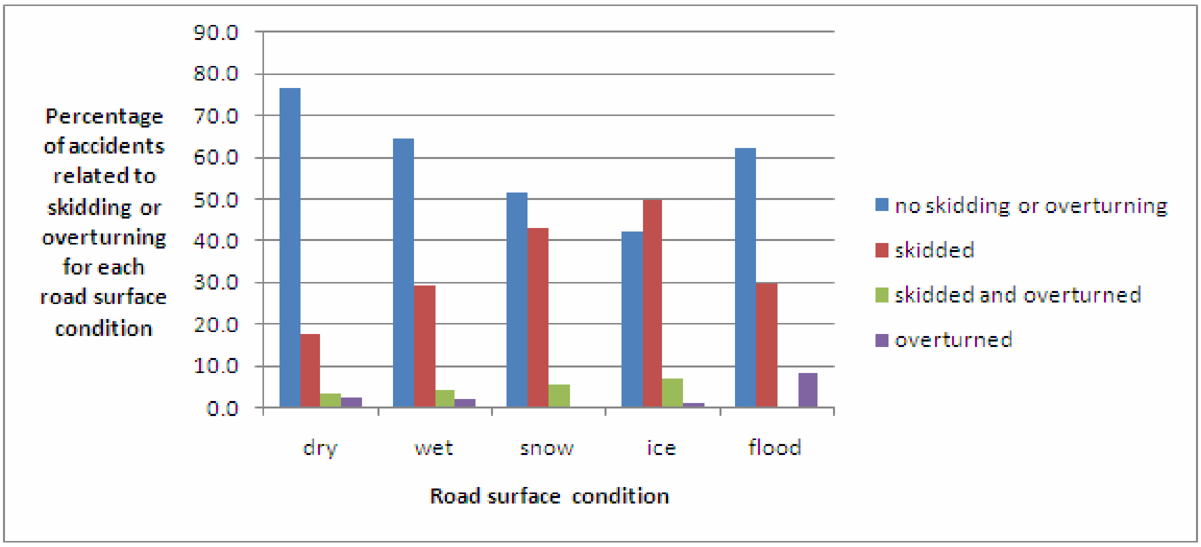


Figure 17: Road surface condition vs. Skidding/overturning (percentage figures in graph), UK 2005-2007.

The results from the figures (Table 68, Table 69 and Figure 17) are what would be expected intuitively, but the clear relationship between the two factors is interesting to see. As road conditions deteriorate, skidding is much more likely as part of an accident. Compared to dry conditions, riders are over 1.6 times more likely to skid when the road is wet and over 2.8 times more likely when the ground is frosty. The likelihood of overturning also increases with deteriorating road surface condition, but to a lesser degree.

In absolute terms it is clear that no skidding (both in the dry and wet), and skidding in the dry are the most common conditions for accidents.

3.4.3.5. Road surface condition vs. Age

Table 70: Road surface condition vs. Age (actual count values), UK 2005-2007.

Road surface condition	16	17	18	19	20	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61+
Dry	4748	3806	2293	1787	1493	14127	6622	5956	5971	6352	5515	3670	2295	1608	1347
Wet/damp	1922	1612	909	681	561	5685	2004	1653	1634	1765	1472	988	639	449	320
Snow	11	7	4	5	1	28	10	12	8	14	5	2	5	3	
Frost/ice	70	56	28	22	16	192	75	46	57	71	44	27	27	15	8
Flood	4	3	2	1	1	11	4	3	6	1	6	3		1	

Table 71: Road surface condition vs. Age (percentage), UK 2005-2007.

	Age													
Road surface condition	16	17	18	19	20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61+
Dry	70.3	69.4	70.9	71.6	72.1	76.0	77.7	77.8	77.4	78.3	78.3	77.4	77.5	80.4
Wet/damp	28.5	29.4	28.1	27.3	27.1	23.0	21.6	21.3	21.5	20.9	21.1	21.5	21.6	19.1
Snow	0.2	0.1	0.1	0.2	0.0	0.1	0.2	0.1	0.2	0.1	0.0	0.2	0.1	0.0
Frost/ice	1.0	1.0	0.9	0.9	0.8	0.9	0.6	0.7	0.9	0.6	0.6	0.9	0.7	0.5
Flood	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0

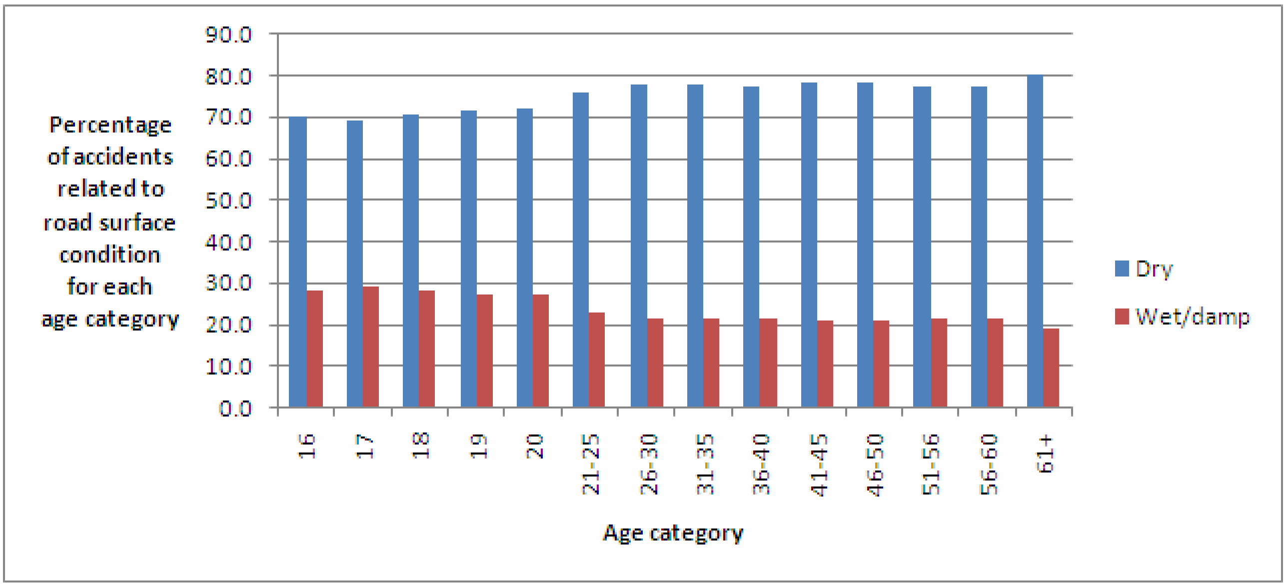


Figure 18: Road surface condition (dry, wet/damp) vs. Age (percentage figures in graph), UK 2005-2007.

The results (Table 70, Table 71 and Figure 18) suggest that younger riders are more susceptible to adverse road surface conditions, although it could be that they ride more often in wet conditions than older drivers. Accidents related to wet road conditions make up a higher percentage of accidents for younger drivers, with this percentage generally reducing as riders age, roughly stabilising as riders reach their mid to late 20’s. It is not clear whether this is related to age or length of riding experience.

3.4.3.6. Junction detail vs. Age

1.16 Junction detail

0. not at or within 20m of junction
1. roundabout
2. mini roundabout
3. T or staggered junction
5. slip road
6. crossroads
7. multiple junction
8. using private drive or entrance
9. other junction

Table 72: Junction detail vs. Age (actual count values), UK 2005-2007.

	Age													
Junction detail	16	17	18	19	20	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61+
0	2285	1778	1041	782	657	6543	2936	2535	2618	2966	2565	1701	1045	712	572
1	505	413	280	202	156	1556	736	619	652	766	748	520	353	264	228
2	92	82	39	18	15	246	87	42	51	40	41	32	29	24	21
3	2556	2105	1219	972	832	7684	3156	2868	2779	2767	2281	1482	962	662	500
5	26	37	23	18	17	121	102	92	102	108	105	67	31	37	28
6	512	417	278	220	153	1580	814	737	721	705	599	388	229	166	140
7	81	55	33	30	24	223	123	125	118	114	96	57	47	40	25
8	398	382	185	158	132	1255	471	411	383	432	378	266	171	92	104
9	307	220	140	98	87	852	299	246	261	307	232	178	101	79	57

Table 73: Junction detail vs. Age (percentage), UK 2005-2007.

	Age													
Junction detail	16	17	18	19	20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61+
0	33.8	32.4	32.1	31.3	31.7	33.7	33.0	34.1	36.1	36.4	36.3	35.2	34.3	34.1
1	7.5	7.5	8.6	8.1	7.5	8.4	8.1	8.5	9.3	10.6	11.1	11.9	12.7	13.6
2	1.4	1.5	1.2	0.7	0.7	1.0	0.5	0.7	0.5	0.6	0.7	1.0	1.2	1.3
3	37.8	38.3	37.6	38.9	40.1	36.2	37.4	36.2	33.7	32.4	31.6	32.4	31.9	29.9
5	0.4	0.7	0.7	0.7	0.8	1.2	1.2	1.3	1.3	1.5	1.4	1.0	1.8	1.7
6	7.6	7.6	8.6	8.8	7.4	9.3	9.6	9.4	8.6	8.5	8.3	7.7	8.0	8.4
7	1.2	1.0	1.0	1.2	1.2	1.4	1.6	1.5	1.4	1.4	1.2	1.6	1.9	1.5
8	5.9	7.0	5.7	6.3	6.4	5.4	5.4	5.0	5.3	5.4	5.7	5.8	4.4	6.2
9	4.5	4.0	4.3	3.9	4.2	3.4	3.2	3.4	3.7	3.3	3.8	3.4	3.8	3.4

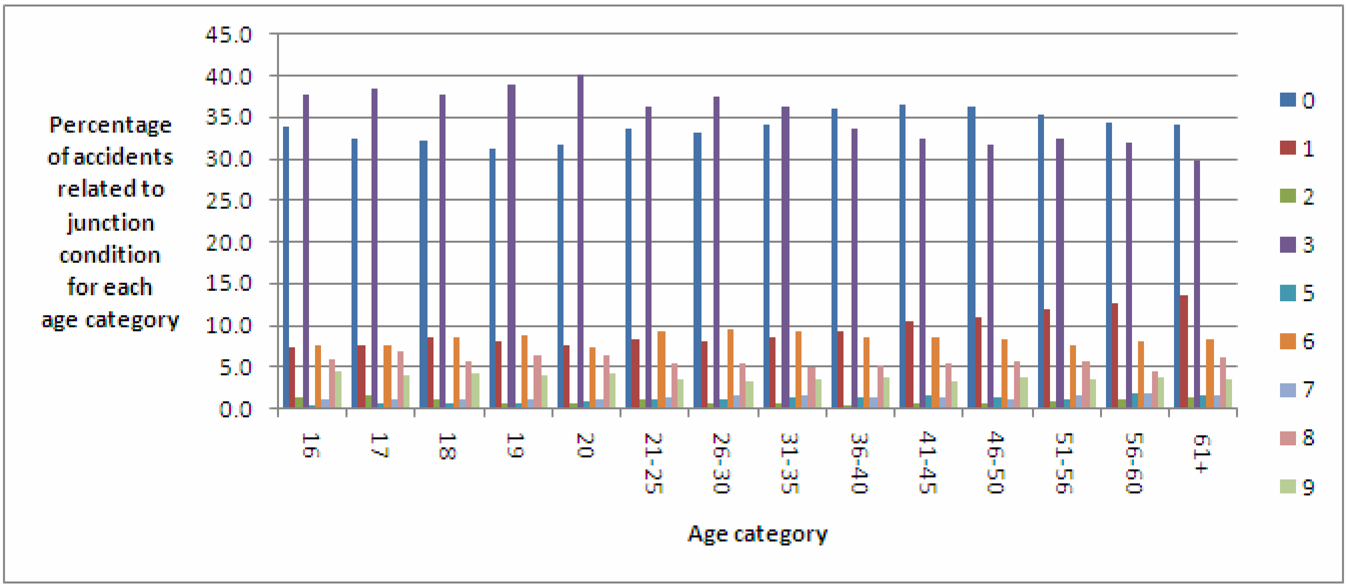


Figure 19: Junction detail vs. Age (percentage figures in graph), UK 2005-2007.

The figures (Table 72, Table 73 and Figure 19) show at least two apparent trends within the data:

Proportionally it appears that riders in the age categories 31-35 and below are more likely to be involved in an accident at a T-junction than any other category (including 'not at a junction'). In the age categories 36-40 and above this switch, with 'not at a junction' becoming the primary scenario for rider accidents.

There is also an apparent rise in the relative incidence of accidents at roundabouts in riders in the higher age categories. It remains fairly stable up to the 31-35 age category, beyond which it increases with each age group until, at 61+, riders are proportionally almost twice as likely to be involved in an accident at a roundabout than those aged 16 or 17.

It is not clear whether these trends are related directly to rider age or to rider experience and without further evidence this cannot be stated. It would however be an interesting topic for further study.

3.4.3.7. Age vs. Manoeuvre

2.7 Manoeuvre

1. reversing
2. parked
3. waiting to go ahead but held up
4. slowing or stopping
5. moving off
6. U turn
7. Turning left
8. Waiting to turn left
9. Turning right
10. Waiting to turn right
11. Changing lane to left
12. Changing lane to right
13. Overtaking moving vehicle on its offside
14. Overtaking stationary vehicle on its offside
15. Overtaking on nearside
16. Going ahead left hand bend
17. Going ahead right hand bend
18. Going ahead other

Table 74: Age vs. Manoeuvre (actual count values), UK 2005-2007.

	Age														
Manoeuvre	16	17	18	19	20	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61+
1	9	4	3	3	1	20	4	13	9	6	7	5	2	3	1
2	17	12	6	3	1	39	11	19	14	27	20	22	8	14	8
3	125	107	40	38	37	347	172	199	192	242	228	209	118	58	69
4	368	287	158	121	80	1014	374	316	306	348	321	244	164	99	92
5	120	86	53	27	32	318	122	107	103	138	126	82	47	42	41
6	37	19	10	3	1	70	19	20	16	17	24	8	8	6	5
7	199	121	83	55	43	501	167	173	162	121	136	112	58	51	46
8	10	9	5	2	4	30	18	27	30	31	20	13	10	7	11
9	398	264	161	113	89	1025	319	239	251	261	232	124	110	87	94
10	77	43	17	8	3	148	43	38	46	55	54	20	21	16	10
11	17	6	13	9	5	50	46	32	34	40	52	21	17	15	8
12	28	19	8	4	10	69	49	50	52	50	42	29	14	11	18
13	377	405	283	193	167	1425	791	711	738	718	640	397	258	147	103
14	304	253	138	125	81	901	394	357	338	356	298	172	120	88	57

15	95	94	44	45	29	307	161	166	161	134	124	81	35	31	13
16	302	260	161	143	119	985	566	482	519	614	527	351	228	143	108
17	308	262	167	130	113	980	489	379	440	485	403	292	175	132	96
18	3969	3236	1888	1476	1258	11827	4979	4346	4273	4561	3791	2508	1574	1126	893

Table 75: Age vs. Manoeuvre (percentage), excluding "going ahead other", UK 2005-2007.

	Age													
Manoeuvre	16	17	18	19	20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61+
1	0.3	0.2	0.2	0.3	0.1	0.1	0.4	0.3	0.2	0.2	0.2	0.1	0.3	0.1
2	0.6	0.5	0.4	0.3	0.1	0.3	0.6	0.4	0.7	0.6	1.0	0.6	1.5	1.0
3	4.5	4.8	3.0	3.7	4.5	4.6	6.0	5.6	6.6	7.0	9.6	8.5	6.1	8.8
4	13.2	12.7	11.7	11.8	9.8	10.0	9.5	9.0	9.6	9.9	11.2	11.8	10.4	11.8
5	4.3	3.8	3.9	2.6	3.9	3.3	3.2	3.0	3.8	3.9	3.8	3.4	4.4	5.3
6	1.3	0.8	0.7	0.3	0.1	0.5	0.6	0.5	0.5	0.7	0.4	0.6	0.6	0.6
7	7.1	5.4	6.1	5.4	5.3	4.5	5.2	4.7	3.3	4.2	5.1	4.2	5.4	5.9
8	0.4	0.4	0.4	0.2	0.5	0.5	0.8	0.9	0.9	0.6	0.6	0.7	0.7	1.4
9	14.3	11.7	11.9	11.1	10.9	8.5	7.2	7.4	7.2	7.1	5.7	7.9	9.2	12.1
10	2.8	1.9	1.3	0.8	0.4	1.1	1.1	1.3	1.5	1.7	0.9	1.5	1.7	1.3
11	0.6	0.3	1.0	0.9	0.6	1.2	1.0	1.0	1.1	1.6	1.0	1.2	1.6	1.0
12	1.0	0.8	0.6	0.4	1.2	1.3	1.5	1.5	1.4	1.3	1.3	1.0	1.2	2.3
13	13.5	18.0	21.0	18.9	20.5	21.1	21.4	21.6	19.7	19.7	18.2	18.5	15.5	13.2
14	10.9	11.2	10.2	12.2	9.9	10.5	10.7	9.9	9.8	9.2	7.9	8.6	9.3	7.3
15	3.4	4.2	3.3	4.4	3.6	4.3	5.0	4.7	3.7	3.8	3.7	2.5	3.3	1.7
16	10.8	11.6	11.9	14.0	14.6	15.1	14.5	15.2	16.9	16.2	16.1	16.4	15.1	13.8
17	11.0	11.6	12.4	12.7	13.9	13.1	11.4	12.9	13.3	12.4	13.4	12.6	13.9	12.3

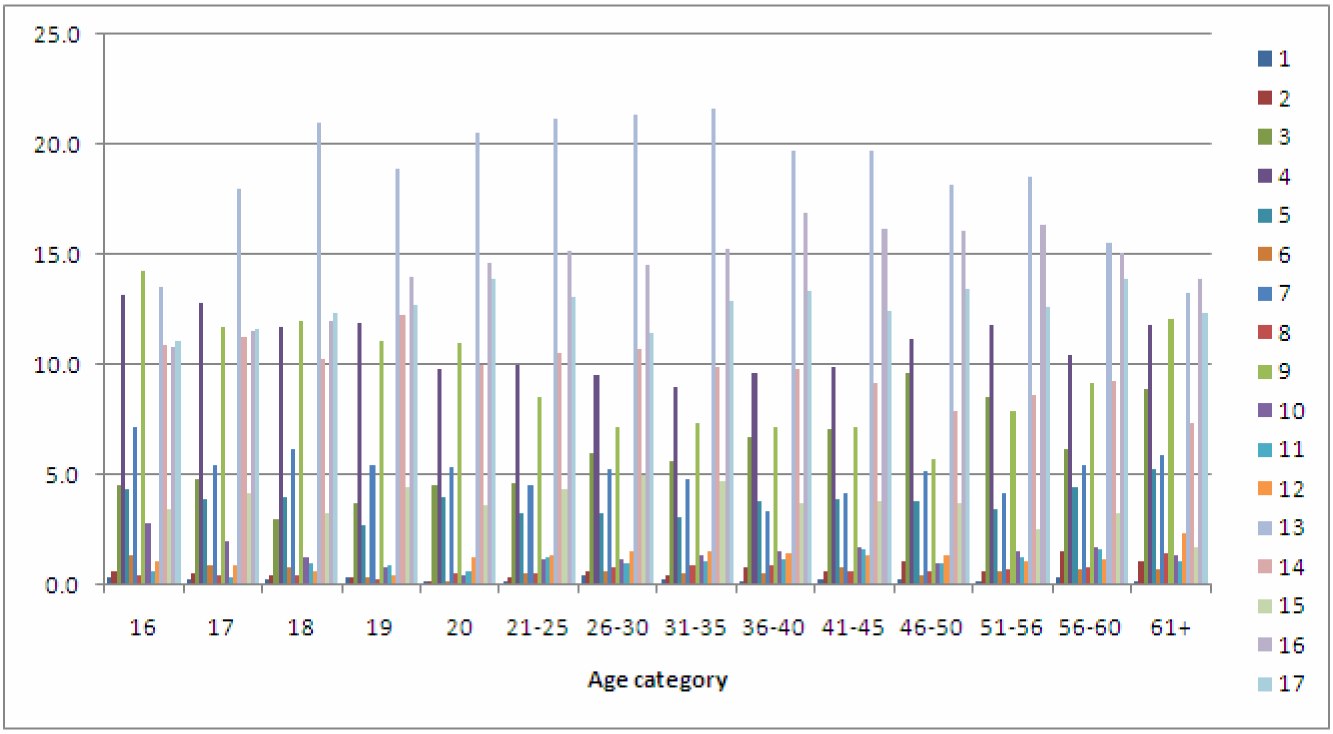


Figure 20: Age vs. Manoeuvre (percentage figures in graph), UK 2005-2007.

The data do not appear to show any clear relationships between ages and manoeuvre (Table 74, Table 75 and Figure 20). There do seem to be some systematic variations within the data, but further analysis will be required to determine if these are statistically significant.

Of the 18 manoeuvre categories, there are three which stand out as showing the greatest variability with respect to rider age (9, 13 & 16), see Figure 20. These are also among the most numerous of manoeuvres in terms of accident which adds further interest.

Turning right appears to feature in a steadily reducing proportion of accidents as age group increases (roughly 14% of accidents among 16 year olds but under 6% among 46-50 year olds). Above 50 however the rate increases, reaching a rate similar to under 20's in the 61 and over age category.

Overtaking a moving vehicle on its offside is a manoeuvre that is prominent in accidents involving the young and early middle aged (although interestingly not so much for 16 year olds, speculation is that the low powered scooters available to 16 year olds are less often presented with overtaking opportunities). In the middle aged and upwards age categories this manoeuvre drops off in terms of accident involvement rate.

Finally, accidents when going ahead on a left hand bend appear to be most prominent in the upper middle age categories. Rates show a general increase from younger to older categories, with a broad peak between the ages of 36 to 55. Once again, the rate begins to drop off in the oldest age categories.

3.4.3.8. Speed Limit vs. Casualty Severity

Table 76: Speed Limit vs. Casualty Severity (actual count values), UK 2005-2007.

	Speed Limit					
Casualty Severity	20	30	40	50	60	70
Fatal	5	431	194	91	862	139
Severe	58	9449	1653	610	4742	944
Slight	190	35150	4274	1299	7157	1752
No injury	49	4404	301	98	566	143

Table 77: Speed Limit vs. Casualty Severity (percentage), UK 2005-2007.

	Speed Limit					
Casualty Severity	20	30	40	50	60	70
Fatal	1.66	0.87	3.02	4.34	6.47	4.67
Severe	19.21	19.11	25.74	29.08	35.58	31.70
Slight	62.91	71.10	66.55	61.92	53.70	58.83
No injury	16.23	8.91	4.69	4.67	4.25	4.80

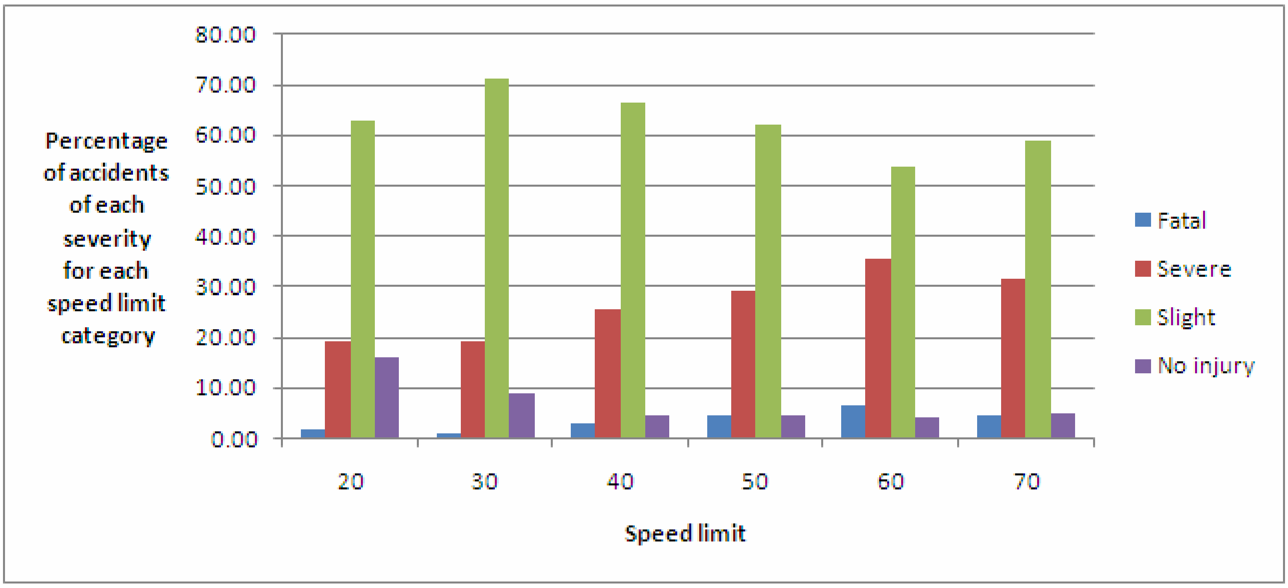


Figure 21: Speed Limit vs. Casualty Severity (percentage figures in graph), UK 2005-2007.

Despite accidents in 30 mph speed limit areas being by far the most common, the data (Table 76, Table 77 and Figure 21) show that this is offset slightly by the fact that as speed limit increases, accidents tend to involve a higher proportion of serious injury or death to riders. Interestingly, this trend peaks on 60 mph roads, with a reduction in serious or fatal injuries on 70 mph roads. It is possible that this is due in part to 70 mph roads being exclusively dual-carriageway and therefore effectively ruling out the opportunity for head-on collisions.

3.4.3.9. Skidding/Overturning vs. Casualty Severity

Table 78: Skidding/overturning vs. Casualty Severity (actual count values), UK 2005-2007.

	Skidding/Overturning			
Casualty Severity	No skidding or overturning	Skidded	Skidded & overturned	Overturned
Fatal	887	625	149	61
Severe	11609	4338	876	630
Slight	37319	9922	1505	1075
No injury	4943	484	77	57

Table 79: Skidding/overturning vs. Casualty Severity (percentage), UK 2005-2007.

	Skidding/Overturning			
Casualty Severity	No skidding or overturning	Skidded	Skidded & overturned	Overturned
Fatal	1.62	4.07	5.72	3.35
Severe	21.20	28.23	33.60	34.56
Slight	68.15	64.56	57.73	58.97
No injury	9.03	3.15	2.95	3.13

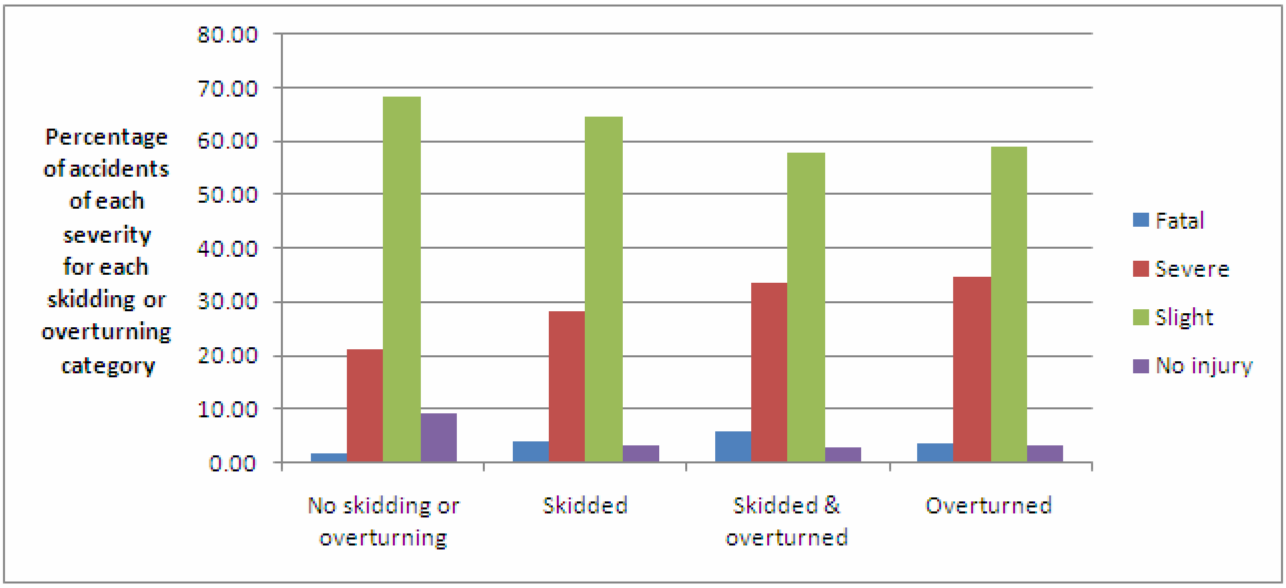


Figure 22: Skidding/overturning vs. Casualty Severity (percentage figures in graph), UK 2005-2007.

It is clear from the data (Table 78, Table 79 and Figure 22) that PTW accidents tend to be more severe if skidding or overturning of the bike is involved, with a higher proportion of fatal or serious injuries. Overturning appears to be particularly linked to an increase in the proportion of serious injuries.

3.4.3.10. Road class vs. Road type vs. Speed limit

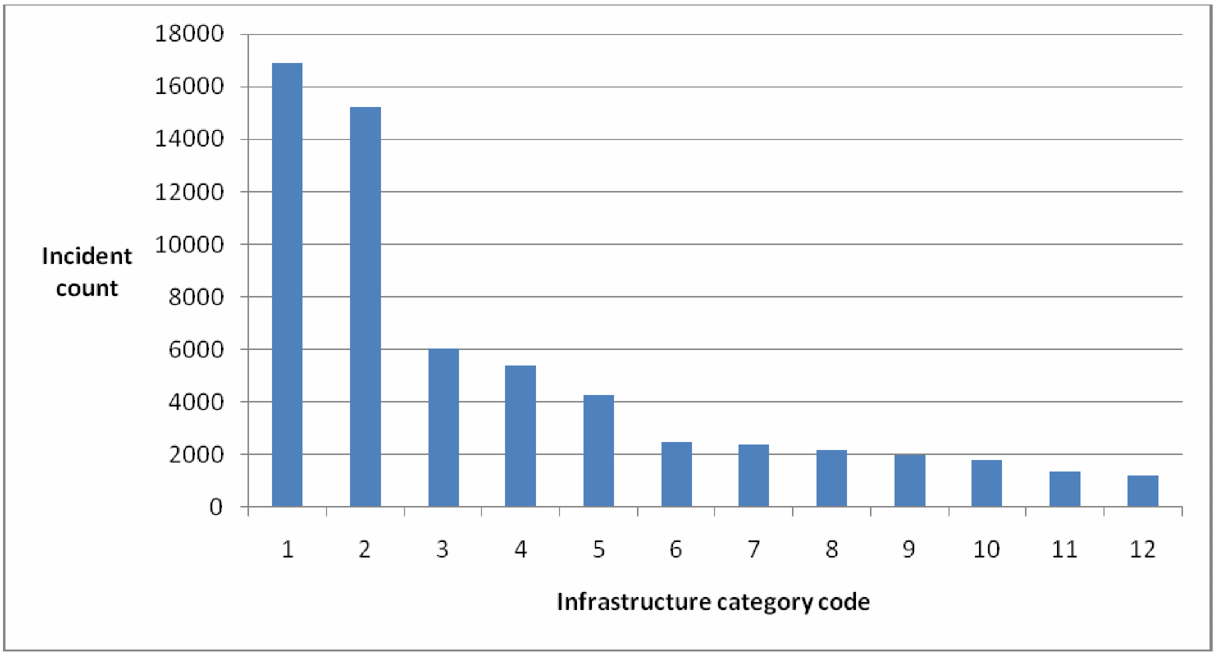


Figure 23: Road class vs. Road type vs. Speed limit, UK 2005-2007.

Figure 23 and Table 80 show the top 12 most common infrastructure factor combinations by number of incidents (those with over 1000 incidents). Note that this refers to absolute frequency only and does not take exposure into account.

Table 80: Road class vs. Road type vs. Speed limit, UK 2005-2007.

Infrastructure category code	Road class	Road type	Speed limit
1	A	Single carriageway	30
2	Unclassified	Single carriageway	30
3	A	Single carriageway	60
4	B	Single carriageway	30
5	C	Single carriageway	30
6	B	Single carriageway	60
7	A	Single carriageway	40
8	A	Dual carriageway	30
9	Unclassified	Single carriageway	60
10	A	Roundabout	30
11	A	Dual carriageway	40
12	C	Single carriageway	60

In addition to the previous cross tabulations, some additional cross-tabulations were compiled to compare larger numbers of factors. Road class, road type and speed limit were regarded to relate to very similar elements, each being intrinsic to the road infrastructure. The above table therefore gives an overall hierarchy of dominant roads infrastructure factors in PTW accidents in GB.

3.4.3.11. Light condition vs. Time vs. Weather vs. Road surface condition

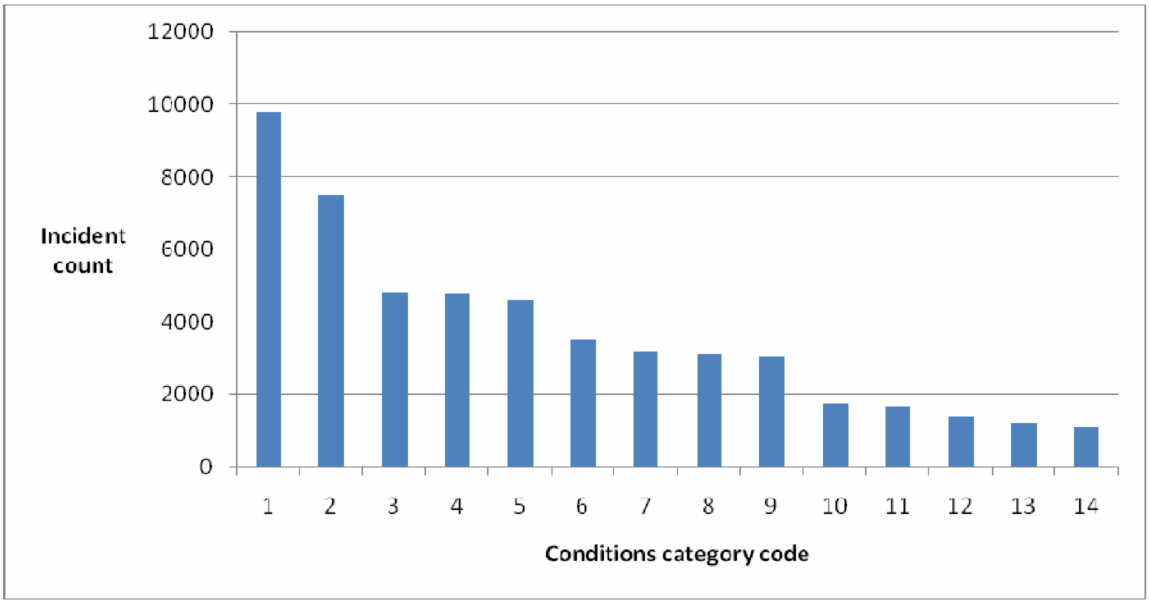


Figure 24: Light condition vs. Time vs. Weather vs. Road surface condition, UK 2005-2007.

Figure 24 and Table 81 show the top 14 most common conditions factor combinations by number of incidents (those with over 1000 incidents). Again, this does not factor in exposure.

Table 81: Light condition vs. Time vs. Weather vs. Road surface condition, UK 2005-2007.

Conditions category code	Light conditions	Time	Weather	Road surface conditions
1	Daylight – street lights present	15:00 - 17:59	Fine without high winds	Dry
2	Daylight – street lights present	12:00 - 14:59	Fine without high winds	Dry
3	Daylight – street lights present	09:00 - 11:59	Fine without high winds	Dry
4	Daylight – street lights present	06:00 - 08:59	Fine without high winds	Dry
5	Daylight – street lights present	18:00 - 20:59	Fine without high winds	Dry
6	Daylight – no street lighting	15:00 - 17:59	Fine without high winds	Dry
7	Darkness with street lights lit	18:00 - 20:59	Fine without high winds	Dry
8	Darkness with street lights lit	21:00 - 23:59	Fine without high winds	Dry
9	Daylight – no street lighting	12:00 - 14:59	Fine without high winds	Dry
10	Daylight – no street lighting	09:00 - 11:59	Fine without high winds	Dry
11	Daylight – no street lighting	18:00 - 20:59	Fine without high winds	Dry
12	Darkness with street lights lit	15:00 - 17:59	Fine without high winds	Dry
13	Daylight – no street lighting	06:00 - 08:59	Fine without high winds	Dry
14	Daylight – street lights present	06:00 - 08:59	Fine without high winds	Wet / damp

Light conditions, time, weather and road surface conditions all relate to environmental factors which are likely to affect the likelihood or type of accident involving PTWs. The hierarchy above shows the predominant overall environmental conditions relating to PTW accidents.

3.4.4. Summary of Findings – Great Britain

Within this report the STATS19 accident data were looked at in different ways providing various levels of complexity. At the highest level, simple frequency counts for the different accident measures showed which were the most common within the data.

Delving deeper, cross-tabulations between pairs of these measures provided similar frequency counts, but also yielded information on how factors related to each other, as well as giving an indication of the relative frequencies of accident types for specific infrastructure elements. In this way, not only did the analysis reveal the most frequent accident types overall, but also which infrastructure elements were more prone to particular types of incident. It is hoped that these data will prove useful in helping to determine the reasons for accidents and therefore how best to prevent them.

The final level of analysis combined multiple factors to identify on overall hierarchy of accident variables related to infrastructure. It is hoped that this hierarchy will allow researchers to identify which combinations of infrastructure elements are most frequently involved in PTW accidents and therefore to target these in later work packages of the project. This should allow the study to target those accident types most frequently represented in the accident statistics, at the minimum cost.

The following is a summary of the key findings:

- A roads are by far the most common road class for collisions by motorcyclists in the UK, making up almost half of all incidents, and with an 'incident per 1000 km' rate of over double that in second place.
- Almost 85% of accidents occur during fine weather without high winds, and over 75% with dry road surface conditions.
- Only just under 6% of accidents involve a carriageway object (not including a moving vehicle) being hit.
- The majority of accidents involve a frontal impact, i.e. the motorcycle hitting a vehicle/object rather than being hit by another vehicle.
- Young riders are proportionally more likely to have an accident when the road is wet/damp than older riders.
- Up to their early to mid thirties the most likely location for riders to have an accident is at a T-junction. Above this age, the most likely location to have an accident is away from any form of road junction. Older riders are also proportionally more likely to have an accident at a roundabout than younger riders.
- By far the most common combinations of infrastructure features in motorbike accidents are either A or unclassified roads, single carriageway and 30 mph speed limit.
- Prevailing conditions will, for the vast majority of the time, be during daylight hours with fine, dry weather and low winds.

3.5. Interaction between Powered Two-Wheeler Accidents and Infrastructure in Italy

3.5.1. Methodology – Italian Data Base and Available Data

In Italy traffic accidents are documented by public authorities (ISTAT). Accidents included in the national database must have occurred on a public roadway and involved at least one injured person. However since their public authorities are not systematically informed of all the accidents, their presence is guaranteed only whenever the presence of an ambulance for medical assistance is required. In fact in this case there is an exchange of information between the medical care network and the public authorities, while there is no guarantee of their presence at the accident scene if the injured person can move autonomously to the hospital.

Base for statistical analysis: The following analysis was performed using data extracted from the Italian national database, years 2005-2007. In this period 261.475 accidents involving at least one PTW (moped – 10.7901; 41.3% –, motorcycle or scooter – 15.3574; 58.7% –) were registered.

An aggregate data analysis was performed for all the PTW types since the attention was mainly concentrated on the link between accidents and road infrastructure, which is the general aim of activity 1.2. For each query the following information was extracted:

- number of accidents;
- total deaths;
- total injured.

In addition the *severity index* parameter, defined as the number of deaths over the number of deaths plus injured people, was computed.

The following database fields were considered relevant for the analysis:

- road type (one carriageway – single way; one carriageway – two ways; two carriageways; more than two carriageways);
- accident type;
- (no-)junction type;
- pavement type;
- pavement state;
- age first delivery license (PTW rider);
- information on traffic signals;
- PTW rider's age;
- weather condition;
- time of the accident.

The following cross tables were created to analyse the data more in detail:

- road type vs. accident type;
- (no-)junction type vs. accident type;
- pavement state vs. year first delivery licence (PTW rider);
- pavement state vs. pavement type;
- information on traffic signals vs. road type;
- information on traffic signals vs. (no-)junction type;
- (no-)junction type vs. PTW rider's age;
- weather condition vs. time of the accident.

3.5.2. Overview of Interaction between PTW Accidents and Infrastructure in Italy

The majority of PTW accidents (68%) happen on roads with one carriageway and two ways (Figure 25), while the number of accident is equally distributed over junctions/no-junctions (Figure 26). The majority of accidents are on dry roads (89%), while minor percentages on wet road (9%) and slippery (2%) and the other conditions have no relevance (Figure 27). Regarding the weather conditions, the majority of accidents occur with clear weather (89%) and only a minority with rain (5%), (Figure 28). In order to read the latter data, the average number of days with over 1.0mm of rain, ranges between 153 and 77 in Italy (Climatological data by national environmental information system: SCIA system of the APAT, 2009). The range is restricted to 138 – 77 if the more mountainous regions of the country are eliminated, which include scarcely populated areas.

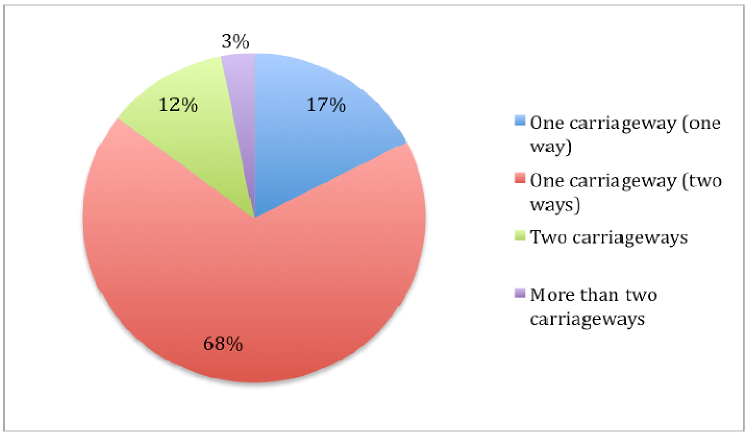


Figure 25: PTW accidents by road type, Italy 2005-2007.

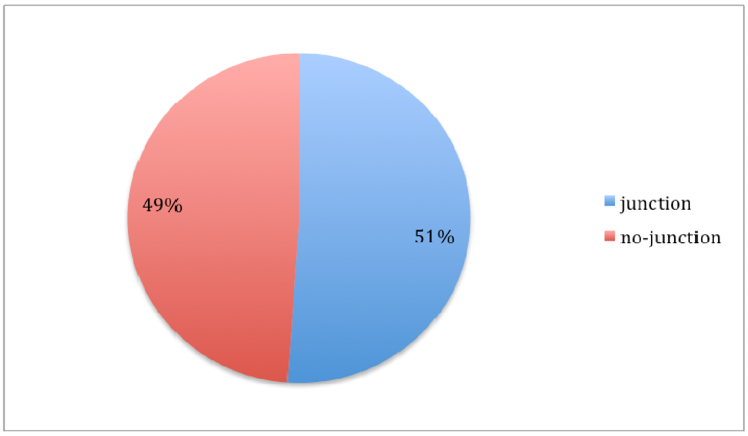


Figure 26: PTW accidents by intersection, Italy 2005-2007.

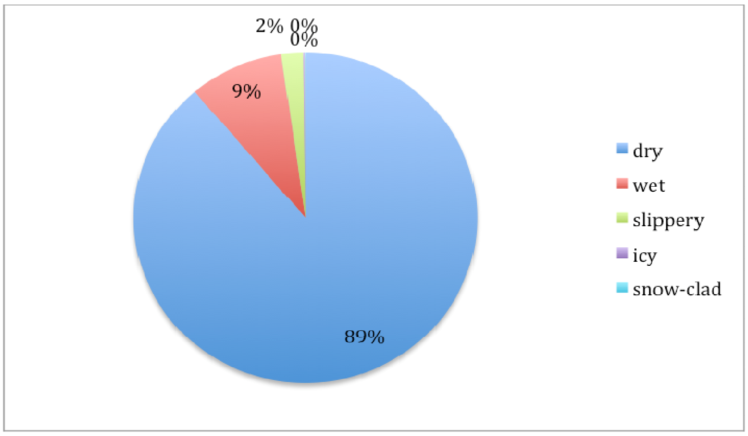


Figure 27: PTW accidents by pavement state, Italy 2005-2007.

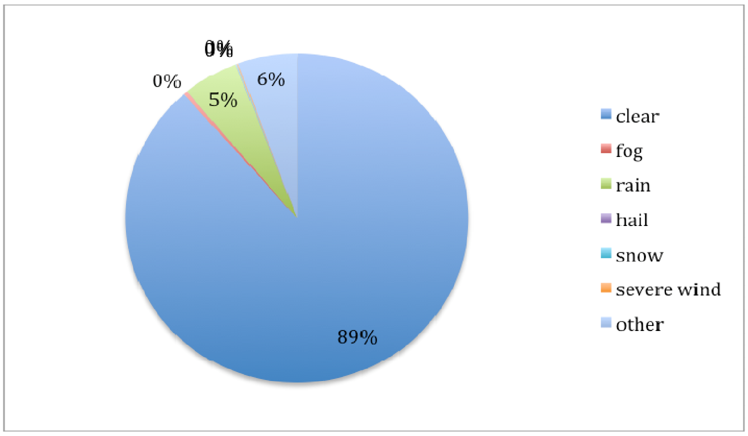


Figure 28: PTW accidents by weather condition, Italy 2005-2007.

3.5.3. Specific queries (Cross-tables between categories)

In the following sections the results of cross analyses between two or more factors are presented. The data tables are included in the text flow, where for each table the most relevant case is highlighted in red and the following 5 in orange.

Accident type categories from the data base used in the queries (definition applies to analyses in 3.5.3.1 to 3.5.3.3):

1. head-on
2. head-on side
3. side crash
4. nose to tail crash
5. running down pedestrian
6. collision with a vehicle slowing/stopping/stationary
7. collision with a parked vehicle
8. collision with an obstacle
9. collision with a train
10. running off-road
11. injury following a sudden braking
12. injury resulting from falling off of the vehicle

3.5.3.1. Road type vs. accident type

The distribution of accident types shows that the 3 most relevant configurations account for 72% of the accidents (head-on side – 42%; side crash –19%; nose to tail crash – 11%; Figure 29). This data crossed with the road type show that the most important case (in terms of number of accidents, dead and injured people) is the *head-on side on road with one carriageway and two ways* (Table 82, Table 83 and Table 84). Other important cases are always related to the same road type and respectively to *side crash, nose-to-tail, head-on* although their relative importance varies according to the parameter considered for the evaluation. The remaining two top configurations vary considerably according to the parameter: if deaths are taken into account *running off-road* and *collision with an obstacle* have to be considered.

An analysis based on the *severity index* (Table 85), introduced to evaluate the threat linked to each case, changes significantly the ranking: the most important configuration is on roads with *one carriageway and two ways* and *collision with an obstacle*. The other 5 cases include: the collision with an obstacle but on road with two carriageways; running off-road both on roads with one carriageway (two ways) and with two carriageways; head on and collision with a parked vehicle on roads with one carriageway (two ways).

The analysis shows that most likely accidents require the interaction of two vehicles and they occur on infrastructure where it is possible the interaction of traffic flows moving in opposite ways, and in configurations which involve the front part and sides of the vehicles. Nonetheless the most severe accidents are single vehicle accidents on the same road type or on roads with two carriageways.

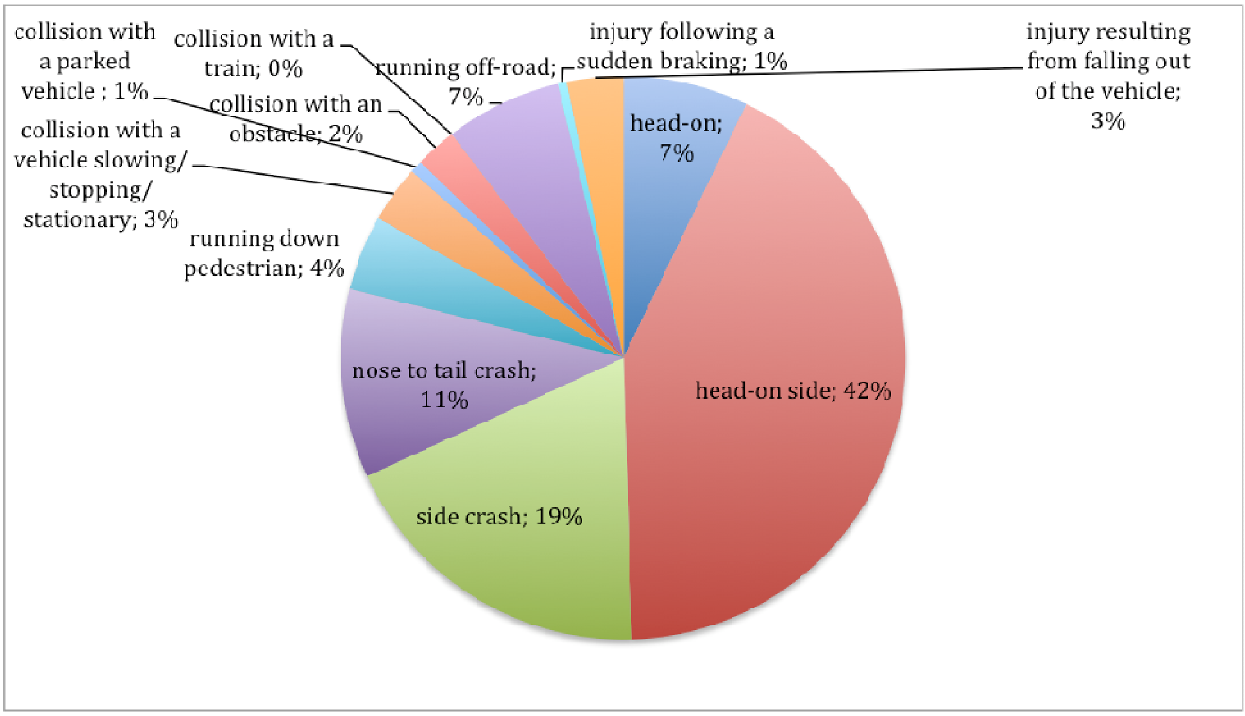


Figure 29: PTW accidents by accident type, Italy 2005-2007.

Table 82: Road type vs. accident type – actual count values (accidents), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
road type	One carriageway (one way)	2098	17230	9975	4771	2281	2075	527	1337	0	3081	266	1905
	One carriageway (two ways)	15469	80378	30049	18096	7195	4835	1024	3590	5	11038	830	5212
	Two carriageways	966	10037	6921	4555	1199	1216	243	1029	0	2690	213	1048
	More than two carriageways	227	3084	1647	886	618	410	51	249	0	607	42	270

Table 83: Road type vs. accident type – actual count values (deaths), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
road type	One carriageway (one way)	25	102	48	27	33	20	11	23	0	43	0	8
	One carriageway (two ways)	758	1497	330	289	182	91	34	230	0	518	10	88
	Two carriageways	28	135	56	77	37	18	7	44	0	105	0	20
	More than two carriageways	5	31	9	3	22	3	0	4	0	5	0	2

Table 84: Road type vs. accident type – actual count values (injured), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
road type	One carriageway (one way)	2451	20541	11464	5740	3168	2391	548	1425	0	3305	281	2047
	One carriageway (two ways)	19021	94867	34807	21982	10359	5576	1075	3655	5	11390	884	5476
	Two carriageways	1154	11873	8000	5633	1726	1434	260	1072	0	2863	228	1128
	More than two carriageways	283	3656	1848	1080	953	481	55	258	0	626	42	293

Table 85: Road type vs. accident type – severity index*100, Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
road type	One carriageway (one way)	1,01	0,49	0,42	0,47	1,03	0,83	1,97	1,59	-	1,28	0,00	0,39
	One carriageway (two ways)	3,83	1,55	0,94	1,30	1,73	1,61	3,07	5,92	0,00	4,35	1,12	1,58
	Two carriageways	2,37	1,12	0,70	1,35	2,10	1,24	2,62	3,94	-	3,54	0,00	1,74
	More than two carriageways	1,74	0,84	0,48	0,28	2,26	0,62	0,00	1,53	-	0,79	0,00	0,68

3.5.3.2. Junction type vs. accident type

The results indicate that the most relevant cases occur at *cross roads* and *indicated junction (with or without traffic lights)* for the most frequent accident types (Table 86, Table 87 and Table 88). In terms of absolute values the most important case is always accident at a *cross road / head-on side*. These figures indicate that roundabouts should be preferred to intersect traffic flows, since they are associated both to a low number of accidents and to low severity index, although quite common both in urban and extra urban areas. On the contrary crossroads and indicated junctions are highly dangerous for riders and thus they should be a preferred data to study interactions among vehicles and PTWs.

If the severity index is considered the most relevant accident cases involve *level crossing* (3 out of 6 cases), but the numerical relevance is extremely low (Table 89). The remaining high severity cases are: *junction not indicated / collision with a parked vehicle*; *roundabout* both *collision with an obstacle* and *running-off road*. In this analysis the severity index identifies accident cases with a very low number of recorded accidents, which limits the validity of the most dangerous scenarios.

Table 86: Junction type vs. accident type – actual count values (accidents), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
Junction	cross road	4841	38445	11115	4807	1162	841	114	486	0	1144	176	881
	roundabout	329	3261	1825	721	125	132	18	208	0	714	40	400
	junction indicated	2639	20686	5487	2631	544	482	75	225	0	1083	91	379
	junction indicated by a traffic light or warden	1269	9907	3969	1991	645	610	22	295	0	975	86	344
	junction not indicated	723	4167	1370	539	110	101	26	48	0	175	24	71
	level crossing	12	33	14	15	3	3	1	11	5	11	0	6

Table 87: Junction type vs. accident type – actual count values (deaths), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
Junction	cross road	137	478	107	51	19	12	3	15	0	18	1	5
	roundabout	8	32	7	8	0	0	0	12	0	30	1	1
	junction indicated	106	399	55	44	17	5	1	4	0	13	0	1
	junction indicated by a traffic light or warden	24	104	24	10	10	1	1	1	0	4	0	1
	junction not indicated	14	66	9	6	3	2	3	1	0	5	0	1
	level crossing	1	2	0	0	0	0	0	4	0	0	0	0

Table 88: Junction type vs. accident type – actual count values (injured), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
Junction	cross road	5794	45847	12995	5876	1576	995	125	514	0	1207	184	951
	roundabout	373	3674	2009	812	160	152	18	213	0	733	39	425
	junction indicated	3095	23944	6263	3187	771	549	79	231	0	1129	96	394
	junction indicated by a traffic light or warden	1536	11852	4490	2413	960	692	24	302	0	1005	90	364
	junction not indicated	851	4958	1617	650	161	118	27	51	0	183	24	81
	level crossing	15	39	16	23	4	3	2	7	5	13	0	6

Table 89: Junction type vs. accident type – severity index*100, Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
Junction	cross road	2,31	1,03	0,82	0,86	1,19	1,19	2,34	2,84	-	1,47	0,54	0,52
	roundabout	2,10	0,86	0,35	0,98	0,00	0,00	0,00	5,33	-	3,93	2,50	0,23
	junction indicated	3,31	1,64	0,87	1,36	2,16	0,90	1,25	1,70	-	1,14	0,00	0,25
	junction indicated by a traffic light or warden	1,54	0,87	0,53	0,41	1,03	0,14	4,00	0,33	-	0,40	0,00	0,27
	junction not indicated	1,62	1,31	0,55	0,91	1,83	1,67	10,00	1,92	-	2,66	0,00	1,22
	level crossing	6,25	4,88	0,00	0,00	0,00	0,00	0,00	36,36	0,00	0,00	-	0,00

3.5.3.3. No-junction type vs. accident type

An analysis based on the counted values of accidents, dead and injured persons evidences that the most relevant infrastructure feature is the *straight road* (Table 90, Table 91 and Table 92). In this case the most relevant case is accident on a *straight road / head-on side*, independently of the parameter used. Also the other relevant configurations are mostly linked to a straight road (*head-on; side crash; nose-to-tail; running down a pedestrian; running off-road*). It is important to highlight the presence of a case with pedestrians involved (213 deaths). If the number of deaths is considered also *bends* become relevant linked to *head-on* and *running off-road* accident types.

In terms of severity index the most important accident case is *collision with an obstacle* at a *bend* (Table 93). The other important cases are always at a *bend* or *hump or narrow passage* in conjunction with *head on* and *running off-road* accident types. Specifically for *hump or narrow passage* the case of *sudden braking* is also relevant.

Figures suggest that:

- straight road is extremely dangerous, but most probably because of factors not linked to infrastructure (i.e. PTW conspicuity, rider/driver attentiveness, rider exposure to a specific road type);
- bends, humps and narrow passages should be considered with particular attention since they are present in the most severe accidents. Thus appropriate signals, road design and road side barriers should be considered in order to reduce the severity.

Table 90: No-Junction type vs. accident type – actual count values (accidents), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
no-Junction	straight road	6250	30233	22009	15994	8309	5758	1317	3362	0	8310	729	4383
	bend	2455	3534	2360	1279	299	487	232	1398	0	4703	170	1713
	hump or narrow passage	84	139	136	83	20	48	1	41	0	79	11	76
	slope	140	285	247	153	71	60	36	87	0	145	19	117
	lit up tunnel	16	29	53	91	5	11	1	39	0	66	4	58
	unlit tunnel	2	10	7	4	0	3	2	5	0	11	1	7

Table 91: No-Junction type vs. accident type – actual count values (deaths), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
no-Junction	straight road	300	523	185	247	213	95	38	129	0	244	5	64
	bend	213	154	41	22	8	15	6	130	0	339	2	43
	hump or narrow passage	9	4	7	1	0	1	0	2	0	6	1	0
	slope	3	2	5	3	4	1	0	2	0	8	0	1
	lit up tunnel	1	1	3	4	0	0	0	1	0	4	0	1
	unlit tunnel	0	0	0	0	0	0	0	0	0	0	0	0

Table 92: No-Junction type vs. accident type – actual count values (injured), Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
no-Junction	straight road	7729	35691	25456	19392	11951	6663	1372	3502	0	8720	777	4621
	bend	3235	4353	2764	1665	479	573	249	1405	0	4879	188	1830
	hump or narrow passage	101	168	155	102	34	50	1	43	0	80	11	82
	slope	154	349	281	189	102	69	38	98	0	152	21	120
	lit up tunnel	23	47	63	119	8	14	1	39	0	69	4	62
	unlit tunnel	3	15	10	7	0	4	2	5	0	14	1	8

Table 93: No-Junction type vs. accident type – severity index*100, Italy 2005-2007.

		accident type											
		1	2	3	4	5	6	7	8	9	10	11	12
no-Junction	straight road	3,74	1,44	0,72	1,26	1,75	1,41	2,70	3,55	-	2,72	0,64	1,37
	bend	6,18	3,42	1,46	1,30	1,64	2,55	2,35	8,47	-	6,50	1,05	2,30
	hump or narrow passage	8,18	2,33	4,32	0,97	0,00	1,96	0,00	4,44	-	6,98	8,33	0,00
	slope	1,91	0,57	1,75	1,56	3,77	1,43	0,00	2,00	-	5,00	0,00	0,83
	lit up tunnel	4,17	2,08	4,55	3,25	0,00	0,00	0,00	2,50	-	5,48	0,00	1,59
	unlit tunnel	0,00	0,00	0,00	0,00	-	0,00	0,00	0,00	-	0,00	0,00	0,00

3.5.3.4. Pavement state vs. year first delivery licence (PTW rider)

As evidenced in section 3.5.2 the majority of accidents occur on dry pavement and just secondarily on wet pavement. When cross tabled with the delivery year of the driving licence it appears clearly that experience (experience is assumed proportional to the time passed since the delivery of the driving license) plays a major role for the number of accidents, dead and injured persons (Table 94, Table 95 and Table 96). In fact the most relevant case is on *dry pavement* with riders having less than 10 years of experience.

A different picture can be observed when the severity is analysed. In this case all the pavement state indicate that most severe accidents involve more experienced riders (the oldest ranges must be considered carefully since there is a low number of accidents reported; Table 97).

Table 94: Pavement state vs. year first delivery licence – actual count values (accidents), Italy 2005-2007.

		year first delivery licence - PTW rider							
		1931-1940	1941-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Pavement state	dry	17	23	78	1579	7308	23447	34638	102606
	wet	2	5	4	135	736	2431	3429	10225
	slippery	0	0	0	32	184	637	913	2145
	icy	0	0	0	1	10	50	66	166
	snow-clad	0	0	0	1	5	20	28	53

Table 95: Pavement state vs. year first delivery licence – actual count values (deaths), Italy 2005-2007.

		year first delivery licence - PTW rider							
		1931-1940	1941-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Pavement state	dry	0	2	4	39	148	459	770	1939
	wet	0	0	0	4	11	20	42	112
	slippery	0	0	0	2	2	2	9	15
	icy	0	0	0	0	0	2	1	0
	snow-clad	0	0	0	0	0	0	1	0

Table 96: Pavement state vs. year first delivery licence – actual count values (injured), Italy 2005-2007.

		year first delivery licence - PTW rider							
		1931-1940	1941-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Pavement state	dry	20	27	86	1794	8451	27144	40380	122184
	wet	2	6	6	161	821	2753	3878	11701
	slippery	0	0	0	34	204	739	1018	2510
	icy	0	0	0	1	10	51	72	173
	snow-clad	0	0	0	3	6	22	27	56

Table 97: Pavement state vs. year first delivery licence – severity index*100, Italy 2005-2007.

Pavement state	year first delivery licence - PTW rider: 1931-1940	1941-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
dry	0,00	6,90	4,44	2,13	1,72	1,66	1,87	1,56
wet	0,00	0,00	0,00	2,42	1,32	0,72	1,07	0,95
slippery	-	-	-	5,56	0,97	0,27	0,88	0,59
icy	-	-	-	0,00	0,00	3,77	1,37	0,00
snow-clad	-	-	-	0,00	0,00	0,00	3,57	0,00

3.5.3.5. Pavement state vs. pavement type

The analysis adds to the previous numerical relevance of dry / wet / slippery pavement state, the information on the pavement type as well as the severity index. Data in Table 98 show that:

- with the same pavement type, the accident severity decreases passing from dry to wet to slippery conditions. These results have to be probably ascribed to the fact that in wet and slippery conditions the rider is more aware of the risk and thus rides more carefully;
- for the two most relevant pavement state (dry and wet) the severity index in the case of *uneven paved road* is higher than for *paved road*, which demonstrates an influence of the pavement type on the accident outcome.

Table 98: Pavement state vs. pavement type; death, injured,severity index*100, Italy 2005-2007.

Pavement state	Pavement type	summary involved in accident: total deaths until 24 hours by accident	total deaths between the 2nd and 30th day by accident	total deaths	total injured	severity index
dry	paved road	3851	701	4552	272061	1,65
	uneven paved road	49	9	58	2282	2,48
	unpaved road	10	0	10	458	2,14
wet	paved road	247	60	307	26029	1,17
	uneven paved road	4	0	4	262	1,50
	unpaved road	2	0	2	57	3,39
slippery	paved road	28	5	33	5272	0,62
	uneven paved road	0	0	0	245	0,00
	unpaved road	6	0	6	65	8,45
icy	paved road	4	0	4	473	0,84
	uneven paved road	0	0	0	10	0,00
	unpaved road	0	0	0	0	-
snow-clad	paved road	1	1	2	189	1,05
	uneven paved road	0	0	0	0	-
	unpaved road	0	0	0	1	0,00

3.5.3.6. Traffic signals vs. road type

Data confirm that the majority of accidents occur on roads with one carriageway (two ways), independently of the traffic signals (Table 99). Traffic signals are divided into two categories: vertical and horizontal ones. Vertical traffic signals include traffic lights and poles, carrying any kind of information; horizontal traffic signals are generally all markings located on the road surface. Nonetheless there is a difference in the severity of the recorded accidents linked to the signals: namely the roads without traffic signals or with just vertical ones have a higher severity index in the case of one carriageway (two ways) and two carriageways (Figure 30).

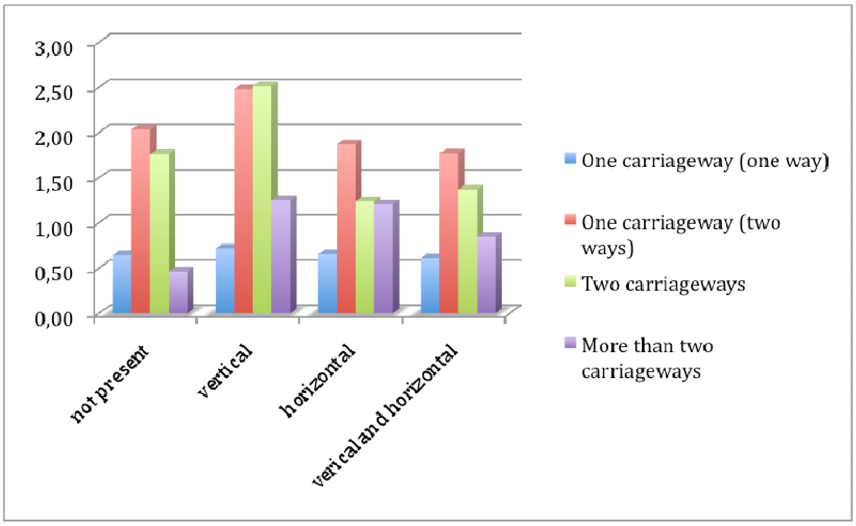


Figure 30: Severity index*100 for accidents categorised according to road type and traffic signals, Italy 2005-2007.

Table 99: Traffic signals vs. road type; death, injured, severity index*100, Italy 2005-2007.

			summary involved in accident				
		Number of directions	**total deaths until 24 hours by accident**	**total deaths between the 2nd and 30th day by accident**	**total deaths**	**total injured**	**severity index**
Information on traffic signals	not present	One carriageway (one way)	31	12	43	6621	0,65
		One carriageway (two ways)	432	84	516	24876	2,03
		Two carriageways	38	14	52	2895	1,76
		More than two carriageways	2	0	2	428	0,47
	vertical	One carriageway (one way)	37	14	51	7044	0,72
		One carriageway (two ways)	486	69	555	21813	2,48
		Two carriageways	48	14	62	2404	2,51
		More than two carriageways	3	1	4	315	1,25
	horizontal	One carriageway (one way)	23	7	30	4541	0,66
		One carriageway (two ways)	423	76	499	26180	1,87
		Two carriageways	38	11	49	3902	1,24
		More than two carriageways	8	0	8	655	1,21
	verical and	One carriageway (one way)	171	45	216	35155	0,61

	horizontal	One carriageway (two ways)	2109	348	2457	136228	1,77
		Two carriageways	295	69	364	26170	1,37
		More than two carriageways	58	12	70	8177	0,85

3.5.3.7. Traffic signals vs. (no-)junction type

Data demonstrate that, whenever traffic signals are in place, they have little influence on the most dangerous accidents (Table 100). In fact in the case of a junction accidents occur more frequently at *cross roads* unless when there are no signals (in this case the most relevant is *junction not indicated*). In case of no-junction they always occur on a *straight road*, while the most dangerous situation is at *bends* (except in the case of vertical ones which is *hump or narrow passage*).

Thus it can be concluded that:

- all junctions should be indicated, since the absence of traffic signals increases the severity of the accident, most probably since the rider is not prepared to look for other vehicles or to adapt its vehicle speed;
- traffic signals at bends should be improved since they do not contribute to a reduction in the severity of accidents. Possible suggestions could include adding information relevant to riders (e.g. curve shape), as traffic signals are mostly conceived for other vehicle drivers.

Table 100: Traffic signals vs. (no-)junction type; death, injured, severity index*100, Italy 2005-2007.

				summary involved in accident				
				total deaths until 24 hours by accident	total deaths between the 2nd and 30th day by accident	total deaths	total injured	severity index
Information on traffic signals	not present	junction	cross road	50	16	66	6704	0,97
			roundabout	3	0	3	316	0,94
			junction indicated	0	0	0	0	-
			junction indicated by a traffic light or warden	0	0	0	0	-
			junction not indicated	89	21	110	8721	1,25
			level crossing	0	0	0	4	0,00
		no-junction	straight road	227	59	286	15409	1,82
			bend	125	12	137	3207	4,10
			hump or narrow passage	1	0	1	105	0,94
			slope	8	2	10	303	3,19
			lit up tunnel	0	0	0	40	0,00
			unlit tunnel	0	0	0	11	0,00
	vertical	junction	cross road	112	21	133	10839	1,21
			roundabout	11	4	15	739	1,99
			junction indicated	62	18	80	4221	1,86

			junction indicated by a traffic light or warden	6	2	8	1046	0,76
			junction not indicated	0	0	0	0	-
			level crossing	0	0	0	17	0,00
		no-junction	straight road	247	44	291	11590	2,45
			bend	124	9	133	2781	4,56
			hump or narrow passage	7	0	7	105	6,25
			slope	4	0	4	202	1,94
			lit up tunnel	1	0	1	23	4,17
			unlit tunnel	0	0	0	13	0,00

				summary involved in accident				
				total deaths until 24 hours by accident	total deaths between the 2nd and 30th day by accident	total deaths	total injured	severity index
Information on traffic signals	horizontal	junction	cross road	69	17	86	5978	1,42
			roundabout	2	4	6	564	1,05
			junction indicated	20	6	26	2265	1,13
			junction indicated by a traffic light or warden	10	1	11	625	1,73
			junction not indicated	0	0	0	0	-
			level crossing	0	0	0	10	0,00
		no-junction	straight road	266	48	314	21813	1,42
			bend	116	17	133	3468	3,69
			hump or narrow passage	4	1	5	150	3,23
			slope	3	0	3	280	1,06
			lit up tunnel	2	0	2	111	1,77
			unlit tunnel	0	0	0	14	0,00
	vertical and horizontal	junction	cross road	463	98	561	52543	1,06
			roundabout	59	16	75	6989	1,06
			junction indicated	455	84	539	33252	1,60
			junction indicated by a traffic light or warden	132	29	161	22057	0,72
			junction not indicated	0	0	0	0	-
			level crossing	7	0	7	102	6,42
		no-junction	straight road	963	189	1152	77062	1,47
			bend	515	55	570	12164	4,48
			hump or narrow passage	18	0	18	467	3,71
			slope	11	1	12	788	1,50
			lit up tunnel	10	2	12	275	4,18
			unlit tunnel	0	0	0	31	0,00

3.5.3.8. Junction type vs. rider age

The analysis identifies the age range 21-30 years old as the most critical linked with *cross road* (Table 101, Table 102 and Table 103). The other top 5 configurations are 14-17, 31-40 and 41-50 always for *cross road* together with 21-30 and 31-40 for *junction indicated*. The analysis of severity index does not provide relevant indications since the cases with the highest index values have little statistical importance because of the low number of recorded cases (Table 104).

Table 101: Junction type vs. rider age – actual count values (accidents), Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
Junction	cross road	11191	6606	15731	13549	8260	3869	1710	869	211
	roundabout	1126	690	1773	1841	1170	594	264	136	31
	junction indicated	5072	3168	8781	7948	4937	2217	995	489	107
	junction indicated by a traffic light or warden	1897	1677	5390	5492	3210	1437	510	164	39
	junction not indicated	1385	792	1749	1565	975	445	188	95	23
	level crossing	12	13	31	32	10	11	1	2	0

Table 102: Junction type vs. rider age – actual count values (deaths), Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
Junction	cross road	106	51	218	188	111	55	39	31	16
	roundabout	9	1	29	28	12	10	8	2	0
	junction indicated	51	36	191	155	101	48	26	24	10
	junction indicated by a traffic light or warden	6	16	62	45	18	15	6	4	5
	junction not indicated	11	10	36	29	9	7	3	3	0
	level crossing	0	2	2	2	1	0	0	0	0

Table 103: Junction type vs. rider age – actual count values (injured), Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
Junction	cross road	13843	8150	18886	15719	9503	4459	1879	961	226
	roundabout	1268	783	1997	2008	1286	652	272	140	32
	junction indicated	6031	3764	10312	9108	5562	2502	1084	527	117
	junction indicated by a traffic light or warden	2364	2098	6435	6367	3678	1648	566	180	39
	junction not indicated	1698	991	2078	1801	1137	508	205	110	27
	level crossing	12	14	36	35	14	17	1	2	0

Table 104: Junction type vs. rider age– severity index*100, Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
Junction	cross road	0,76	0,62	1,14	1,18	1,15	1,22	2,03	3,13	6,61
	roundabout	0,70	0,13	1,43	1,38	0,92	1,51	2,86	1,41	0,00
	junction indicated	0,84	0,95	1,82	1,67	1,78	1,88	2,34	4,36	7,87
	junction indicated by a traffic light or warden	0,25	0,76	0,95	0,70	0,49	0,90	1,05	2,17	11,36
	junction not indicated	0,64	1,00	1,70	1,58	0,79	1,36	1,44	2,65	0,00
	level crossing	0,00	12,50	5,26	5,41	6,67	0,00	0,00	0,00	-

3.5.3.9. No-junction type vs. rider age

A similar analysis performed in the case of no-junction confirms the results of the previous one (section 3.5.3.8) and identifies the age range 21-30 years old as the most critical linked with *straight road* (Table 105, Table 106 and Table 107). If the numbers of accidents or the injured persons are considered, all relevant cases are on *straight road* for riders aged 14 to 60. If deaths are considered, then the relevant cases are also straight roads with reduced age range up to 50 years old. There are two groups of accidents on bends, for riders between 21 and 40 years old, that also have to be included. For the severity index the same considerations of the previous analysis apply (Table 108).

Table 105: No-Junction type vs. rider age – actual count values (accidents), Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
no-Junction	straight road	13642	9692	27248	25373	16065	7059	2818	1305	273
	bend	2268	1321	4991	4721	2808	1337	506	207	46
	hump or narrow passage	72	70	174	182	134	48	12	11	2
	slope	166	129	333	315	199	92	35	20	10
	lit up tunnel	16	29	99	103	68	30	10	7	2
	unlit tunnel	1	6	13	12	10	7	2	1	0

Table 106: No-Junction type vs. rider age – actual count values (deaths), Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
no-Junction	straight road	186	135	602	487	297	124	61	54	18
	bend	73	44	280	314	136	57	30	12	6
	hump or narrow passage	1	0	10	7	5	1	0	4	0
	slope	2	3	10	5	4	1	1	1	0
	lit up tunnel	0	1	5	4	1	1	2	0	0
	unlit tunnel	0	0	0	0	0	0	0	0	0

Table 107: No-Junction type vs. rider age – actual count values (injured), Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
no-Junction	straight road	16649	12036	32546	29354	18572	8145	3138	1435	288
	bend	2726	1584	5834	5371	3200	1547	549	253	49
	hump or narrow passage	80	85	204	204	159	57	12	10	2
	slope	191	161	380	356	237	108	39	21	10
	lit up tunnel	16	36	121	132	85	32	9	7	2
	unlit tunnel	1	8	18	14	13	9	2	4	0

Table 108: No-Junction type vs. rider age– severity index*100, Italy 2005-2007.

		PTW rider age								
		14-17	18-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
no-Junction	straight road	1,10	1,11	1,82	1,63	1,57	1,50	1,91	3,63	5,88
	bend	2,61	2,70	4,58	5,52	4,08	3,55	5,18	4,53	10,91
	hump or narrow passage	1,23	0,00	4,67	3,32	3,05	1,72	0,00	28,57	0,00
	slope	1,04	1,83	2,56	1,39	1,66	0,92	2,50	4,55	0,00
	lit up tunnel	0,00	2,70	3,97	2,94	1,16	3,03	18,18	0,00	0,00
	unlit tunnel	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-

3.5.3.10. Weather conditions vs. time of accident

As highlighted in section 3.5.2, 94% of the accidents occur with clear weather or rain. Thus the analysis will be focused on these weather conditions.

The results indicate that there is little correlation with weather conditions, since the trends for number of accidents, dead and injured persons are similar in the case of clear weather and rain (Figure 31). In both cases the conclusions are the following:

- the peak of accidents is in the time range (approx. 15:30-21:29);
- the severity index is at its highest in the time range 23:30-6:29 (Figure 32).

These results are most probably linked to the fact that:

- in the afternoon there are intense traffic flows and people are tired because of the time spent working;
- during the night the traffic is not intense but the light conditions are not ideal, so rider perceptions and reactions can be slower. The latter can also be especially influenced by the drowsiness.

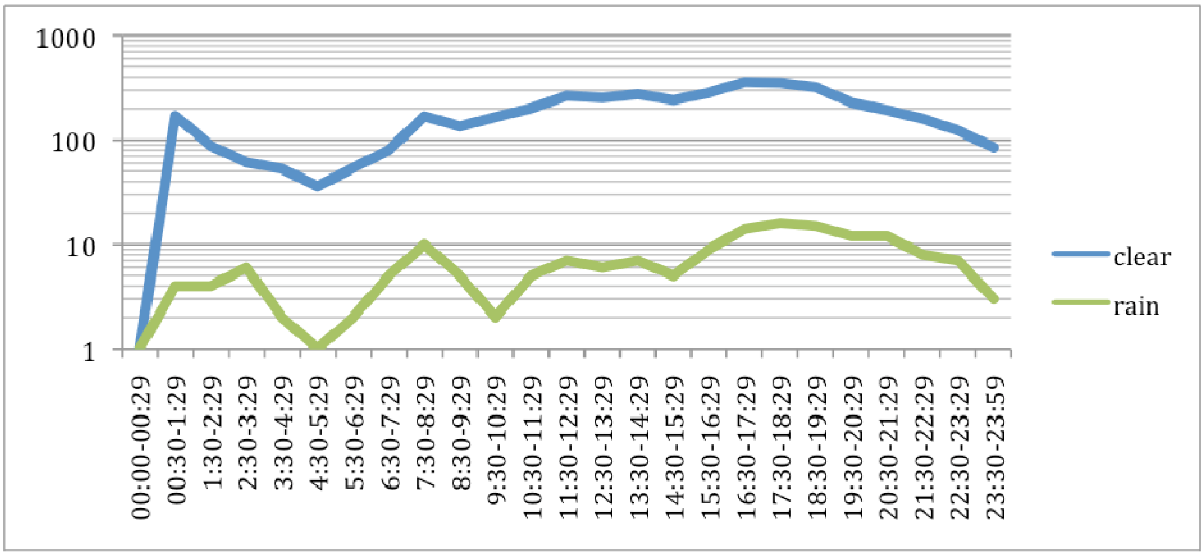


Figure 31: Weather conditions vs. time of accident (accidents), Italy 2005-2007.

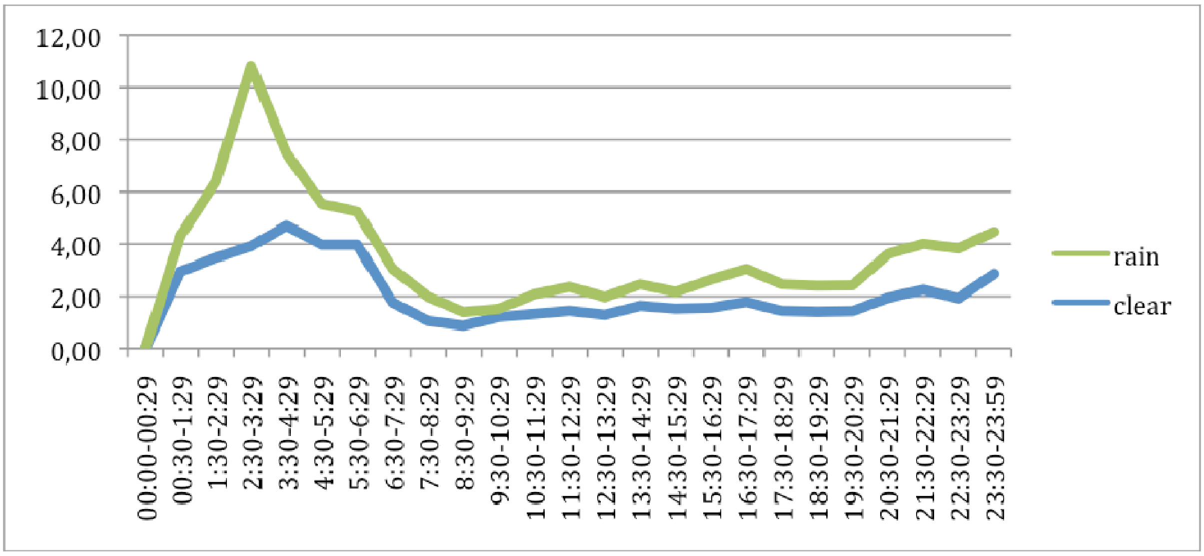


Figure 32: Weather conditions vs. time of accident (severity index*100), Italy 2005-2007.

3.5.4. Summary of Findings - Italy

The Italian national database (ISTAT) was investigated to determine possible interactions between PTW accidents and road infrastructure. The analysis was performed with the queries defined in activity 1.2. The following conclusions can be derived:

- roads with one carriageway and two ways have the highest number of accidents;
- taking into account the accident type, the most relevant accident case is *head-on side on road with one carriageway and two ways*, but the most severe is *one carriageway and two ways* and *collision with an obstacle*;
- crossing junction type with accident type the most relevant case is *head-on side at cross roads*;
- in case of no-junction the most relevant case is *head-on side on straight road*;
- the majority of accidents occur on dry roads (89%) and the largest share involves riders who received the driving licence during the last decade. The number of accidents decreases with an increase in the length of time since the driving licence was delivered;
- a joint analysis of pavement state and type, shows that accidents on wet and slippery roads are less severe than on dry roads (with the same pavement type), while uneven paved roads increase the accident severity;
- roads without traffic signals or with just vertical ones have an higher severity index in the case of one carriageway (two ways) and two carriageways;
- no relevant correlation was found between traffic signals and (no-)junction type;
- riders 21-30 years old are more often involved in accidents; the most dangerous accident cases for this age group are at *cross road* and on a *straight road*;
- there is no correlation between weather conditions and the time of the accident, but the latter parameter is significant since the majority of accidents occur in the 15:30-21:29 range, but the most severe ones in the 23:30-6:29 range.

4. Microscopic Analysis

4.1. Introduction

Within the third sub-activity in activity 1.2, analysis at a micro-level will be performed to identify the critical characteristics of road infrastructure that constitute PTW risk factors.

In-depth data from accident databases and road geometry data (Austria, Germany and Spain) and appropriate software tools (MARVin, RoadVIEW) have been employed and used to conduct this detailed analysis. The software tools allow correlating road measurement data together with PTW accident data.

Similarities of road design elements and surface conditions (various curve radii, radii relations, curvature, crossfall in road sections, type of pavement, skid resistance, texture etc.) and the combination of these data at accident locations will be determined as well as typical crash-causal-circumstances.

The Spanish databank DIANA delivers lots of gathered in-depth accident information, which lead to unique analyses shown in chapter 4.3. The studies carried out in Germany (BASt, data by TU Dresden) and Austria (AIT) use measured road surface data. Descriptions on the measurement parameters and the specific devices are included in the report.

The microscopic analyses should prove in a higher detail the possible critical combinations of road infrastructure influences on PTW accident risks. A closer look at the parameters and factors of road surface characteristics is considered.

4.2. Interaction between Powered Two-Wheeler Accidents and Infrastructure in Austria

4.2.1. Methodology – Austrian Data Base and Available Data

The following report shows the outputs of the analysis of the Austrian data with MARVin software tools. MARVin is the acronym for “Model for Assessing Risks of Road Infrastructure”, in German “Modell zur Abschätzung des Risikopotenzials von Verkehrsinfrastruktur”. The methodology of MARVin is described later in the text.

The analyses in this report are focusing on measurement data of road condition and road geometry in combination with Powered Two-Wheeler (PTW) accidents.

PTW means in this report all motorcycles, which can be allocated in one of the following groups:

- *Motorcycles with engine power less than 25 kW (33HP); relation Weight / Engine power max. 0.16 kW / kg.*
- *Motorcycles with more than 25 kW engine power.*

Moped accidents are not included, because of the fact that the infrastructure data are just gathered at rural roads, outside urban areas. Moped accident hotspots in Austria are mainly located in urban areas, where the influence of road infrastructure especially on the vehicle dynamics is insignificant.

The analyses are based on the annual accident statistic of the years 2000 to 2007, based on the data of *Statistik Austria*. The correlation between PTW accidents of these years (N=10.558) with measured data by the device “RoadSTAR” (actual data) is done by a connection of the data sets via accident location (GPS signal and map matching).

Especially, the curve radius is in the focus of attention, due to the fact that the most severe PTW accidents occur in or after curves. The first step of analysis is based on relations by radii – most of them in double bends, just a few in oval curve combinations. The base hypothesis indicates a dependency of the radii relation and the event of accident (accident type), in the following ways:

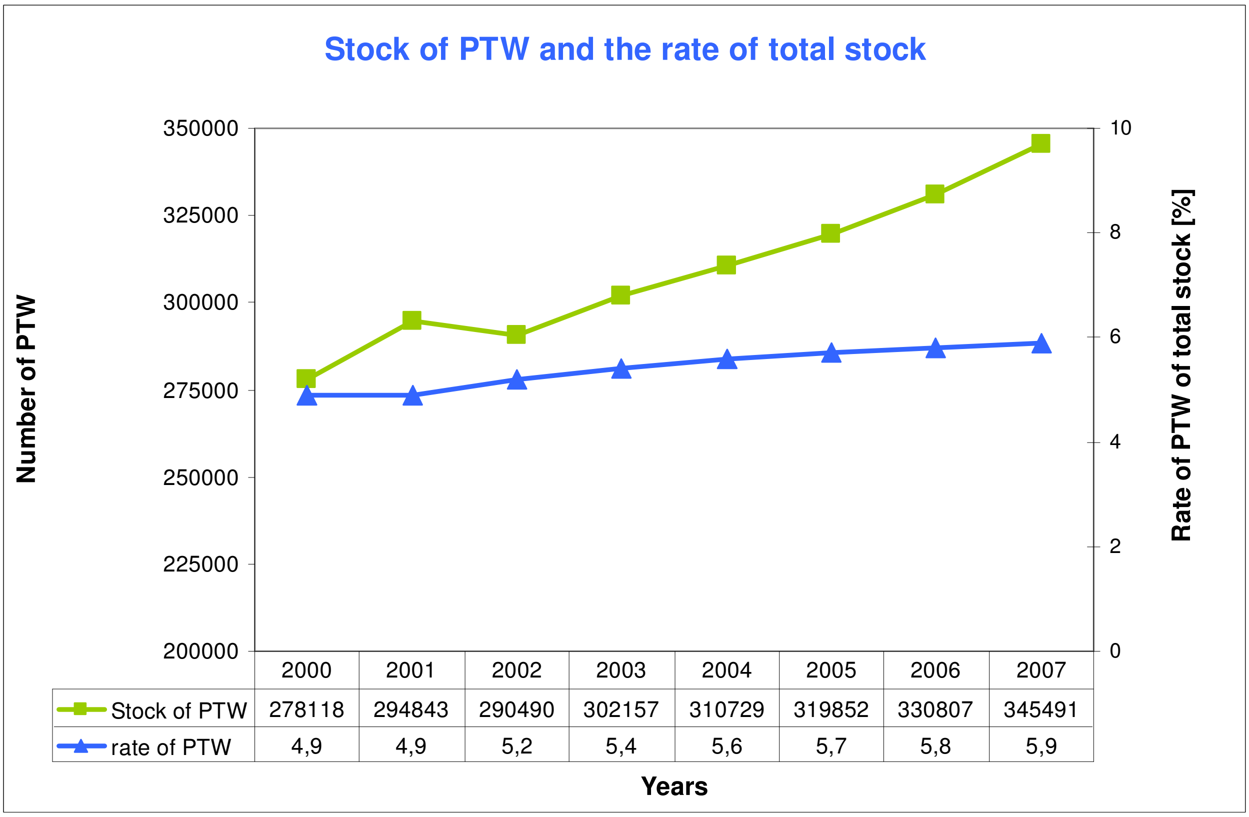
- *Straight lane following by a curve*
- *Curve with large radius following by a curve with smaller radius*
- *Curve with small radius following by a curve with larger radius (probably uncritical)*

The analysis procedure of the whole work was as follows:

- *General statistics for the years 2000 to 2007*
- *National analyses of PTW accidents in context with infrastructure data*
- *Analyses based on the relation of radii in road sections, where PTW crashes occur*
- *Analyses based on specific motorcycle routes (sections in the federal roads network)*

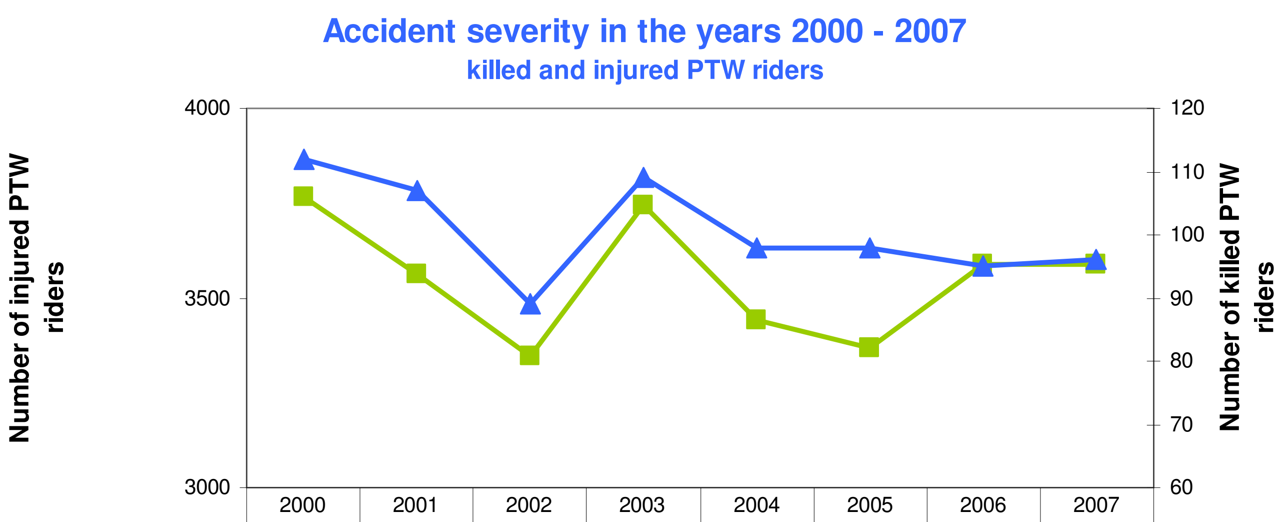
4.2.2. General statistics of PTW accidents in Austria (2000 to 2007)

Figure 33 shows the development of PTW in Austria in the years 2000 till 2007. The increase of PTW in Austria amounts 24%, this correspond a number of nearly 68.000 PTW in the analysed 8 years. Similar to the raising of PTW's in Austria is the increasing rate PTW's relating to the whole stock of powered vehicles in Austria.



	2000	2001	2002	2003	2004	2005	2006	2007
Stock of PTW	278118	294843	290490	302157	310729	319852	330807	345491
rate of PTW	4,9	4,9	5,2	5,4	5,6	5,7	5,8	5,9

Figure 33: Stock of PTW and the rate of PTWs depending on total stock, Austria 2000-2007.



	2000	2001	2002	2003	2004	2005	2006	2007
injured PTW riders	3765	3564	3348	3744	3442	3367	3587	3587
killed PTW riders	112	107	89	109	98	98	95	96

Years

Figure 34: Killed and injured PTW riders, Austria 2000-2007.

Although the stock of PTWs in Austria is still growing, the trend of injured or killed PTW riders is slightly decreasing (showed in Figure 34).

This depends on a variety of facts:

- *Number of travelled kilometres is decreasing*
- *Improved technology concerning motorcycles (ABS…)*
- *Improved driving education*
- *Improved drivers protection equipment*
- *Risk awareness of drivers is increasing*

Nevertheless the absolute number of injured and killed people is still on a too high level; about 14% of all fatalities on Austrian roads are motorcyclists. Regarding the average mileage of a motorcycle per year, which is about one third of the average mileage of a passenger car, the 14% gets another weight.

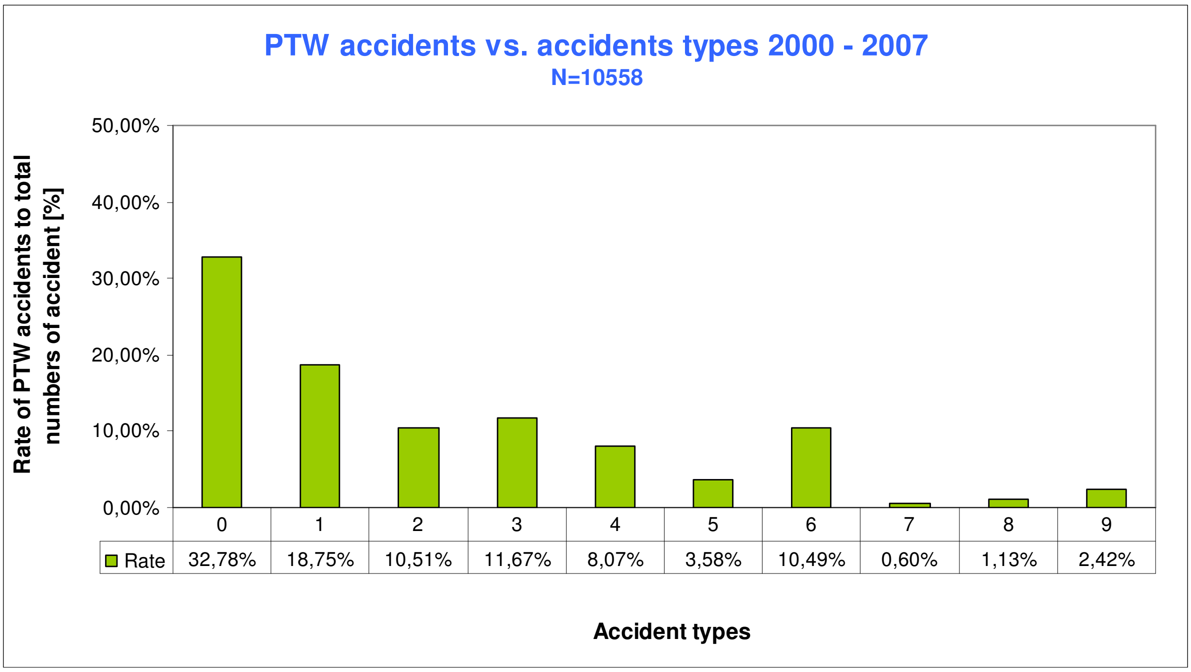


Figure 35: Rate of PTW accidents in relation to accident types, Austria 2000-2007.

The accident data are classified in 10 different accident types and in specified subtypes of particular type. Figure 35 shows the distribution of the found 10.558 PTW accidents in accident type classes. In specific analyses it was figured out that especially run-off accidents (within accident type 0) in and after curves have a very high absolute number and also fatality rate. A reason for that is the driving manoeuvre itself, the braking in curves and the fact of very often fixed crash barriers on the sides of the rural roads.

The separate classes represent the following attributes of accident events:

- 0 = Accident with one involved participant (Single vehicle accident)
- 1 = Accident with two or more involved vehicles in similar direction of traffic
- 2 = Accident with two or more involved vehicles in opposite direction of traffic
- 3 = Accident while turning in similar direction of traffic
- 4 = Accidents while left turning between turning and straight driving vehicle
- 5 = Orthogonal collision with two or more involved vehicles at crossroads (Accidents between vehicles, which are driving on two different ways and no turning at crossroads)
- 6 = Orthogonal collision with two or more involved and turning vehicles at crossroads
- 7 = Accidents with stopped or parked vehicles
- 8 = Accidents with pedestrians
- 9 = Diverse accident with two or more involved participants

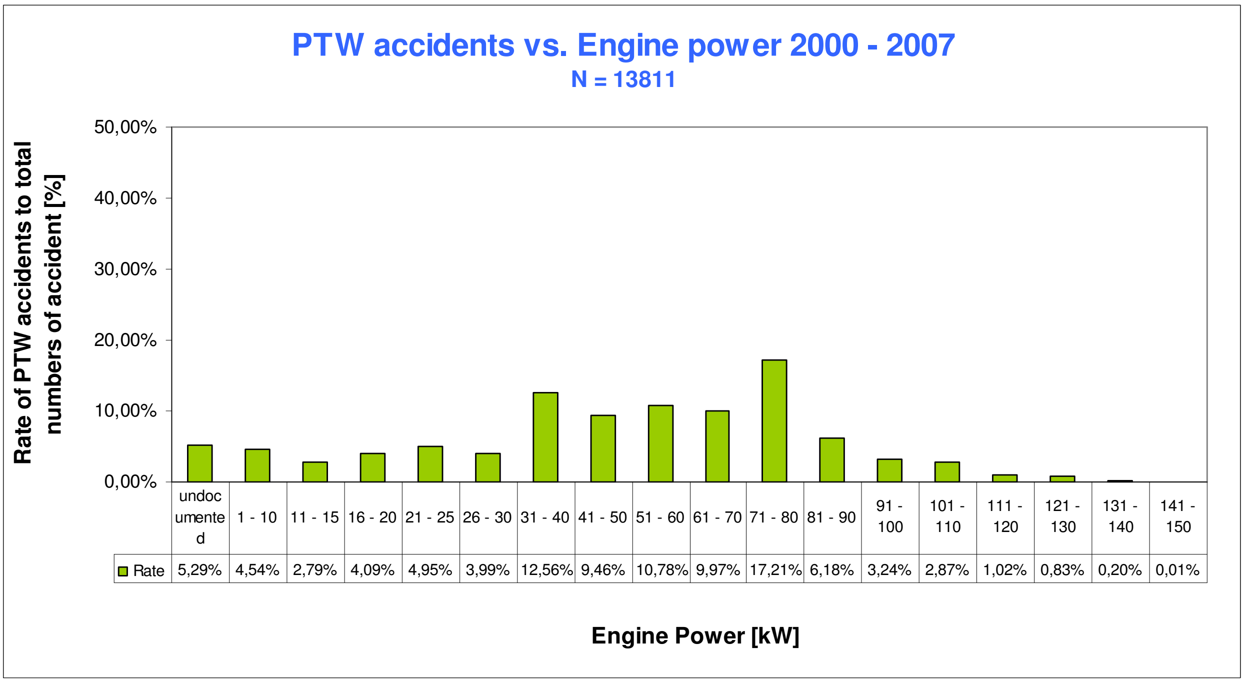


Figure 36: Rate of PTW accidents in relation to Engine power, Austria 2000-2007.

Figure 36 shows the ratios of the engine power of the participated PTWs. 13.811 motorcycles (active motorcycle riders in 10.588 PTW accidents) were figured out in the query. The local maximum is with 17% at PTWs with an engine power of 71 to 89 kW, followed by 31 to 40 kW.

4.2.3. RoadSTAR and MARVin

The following two chapters will describe the measurement device RoadSTAR and the accident risk assessment software tool MARVin.

4.2.3.1. RoadSTAR – Road Surface Tester of AIT (former arsenal research)

The RoadSTAR (Figure 37) was developed by arsenal research experts in close cooperation with the Stuttgart Research Institute of Automotive Engineering and Vehicle Engines. The RoadSTAR allows the most important surface properties and road geometry parameters to be measured under normal traffic conditions at measuring speeds between 40 km/h and 120 km/h (standard speed 60 km/h). Measuring runs are additionally recorded digitally on (DV) video tapes. All measured values are tagged with differentially corrected GPS coordinates.

The RoadSTAR is mounted on an ÖAF 2-axle truck. Engine power is sufficient to allow the RoadSTAR to measure a road with a skid resistance of $\mu = 1.0$ and a gradient of 8 % at a speed of 80 km/h with a full water tank holding 6000 litres.

The RoadSTAR allows following important surface properties and road geometry parameters to be measured under normal traffic conditions:

Skid Resistance

- 18 % Slip (Standard)
- Blocked wheel
- Antilock Braking System (ABS)
- Temperature of the road surface
- Temperature of the measuring tire

Macro-Texture

- MPD (Mean Profile Depth)
- ETD (Estimated Texture Depth)

Transverse Evenness

- Rut depth (left, right)
- Profile depth (left, right)
- Rut width
- Rut Volume
- Theoretical waterfilm thickness
- Waterfilm width
- Waterfilm volume

Roughness

- IRI (International Roughness Index)
- RN (Ride Number)
- FFT-Analysis
- longitudinal profile

Road Geometry

- Curvature
- Crossfall
- Gradient
- Height profile
- dGPS-co-ordinates

Figure 37 on the next page shows the two RoadSTAR measurement trucks. With the left one, all used parameters were gathered.

Figure 37: RoadSTAR1 (left) and the new RoadSTAR2 (right).

4.2.3.2. MARVin – Model for assessing risks of road infrastructure

The aim of the MARVin is to find relations between road infrastructure and road accidents. The data used for this software tool are parameters about road surface characteristics and data about the alignment of the Austrian roads which were gathered with the measurement device RoadSTAR and accident data. The basis of MARVin is a database of about 27.500 km of road where all the relevant road parameters (skid resistance, cross fall, gradient, texture, roughness, curve radius, etc.) belonging to a certain accident can be retrieved.

With MARVin it is possible to strike a new path in crash-causes-research, as “virtual” road sections with a high crash risk potential or “virtual” hot spots can be identified. It is possible to realize route graphs which show all kinds of infrastructure parameters and located accident events (Figure 38).

In Austria 23% of the car accidents causing personal injury happen on hot spots. Hence 77% of the accidents are ignored by just researching the accidents happening on hot spots. It is plausible that groups of similar accident sites exist, of which none is a hot spot. Such a group of almost identical sites could be called a “virtual” hot spot, which is not seen as a hot spot by traditional accident research, because it does not identify these sites as similar.

Another aim of the MARVin system is to demonstrate the connection of different parameters for accident sources using mathematical models (e.g. linear regressions, correlation analyses), the clarification of accident events on similar route sections and develop innovative accident prognoses and derived preventive measures.

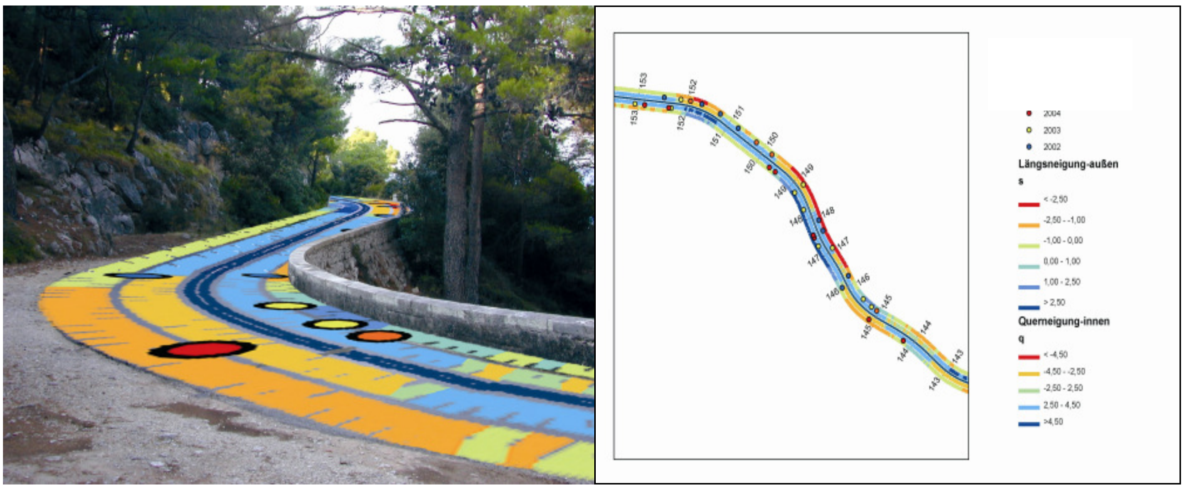


Figure 38: Illustrations of combined road infrastructure data and accident data.

The most important tool of MARVin, the so-called “Similarity Search”, was developed to find “virtual” road sections in the whole road network. It is possible to create an artificial road, a template (see Figure 39), (e.g. specific trace geometry and road condition-parameters) and to find similar, but existing road sections. This is important for a safety-check of planned roads and to show potential hazard areas which indicates changes of the planning as an economic accident preventive measure.

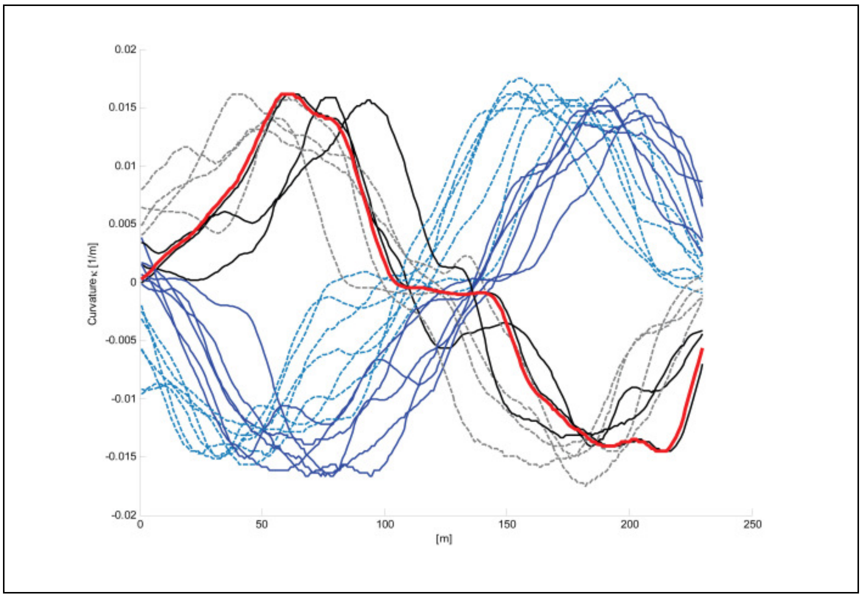


Figure 39: Results of the MARVin Similarity Search (Curvature) plus template (red line).

The red line in Figure 39 shows the designed curvature template for this specific example of “Similarity Search”. All kinds of different RoadSTAR data can be included in predefined template.

4.2.4. Analyses of PTW accidents vs. RoadSTAR data in Austria

4.2.4.1. Analytic procedure

With MARVin it is possible to observe the large number of accidents combined with statistical methods in specific queries using lots of selectable criteria. The basic filtering regarding the PTW accident events was done at the beginning of the analysis.

Accident base after the filtering was a number of 10.558 PTW accident events – the selected parameters are cited in the following tables (see Table 109, Table 110).

Table 109: Accident based criteria for MARVin query.

Accident based criteria			
Accident ID	all	Rainfall	all
Province	all	Time	all
Road type	Rural roads	Lighting conditions	all
Easting	all	Road condition	all
Northing	all	Weather	all
Road kilometre	all	GPS - Long	all
Political region	all	GPS - Lat	all
Commune	all	Highest degree of violation	all
Road number	all	Number of active involved persons	all
Driving direction	all	Number of involved persons	all
Accident date	all	Number of killed persons	all
Accident type	all	Number of seriously injured persons	all
Road surface	all	Number of slightly injured persons	all

Table 110: Accident victims based criteria for MARVin query.

Personal based criteria	
Involved ID	all
Sex	all
Safety	all
Ending year of age	all
Date of acquirement the driving license	all
Degree of injury	all
Type of participations	PTW
Driving direction	all
Registration date	all
Engine power	all
Circumstances of accident	all

The query results were 10.558 PTW accidents with 19.997 involved accident victims (13.811 riders). These accidents were correlated with measurement data of the road sections 100 meters (estimated length where the accident took place) before the accident spots.

After the database connection 3.203 PTW accidents are left for the microscopic analyses of each single road section.

Cross tabulations of these accidents with specific RoadSTAR parameters are finally done.

The tables in the next few chapters show the results of accomplished analyses.

Declaration for reading the tables:

- *Category = Classification of quality in classes*
- *Number of PTW accidents = Number of accidents allocated to the different categories*
- *Rate of PTW accidents = Rate of accidents to the sum of allocated PTW accidents*
- *Occurrence of condition classes = Occurrence of road condition in Austria. Detected in a measurement campaign 2001 - 2002 for 10.000 km of rural roads.*
- *The quality classes (from very good to very poor) were defined by RVS 13.01.15 (FSV Austria, Austrian direction for road construction, 2006). The classes within this directive are basically defined for A-level roads (motorways), in many cases suitable also for the rural roads, but sometimes maybe considered as inappropriate. No specific quality classes are defined for rural roads in Austria.*

4.2.4.2. Longitudinal gradient [s]

Table 111: PTW accidents vs. Longitudinal gradient.

Category	Longitudinal gradient absolute [%]	Number of PTW accidents	Rate of PTW accidents
1	1	1330	41,72%
2	2	708	22,21%
3	3	381	11,95%
4	4	200	6,27%
5	5	150	4,71%
6	6	133	4,17%
7	7	100	3,14%
8	8	71	2,23%
9	9	41	1,29%
10	10	30	0,94%
11	> 10	44	1,38%
sum		**3188**	**100,00%**
not known	15		

The longitudinal gradient (see Table 111) is the slope of the gradient in driving direction. The absolute gradient does not differentiate between decline and inclination. Most of the accidents happen on nearly plane road sections. Rations for the gathered data in the whole road network are not available. But it can be estimated that most of the built roads are nearly planar.

4.2.4.3. Crossfall [q]

Table 112: PTW accidents vs. Crossfall.

Category	Transversal gradient absolute [%]	Number of PTW accidents	Rate of PTW accidents
1	1	160	5,02%
2	2	718	22,52%
3	3	939	29,45%
4	4	782	24,53%
5	5	352	11,04%
6	6	157	4,92%
7	7	57	1,79%
8	8	17	0,53%
9	9	3	0,09%
10	10	2	0,06%
11	> 10	1	0,03%
sum		**3188**	**100,00%**
not known	15		

The crossfall of a road surface is the inclination in transversal axes of the road and perform task of driving dynamics and drainage of the road surface. In the Austrian road construction directives the crossfall is defined as 2.5% for straight roads to optimise the drainage, in curves and all changes of curve directions the crossfall can be lower or higher than 2.5%. The Table 112 above shows that the most PTW crashes occur on roads with an gradient around 2.5%.

4.2.4.4. Skid resistance [µ]

Table 113: PTW accidents vs. Skid resistance.

Category	Quality Classes	Skid resistance µ [-]	Number of PTW accidents	Rate of PTW accidents	Occurrence of conditions classes
1	very good	µ > 0,75	1711	53,77%	57,60%
2	good	0,75 ≥ µ > 0,59	985	30,96%	27,05%
3	average	0,59 ≥ µ > 0,45	342	10,75%	10,75%
4	poor	0,45 ≥ µ > 0,38	91	2,86%	2,67%
5	very poor	µ ≤ 0,38	53	1,67%	1,93%
sum			**3182**	**100,00%**	**100,00%**
not known	21				

The skid resistance of a road surface means the property to develop friction between the tire and road surface. Table 113 shows PTW accidents related to skid resistance. More than 53% of all accidents on rural or inter urban roads happen on sections with very good road condition quality.

Also the occurrence of the measured skid resistance data in the whole net and the relative numbers can not change this fact. The background for the quality classes and a new Austrian model is shown a publication by Maurer (2007).

4.2.4.5. Longitudinal evenness [IRI]

Table 114: PTW accidents vs. Longitudinal evenness IRI.

Category	Quality Classes	Longitudinal evenness IRI [m/km]	Number of PTW accidents	Rate of PTW accidents	Occurrence of conditions classes
1	very good	0,0 ≤ IRI < 1,0	88	2,77%	5,38%
2	good	1,0 ≤ IRI < 1,8	975	30,66%	38,48%
3	average	1,8 ≤ IRI < 3,0	1298	40,82%	34,85%
4	poor	3,0 ≤ IRI < 4,5	591	18,58%	14,36%
5	very poor	IRI ≥ 4,5	228	7,17%	6,93%
sum			**3180**	**100,00%**	**100,00%**
not known	23				

The International Roughness Index (IRI) is a parameter to describe the evenness in longitudinal driving direction. IRI describes the unevenness of a road surface as a relative velocity between an unsprung and full sprung mass of a virtual suspension in meters per kilometre. Detailed research work in the IRI has been done by Spielhofer et al. (2008).

Table 114 shows that most of the accidents happen in areas of good and average. Also the occurrence of the measured IRI data in the whole net and the relative numbers can not change this fact. But the trend shows that critical IRI values have higher rates at road section where PTW crashes occurred.

4.2.4.6. Texture [MPD]

Table 115: PTW accidents vs. Texture MPD.

Category	Quality Classes	Texture MPD [mm]	Number of PTW accidents	Rate of PTW accidents	Occurrence of conditions classes
1	very good	MPD > 0,8	314	10,23%	14,07%
2	good	0,8 ≥ MPD > 0,7	164	5,34%	6,39%
3	average	0,7 ≥ MPD > 0,6	278	9,06%	10,05%
4	poor	0,6 ≥ MPD > 0,3	1802	58,70%	55,39%
5	very poor	MPD ≤ 0,3	512	16,68%	14,11%
sum			**3070**	**100,00%**	**100,00%**
not known	133				

The Mean Profile Depth (MPD) means the form of a road surface (see Figure 40). MPD does not depend only on the manufactured material but also on process during the manufacture. Additional to the named parameters, texture also changed in course of time. This affect depend on the weather and on the traffic flow.

The results of analysis concerning texture and PTW accidents are shown in Table 115. Most of the accidents happen in category “poor”, more than 58% of the PTW accidents are allocated to this quality class. This class is also largest category at the occurrence of the measured data in the whole net. This means that the most parts of Austrian rural roads are in bad texture condition – or the quality classes are not well divided.

Also the occurrence of the measured MPD data in the whole net and the relative numbers can not change this fact. The interesting outputs of the queries regarding skid resistance and texture give an important link to the possible risk factors for the driving dynamics of PTWs. It seems that influence of the texture and its effect of toothing between tyre rubber and asphalt or concrete surfaces are more significant at accident sites, than the friction values (skid resistance) of the infrastructure. These thesis need further in-depth research in terms of driving manoeuvres – side forces in curves, acceleration and deceleration tests.

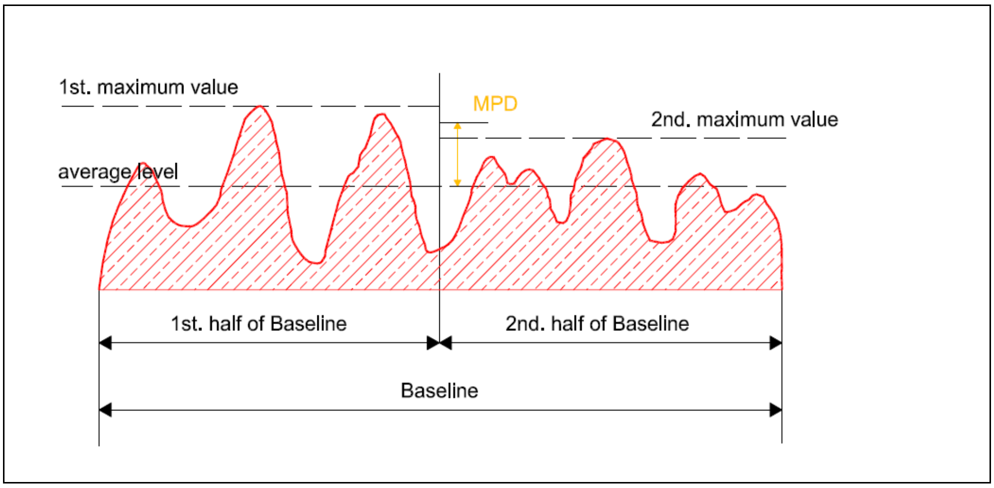


Figure 40: Explanation of Mean Profile Depth MPD.

4.2.4.7. Rut depth [t_s]

Table 116: PTW accidents vs. rut depth t_s.

Category	Quality Classes	Rut depth ts [mm]	Number of PTW accidents	Rate of PTW accidents	Occurrence of conditions classes
1	very good	0,0 ≤ ts < 5,0	1099	34,55%	40,06%
2	good	5,0 ≤ ts < 10,0	1284	40,36%	37,80%
3	average	10,0 ≤ ts < 15,0	587	18,45%	14,67%
4	poor	15,0 ≤ ts < 20,0	180	5,66%	5,20%
5	very poor	ts ≥ 20,0	31	0,97%	2,27%
sum			**3181**	**100,00%**	**100,00%**
not known	22				

The parameter Rut depth means is the largest possible depth gauge in transversal axis of a road profile and below a 2m latch (see Figure 41). The measurement is simultaneous for both rutting in each lane.

Table 116 shows the results for the relation PTW accidents vs. rut depth. Most of the accidents, about 75%, happen in the classes with quality “very good” and “good”. Also the occurrence at whole rural road net in Austria can be allocated to these categories.

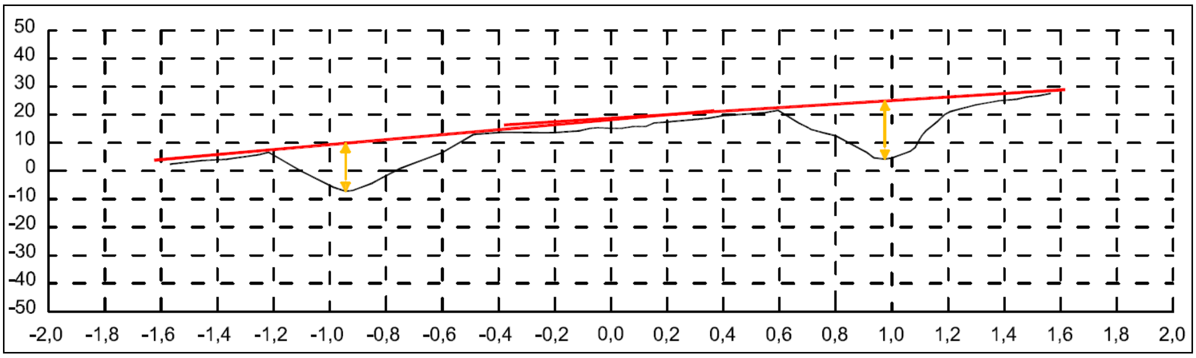


Figure 41: Rut depth t_s below 2m bar.

4.2.4.8. Theoretical water [t_w]

Table 117: PTW accidents vs. theoretical water depth t_w.

Category	Quality Classes	Theor. waterdepth tw [mm]	Number of PTW accidents	Rate of PTW accidents	Occurrence of conditions classes
1	very good	0,0 ≤ tw < 1,0	315	9,90%	73,69%
2	good	1,0 ≤ tw < 2,5	1618	50,86%	12,05%
3	average	2,5 ≤ tw < 4,0	760	23,89%	3,44%
4	poor	4,0 ≤ tw < 6,0	226	7,10%	4,44%
5	very poor	tw ≥ 6,0	262	8,24%	6,36%
sum			**3181**	**100,00%**	**100,00%**
not known	22				

The theoretical water depth indicates the maximum depth of water accumulation in the left and right rutting, which is theoretical possible (see Figure 42). This parameter is dependent on crossfall at profile of roads. In the case of very low crossfall, water can be accumulated in rutting and thus can yield a threat to road safety caused by aquaplaning.

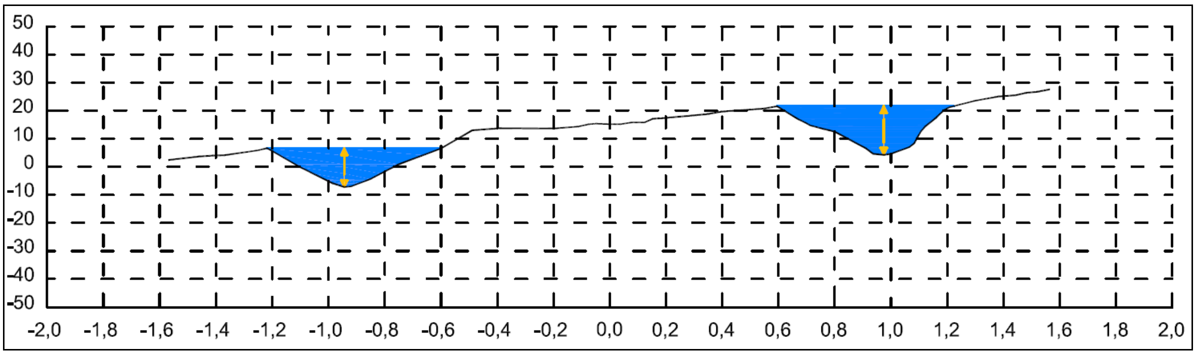


Figure 42: Theoretical water depth t_w.

Table 117 shows the results of relation PTW accidents and theoretical water depth. Most of the accidents are situated in category 2, quality "good". Maybe the quality class "good" is not well adapted depending on the PTW crash risk? This questions needs to be answered in further research work.

Greater significations have the PTW accidents in quality class "average". Nearly 24% of the accidents are allocated to this category, but only 3.44% of the measured data of the whole rural road net in Austria correspondent with this category.

4.2.5. Analyses of radii relations on PTW accident sites in Austria

4.2.5.1. Analytic procedure

First step of analysing the relation of radii relations to PTW accidents was the national wide search with the MARVin "Similarity Search" for predefined relations (templates) at federal roads in Austria. The aim is to figure out if the quality classes, given in the common construction guidelines (German RAS-L, which is also used in Austria), are valid for PTW accidents.

Therefore the analytic procedure was as follows:

- *3 relations for each range (good, average and poor) of the correlation between radius 1 and radius 2 defined in RAS-L (see Figure 43, FGSV, RAS-L, German direction for road construction, 1995)*
- *Evaluation of lengths for MARVin templates (see Figure 44)*
- *MARVin queries*
- *Searching for PTW accidents on road sections (MARVin findings)*
- *Interpretation of correlation between PTW and all other accidents*

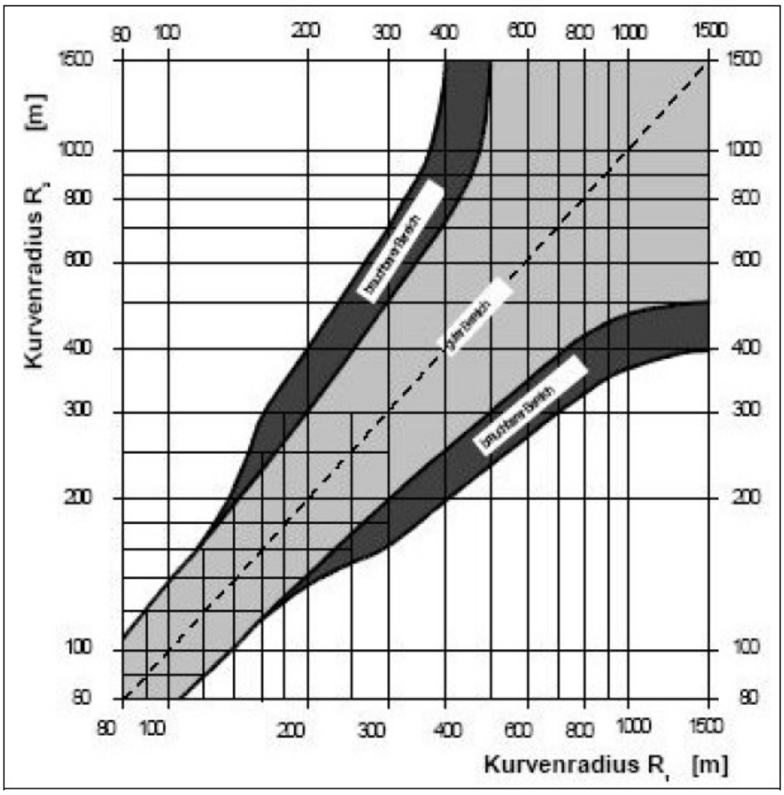


Figure 43: Correlation between radius 1 and radius 2 – so-called "Radii Tulip".

Declaration for reading Figure 43:

- *Guter Bereich = good range (good)… grey area*
- *Brauchbarer Bereich = moderate range (average)… black area*
- *Ungünstiger Bereich = inappropriate range (poor)… white area*

Declaration for reading Figure 44:

- *L1 ….. 25 % of circumference of first radius*
- *L2 ….. Clothoid first radius*
- *L3 ….. Clothoid second radius*
- *L4 ….. 30% of circumference of second radius*

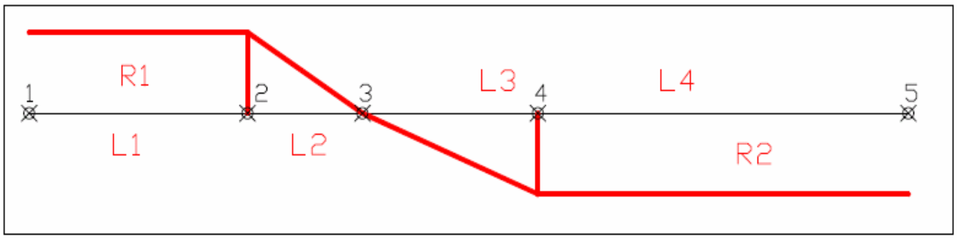


Figure 44: Schematic template for MARVin query - Curvature (1/R).

Example:

R1 = 100m
R2 = 300m
L1 = circumference * 0.25 ≈ 157m
L4 = circumference * 0.30 ≈ 565m

L2, L3 = calculated with Table 2 of RVS 03.03.23 (Austrian direction for road construction, FSV, 2004)

4.2.5.2. Findings based on radii relations (MARVin queries based on given templates)

The results of analysis based on defined radii relations in Austria are enclosed at the end of the report (see Annex). The selected templates for the similarity search were: R1/R2 – 100/100, 200/200, 300/300; 100/150, 160/250, 200/300; 50/150, 100/200, 100/300.

Many of road sections have been found with the MARVin similarity search module. This means that the detected road sections are according to the randomized MARVin template.

PTW accidents could be allocated to these located road sections. But the significance of these results is not given. There are no detectable differences between the defined quality classes and the PTW accidents.

The reasons are the approach itself and the missing of necessary data:

- Because of missing data relating to traffic flow and distribution to different traffic participants (exposure data and modal split is not available), the link between PTW accidents to all accidents is not clear. A significant PTW accident risk can not be identified with this analysis methodology – also because the *"non-accidents"* can not be included in the analyses in a comparable way.
- To tackle some aspects of this failure it is necessary to analyse defined road sections, where the traffic flow is approximately constant. In this case of nearly similar traffic flows, there is no larger arterial road existing or any other federal roads crossing. The radii relations on the complete single section are comparable, because the relative accident risk regarding the constant exposure (even there are no absolute numbers) is defined.
- The variation of queries, caused by the 9 predefined construction of the template is limited. Further analyses with this method need much more templates to be checked.
- The assumption of radii ranges till 300m is justified by the annual PTW accident statistic, but it causes problems, especially when PTW accidents occur in curves following after a straight road section. These combinations were not covered by the similarity search approach.
- These arguments are the reason for the next analysis step, to choose defined road sections, with an estimated higher motorcycle exposure (motorcycle routes).

4.2.6. Analyses based on radii relations on road sections in the Austrian federal roads network

The reason for the choice of seven defined road sections at typical motorcycles routes is, that the traffic flow inside the sections is nearly constant, also the modal split. The exposure of motorcycles is relatively high on these specific sections in Austria. Another advantage of this kind of investigation is, that also road sections with *no registered accidents* are analysed in a comparable way, so the risk assessments are more appropriate and significant.

The analysis procedure was the following:

- *Searching for defined road sections*
- *Query of PTW accidents at different road sections from 2000 to 2007*
- *Identification of radii [m] and radii relations on the whole section*
- *Positioning of PTW accidents in map*
- *Allocation of PTW accident or no-accident to radii relation*
- *Inscription of PTW accidents or no-accident in "Radii Tulip" (see Figure 43)*
- *Query of all other accidents at all road sections*
- *Positioning of other accidents in map*
- *Allocation of other accidents and no-accidents to radii relation*
- *Inscription of other accidents and no-accidents in "Radii Tulip"*

A critical point within these queries was, that just for 140 of 172 in detail analysed and located accidents, the direction of travel could be allocated.
The road sections have been checked in both directions (increasing and decreasing km). The detailed outputs (figures of the radii tulips, were the accidents and no-accidents are drawn in) of the specific inspections and the results for other vehicles accidents are enclosed in the Annex of the report.

Figure 45 shows the description of allocation PTW and all other accidents to radii relation. The scene of accident is always situated in radius 2. The background for this conclusion is that an accident, especially PTW accident, starts to happen some meters before the actual spot of the crash event.

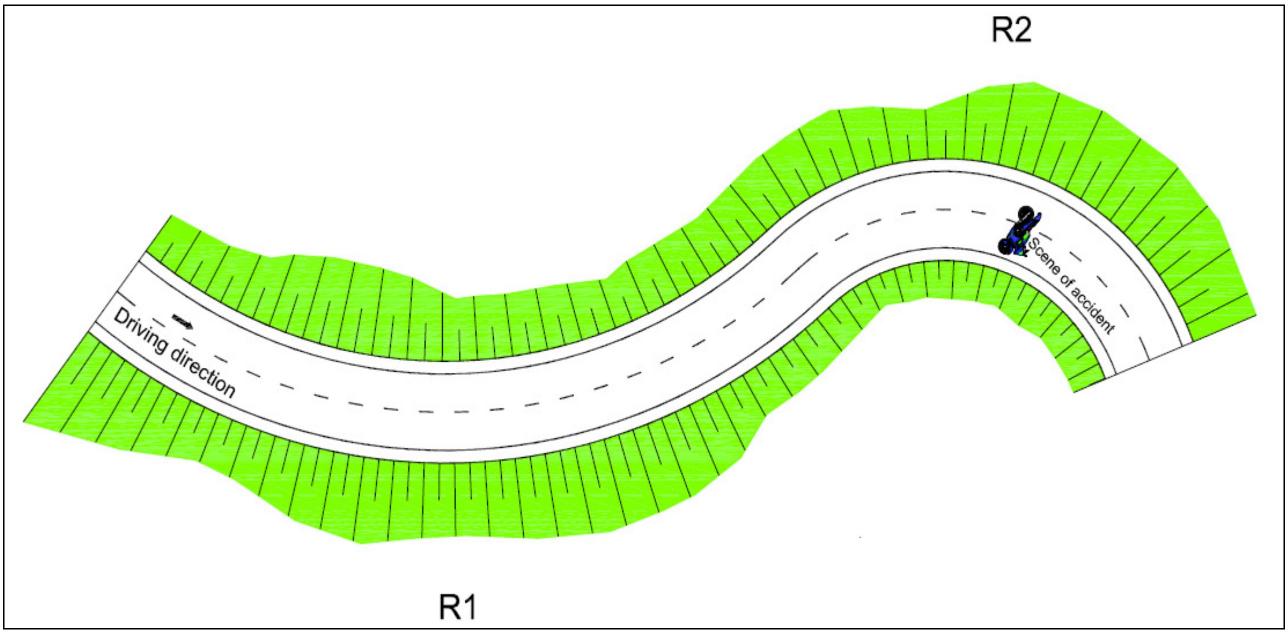


Figure 45: Description for the positioning of PTW accident (or other accidents) in radii relation.

For the recording of PTW accidents and all other accidents in the radii tulips, all accidents are checked on their accident types and driving directions. Accidents with no defined driving direction are filtered out and eliminated, also accidents with mistakes (e.g. impossible accident type) in the data base in some cases.

4.2.6.1. Selected road sections

I. B20 "Türnitz - Annaberg

Table 118: General information about road section B20 "Türnitz - Annaberg".

Road name	B 20
Road from - to	St. Pölten to Kapfenberg
Section length [km]	18.87
Section start	Km 39.180
Section end	Km 53.050
Sum of accidents	16
Registered count of accidents	13

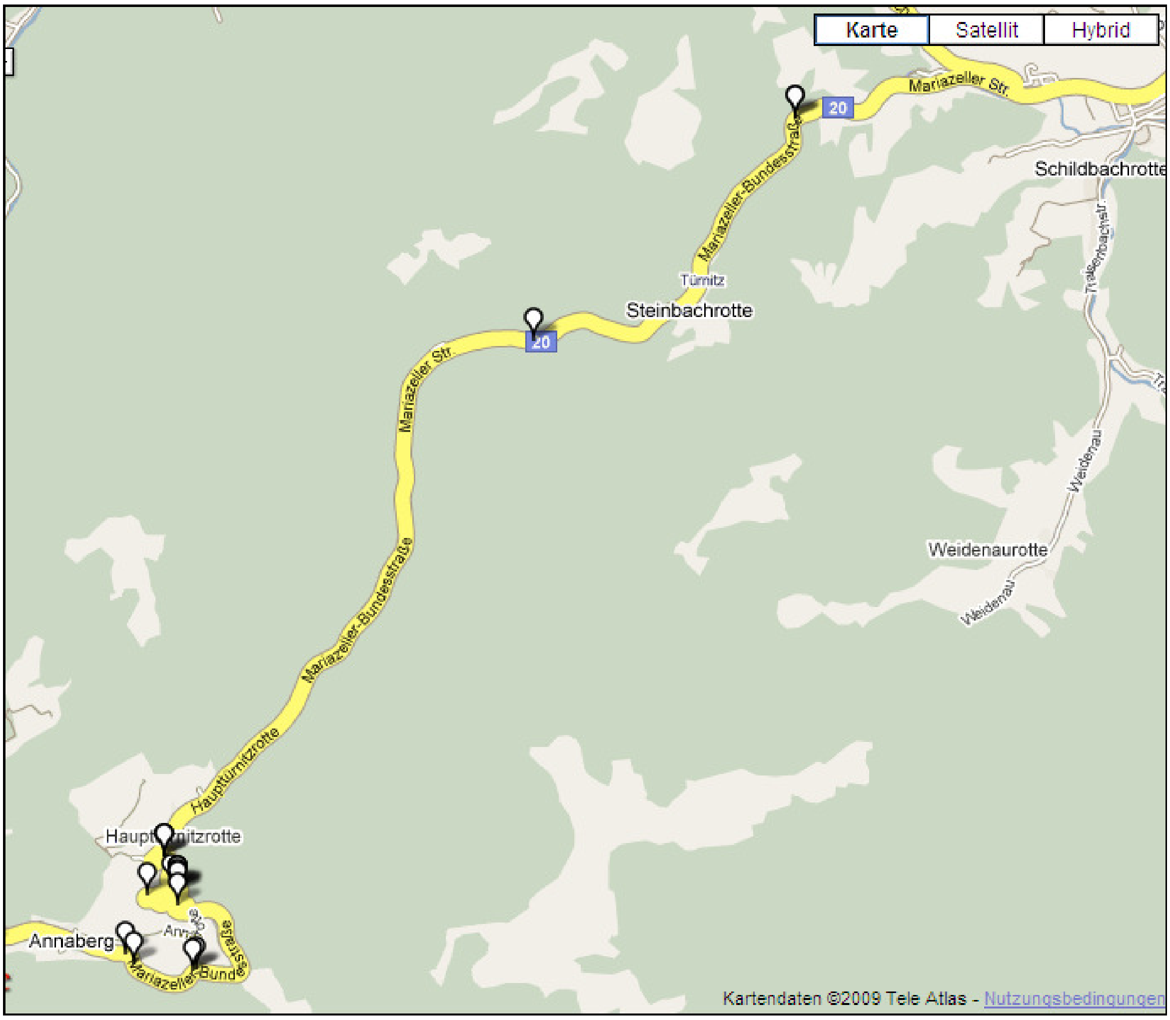


Figure 46: Road section B20 "Türnitz - Annaberg".

General information about the road section "Türnitz - Annaberg" at B20 are presented in Table 118. 13 of 16 accidents could be analysed in detail, because the driving direction was known. The road section, which you can see in Figure 46, has a length of nearly 18.87 kilometers. 90% of the whole road section are designed harmonic and with larger radii and straight lanes, but last part of road section has a very disharmonic trace design. There you have a lot of smaller curves, switchbacks and double bends and critical radii relations. Here most of the PTW accidents take place.

Findings on Road section B20 "Türnitz - Annaberg"

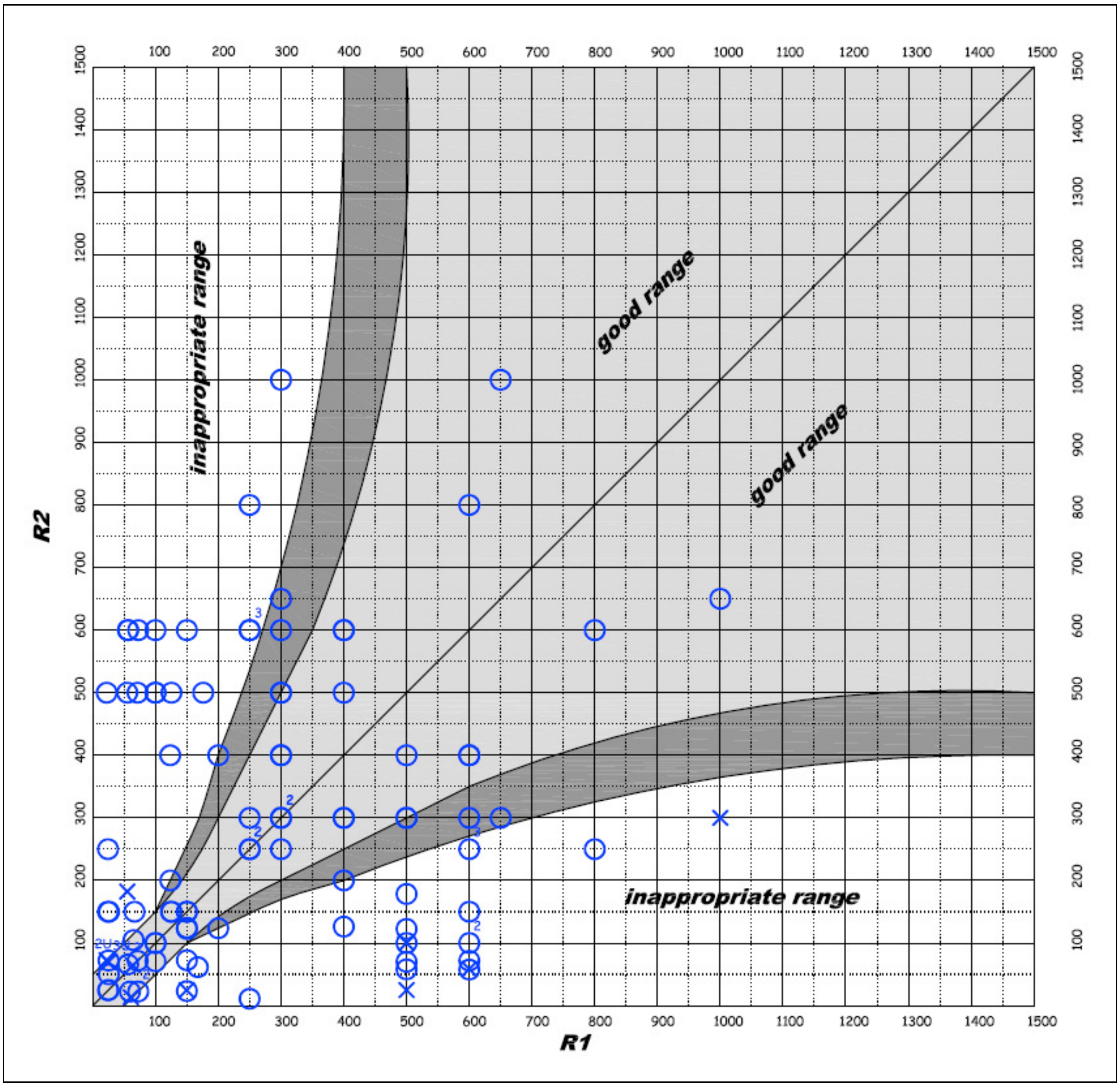


Figure 47: Result of analysed radii relations at "Türnitz - Annaberg".

Results of analysis based on the radii relation (see Figure 47):

- *The most PTW accidents happen in radii relations R1:R2 larger than 1.0 (the accident happens on sections, where the first curve radius is larger than the second one).*
- *The analysis of all other accidents shows similar results (see Annex).*
- *The most PTW accidents happen in the range with a curve radius at R2 smaller than 200m. (see zoomed figure in the Annex)*
- *Areas with other accident participation (truck, passenger car…) are also dangerous for PTWs.*

The crosses in the figures indicate that there is an accident on the specific radii relation, the circle symbolises that on this relation not accident occurred (the numbers beside the symbols are the count for occurrence, U beside the crosses stands for "Unfall", means accident – when more then one accident was on the same location).

II. B20 "Reith – Mitterbach am Erlaufsee"

Table 119: General information about road section B20 "Reith – Mitterbach a. Erlaufsee".

Road name	B 20
Road from - to	St. Pölten to Kapfenberg
Section length [km]	11.66
Section start	Km 59.270
Section end	Km 70.930
Sum of accidents	17
Registered count of accidents	15

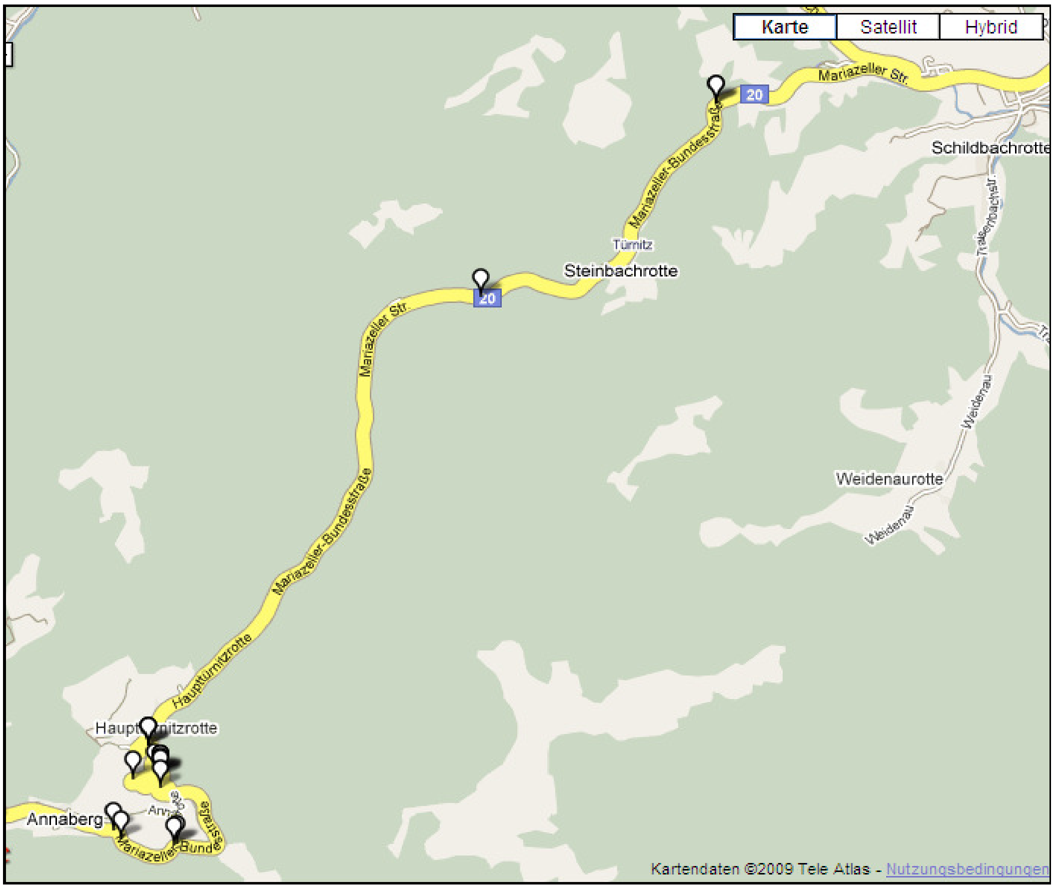


Figure 48: Road section B20 "Reith – Mitterbach a. Erlaufsee".

Table 119 shows general information about road section "Reith – Mitterbach a. Erlaufsee". The whole road section is also disharmonic designed (see Figure 48) – a fact which makes the road very attractive for motorcyclists. The most scenes of PTW accidents are located at small and sharp turns.

Findings on Road section B20 "Reith – Mitterbach a. Erlaufsee"

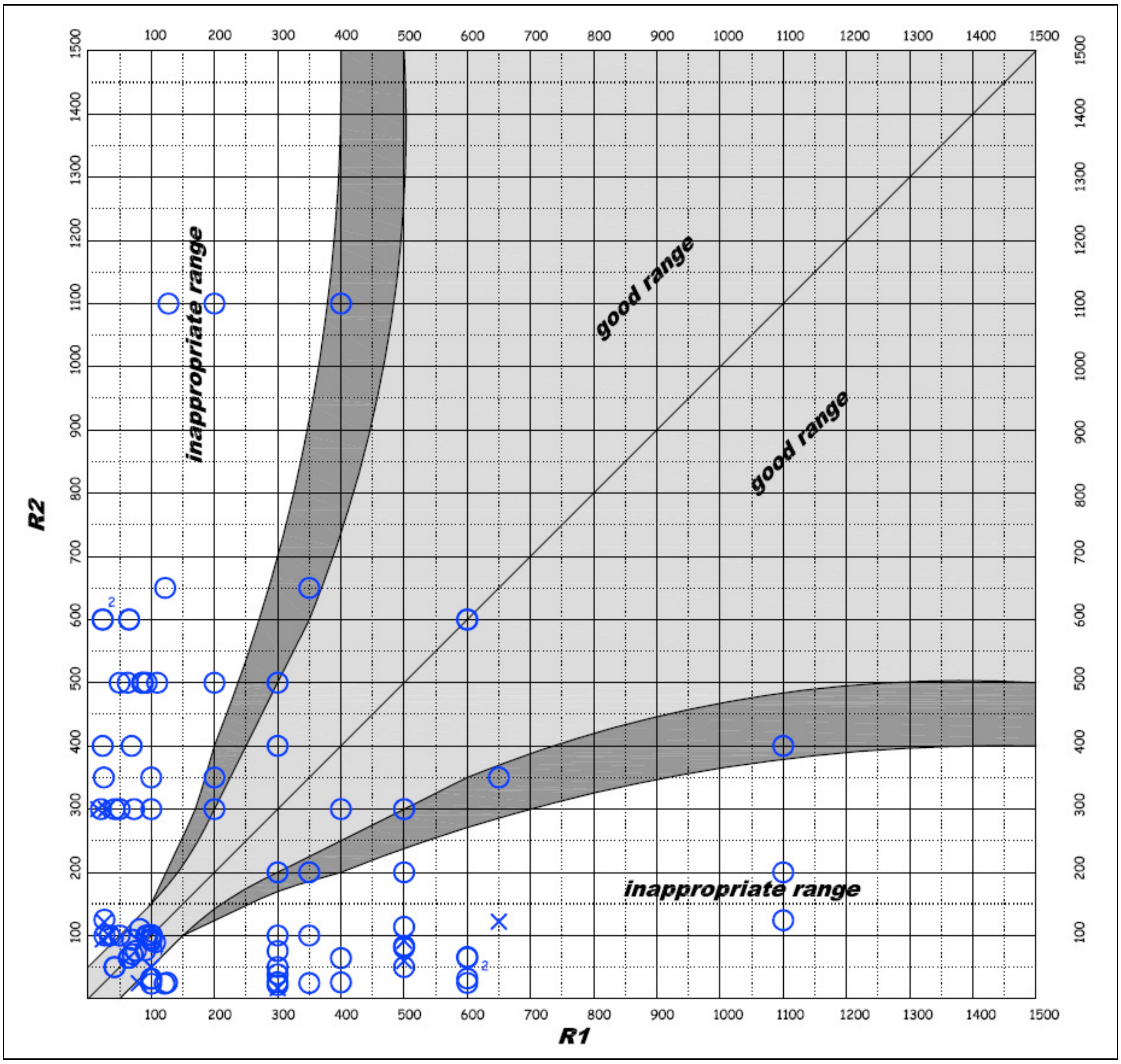


Figure 49: Result of analysed radii relations at "Reith – Mitterbach a. Erlaufsee".

Results of analysis based on the radii relation (see Figure 49):

- *A lot of PTW accidents in the range of R1 = 100m and R2 = 100m – this very good relation probably allows too high speeds. (see zoomed figure in the Annex)*
- *The same results show the analysis of all other accident participations.*
- *The most PTW accidents happen in radii relations R1:R2 larger than 1.0*
- *The most PTW accidents happen in the range, with a curve radius R2 smaller than 200m.*

III. B27 "L134 (Klostertal) – Hirschwang an der Rax"

Table 120: General information about road section B27.

Road name	B 27
Road from - to	Rohr i. Gebirge to Gloggnitz
Section length [km]	14.82
Section start	Km 11.200
Section end	Km 26.020
Sum of accidents	43
Registered count of accidents	39

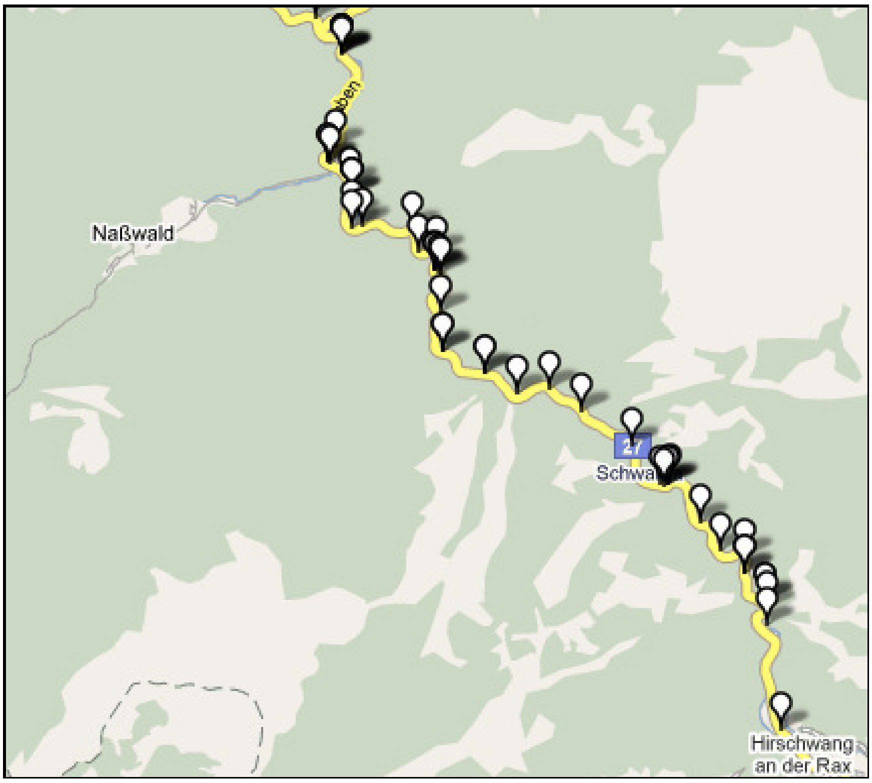


Figure 50: Road section B27 "L134 (Klostertal) – Hirschwang a.d. Rax".

Road section "L134 (Klostertal) – Hirschwang a.d. Rax" is the section with the most PTW accidents, compared to the other six road sections. Table 120 shows general information about this road section. The alignment of road is constructed nearly harmonic; without very sharp curves. The PTW accidents are situated along the whole road section. Although, the road section is nearly constant designed, there are also some sites with an accumulation of PTW accidents, situated at curves with smaller radii.

Findings on Road section B27 "L134 (Klostertal) – Hirschwang a.d. Rax"

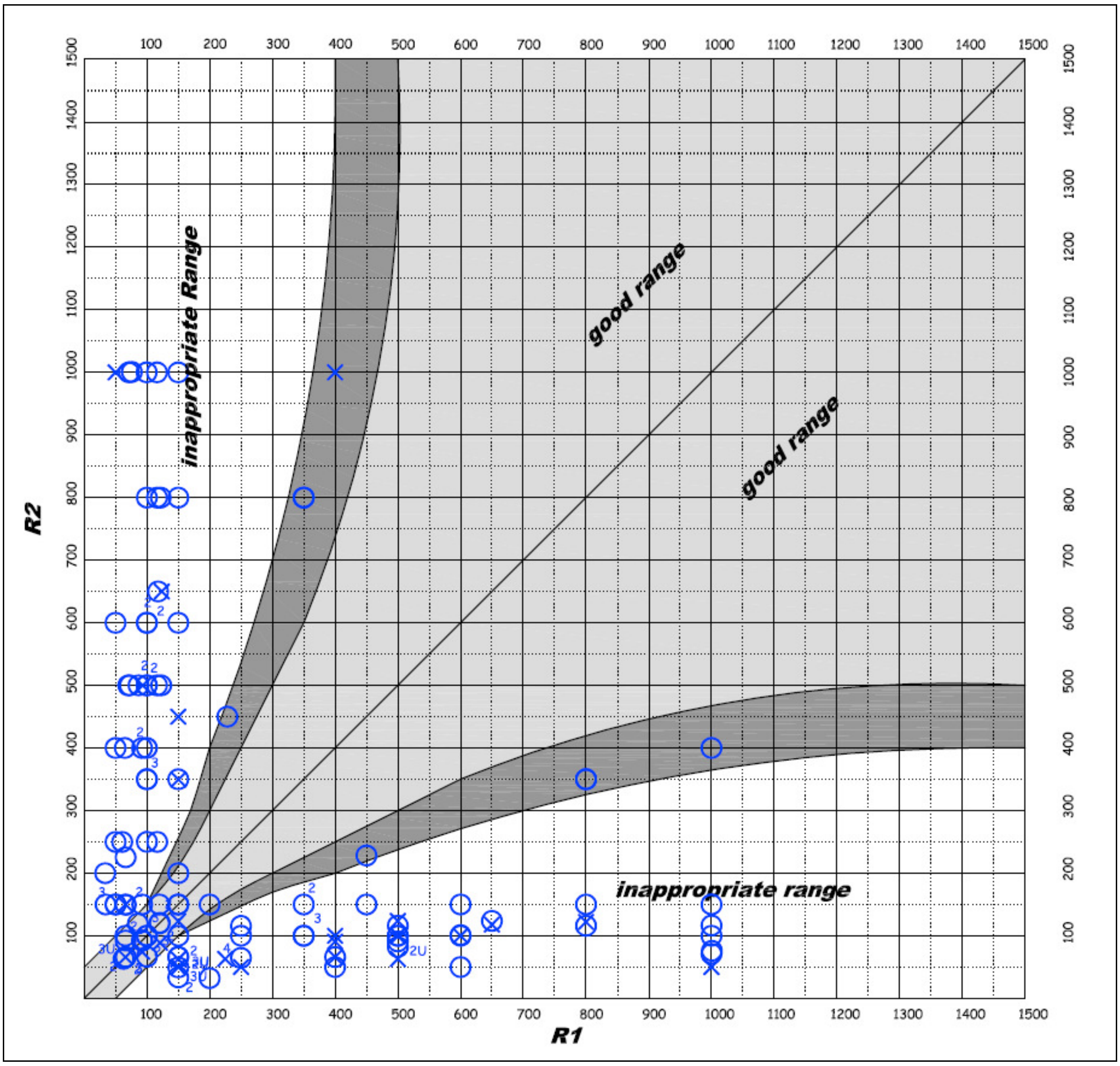


Figure 51: Result of analysed radii relation at "L134 (Klostertal) – Hirschwang a.d. Rax".

Results of analysis based on the radii relation (see Figure 51):

- *The most PTW accidents occure in radii relations R1:R2 larger than 1.0*
- *But there also exist PTW accidents with a radii relation smaller than 1.0 (the second radius is larger then the first one).*
- *Areas with other accident participation (truck, passenger car…) are also dangerous for PTWs.*
- *The most PTW accidents happen in the range with a curve radius R2 smaller than 200m.*

IV. B72 "St. Kathrein am Hauenstein – Krieglach"

Table 121: General information about road section B72.

Road name	B 72
Road from - to	Graz to Krieglach
Section length [km]	12.80
Section start	Km 71.800
Section end	Km 84.600
Sum of accidents	16
Registered count of accidents	11

Figure 52: Road section B72.

Table 121 shows general information about the road section "St. Kathrein a. Hauenstein - Krieglach". The alignment of road is harmonic with some longer nearly straight passages. The PTW accidents are evenly distributed along the whole road section. Figure 52 shows the map of road section with the located accident spots.

Findings on Road section B72 "St. Kathrein a. Hauenstein - Krieglach"

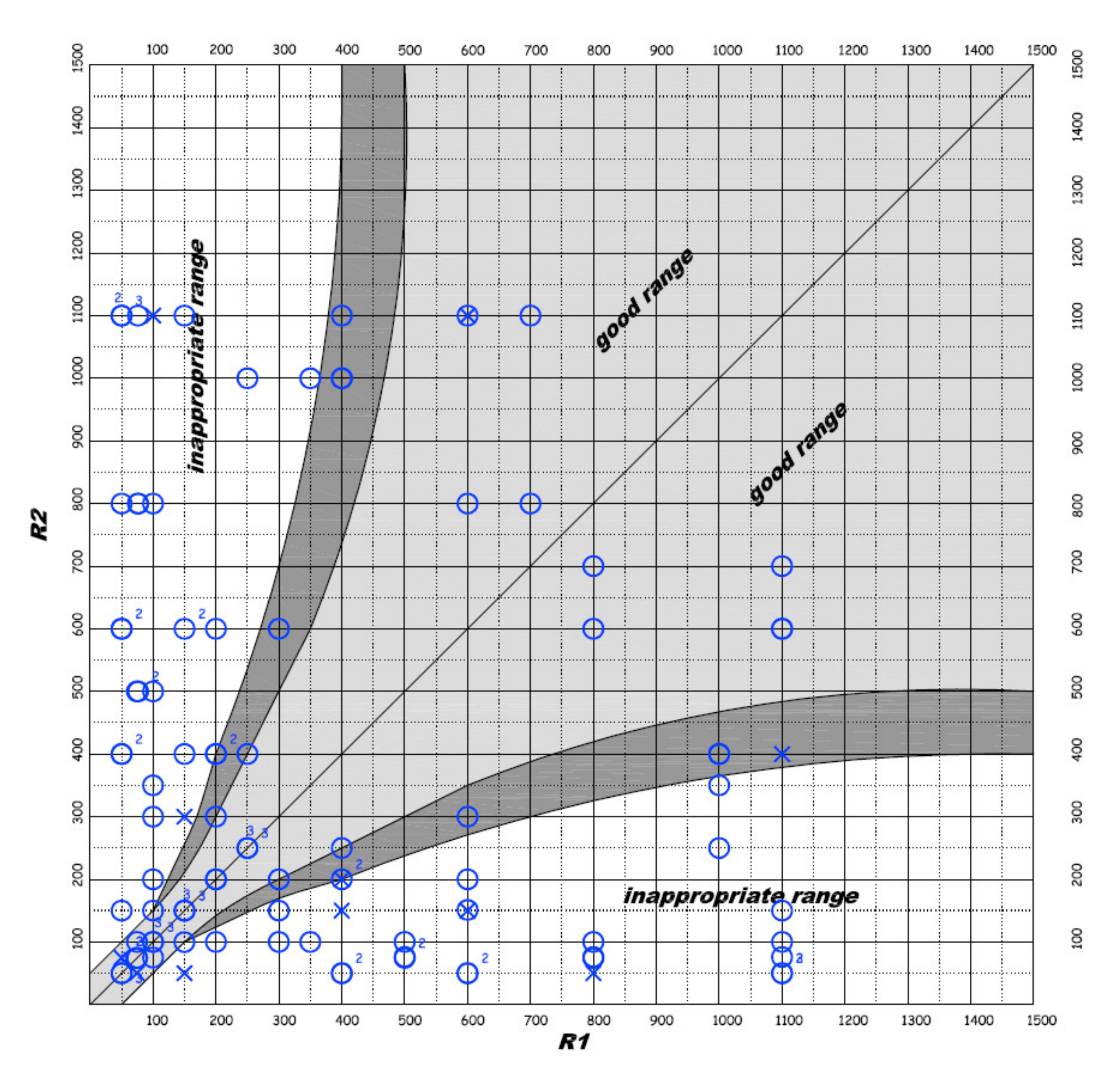


Figure 53: Result of analysed radii relation at "St. Kathrein a. Hauenstein - Krieglach".

Results of analysis based on the radii relation (see Figure 53):

- *Most of the PTW accidents happen in radii relations R1:R2 larger than 1.0.*
- *Areas with other accident participation (truck, passenger car…) are also dangerous for PTWs.*

V. B95 "Reichenau – Turracherhöhe"

Table 122: General information about road section B95.

Road name	B 95
Road from - to	Klagenfurt to Mauterndorf
Section length [km]	9.10
Section start	Km 52.300
Section end	Km 61.400
Sum of accidents	27
Registered count of accidents	17

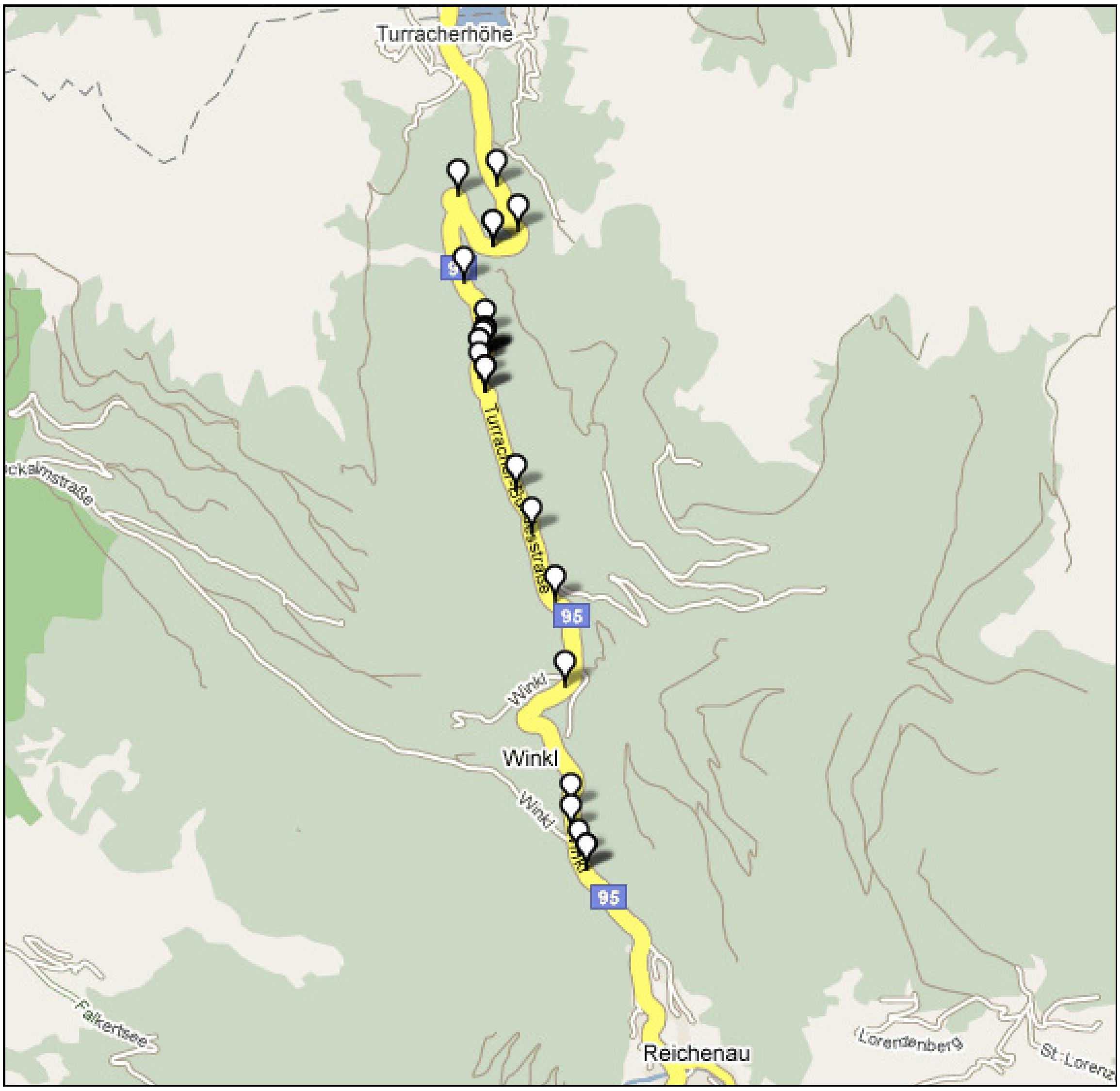


Figure 54: Road section B95 - "Reichenau - Turracherhöhe".

General information about the road section "Reichenau – Turracherhöhe" is adduced in Table 122. Just 17 of 27 accidents have been analysed, 10 PTW accidents had no information about the driving direction.

The alignment of this road section is normally designed (see Figure 54).

The PTW accidents are equally distributed along the whole road section. The largest density of PTW accidents happened in a passage of 300m length.

Findings on Road section B95 "Reichenau - Turracherhöhe"

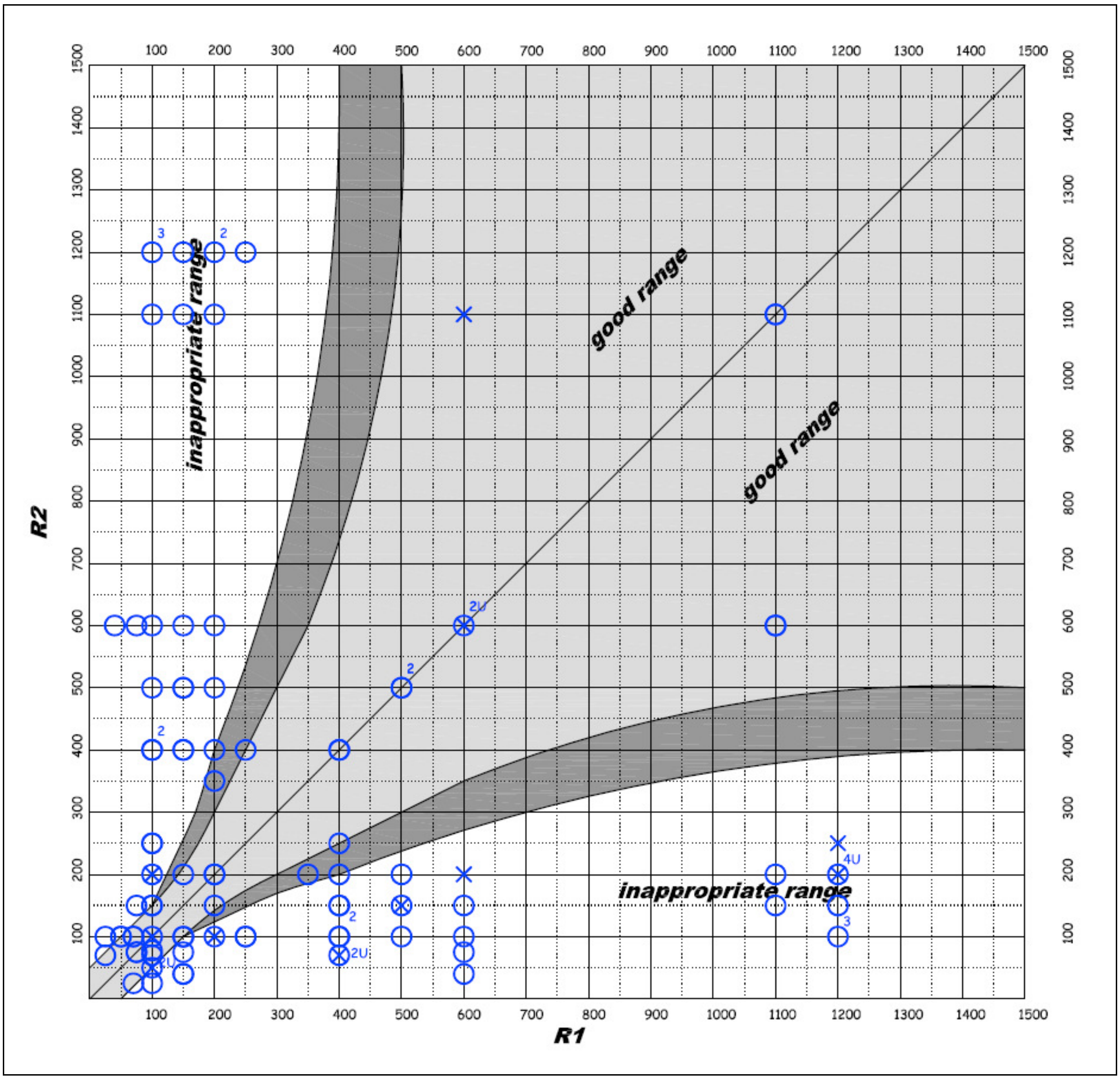


Figure 55: Result of analysed radii relation at "Reichenau - Turracherhöhe".

Results of analysis based on the radii relation (see Figure 55):

- *The most PTW accidents happen in radii relations R1:R2 larger than 1.0.*
- *There are also PTW accidents in good range.*
- *Areas with other accident participations are not so dangerous for PTWs. Other road sections show a higher correlation between PTW and other accident participations.*
- *Especially of interest is the range between 0 and 200m.*

VI. B127 "Rottenegg – Lacken"

Table 123: General information about road section B127.

Road name	B 127
Road from - to	Linz to Rohrbach
Section length [km]	4.49
Section start	Km 15.800
Section end	Km 20.290
Sum of accidents	13
Registered count of accidents	9

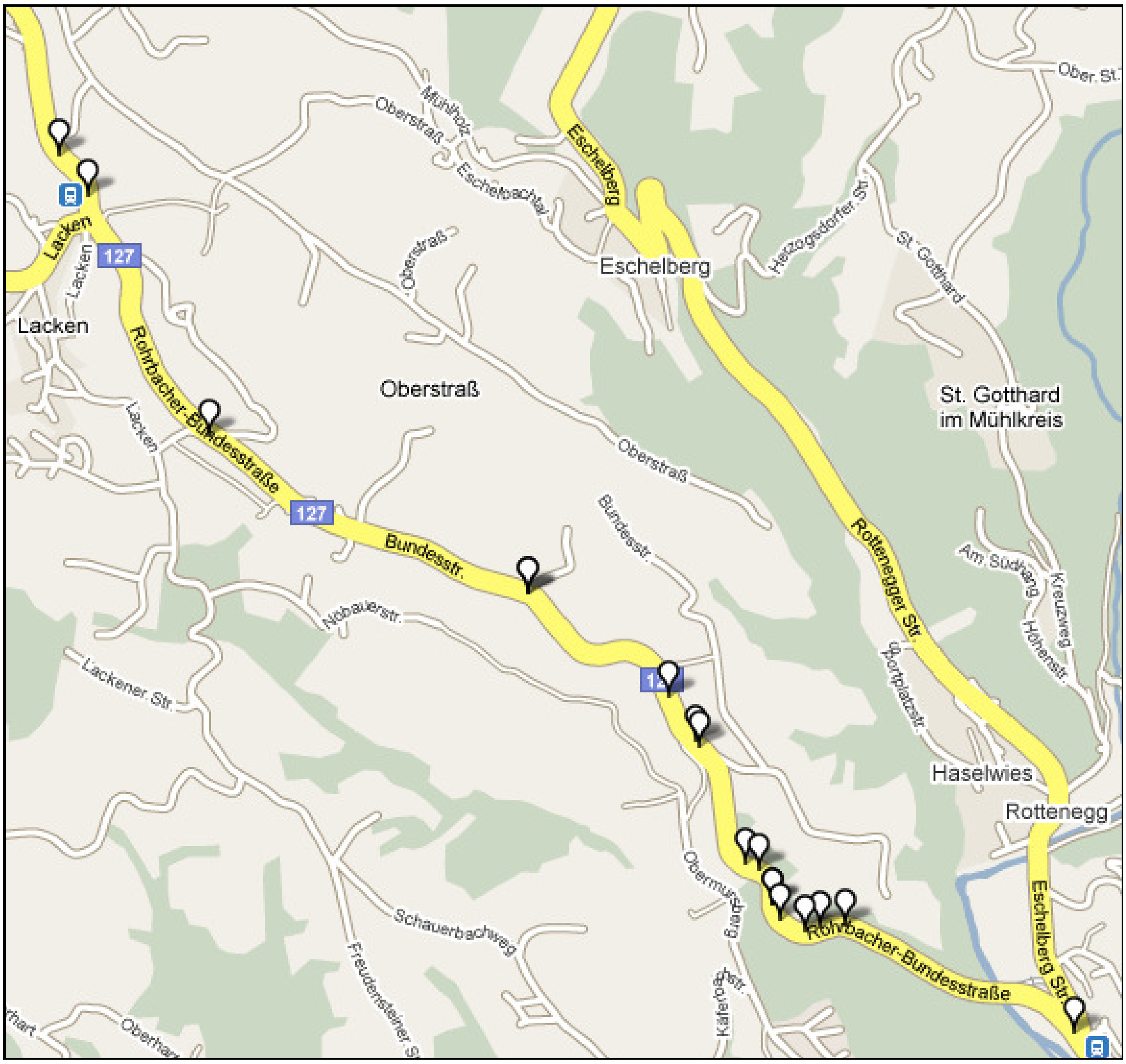


Figure 56: Road section B127 - "Rottenegg - Lacken".

The shortest road section of the seven selected ones is on B127. General information about the road section "Rottenegg - Lacken" is presented in Table 123. The map is shown in Figure 56.

Although this road section is not the longest there is a very interesting hot spot identified. 8 of the 9 PTW accidents are located inside of a 460m passage.

Findings on Road section B127 "Rottenegg - Lacken"

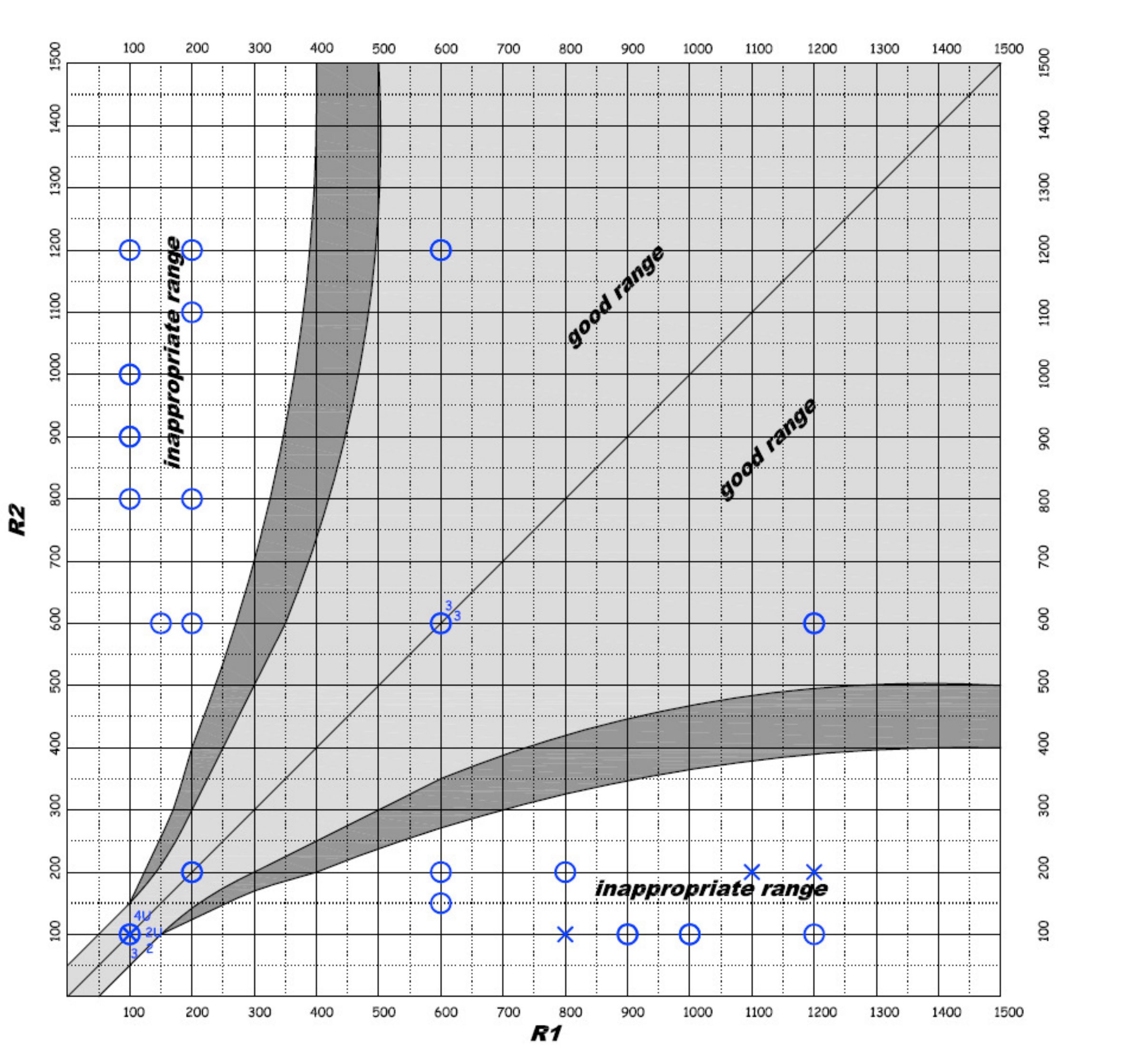


Figure 57: Result of analysed radii relation at "Rottenegg - Lacken".

Results of analysis based on the radii relation (see Figure 57):

- *The most PTW accidents happen in radii relations R1:R2 larger than 1.0.*
- *The most PTW accidents happen in the range, with a curve radius R2 smaller than 200m.*
- *Noticeable is the radii relation 1.0 with R1 = 100m and R2 = 100m. 6 of the 9 registered crashes occur on a single part with this relation (4 respectively 2 in each direction)*
- *The statement of "other accidents areas are also dangerous for PTWs" does not apply for this road section.*

VII. B164 “Bischofshofen – Mühlbach am Hochkönig“

Table 124: General information about road section B164.

Road name	B 164
Road from - to	Bischofshofen to St. Johann i. Tirol
Section length [km]	8.30
Section start	Km 0.500
Section end	Km 8.800
Sum of accidents	40
Registered count of accidents	36

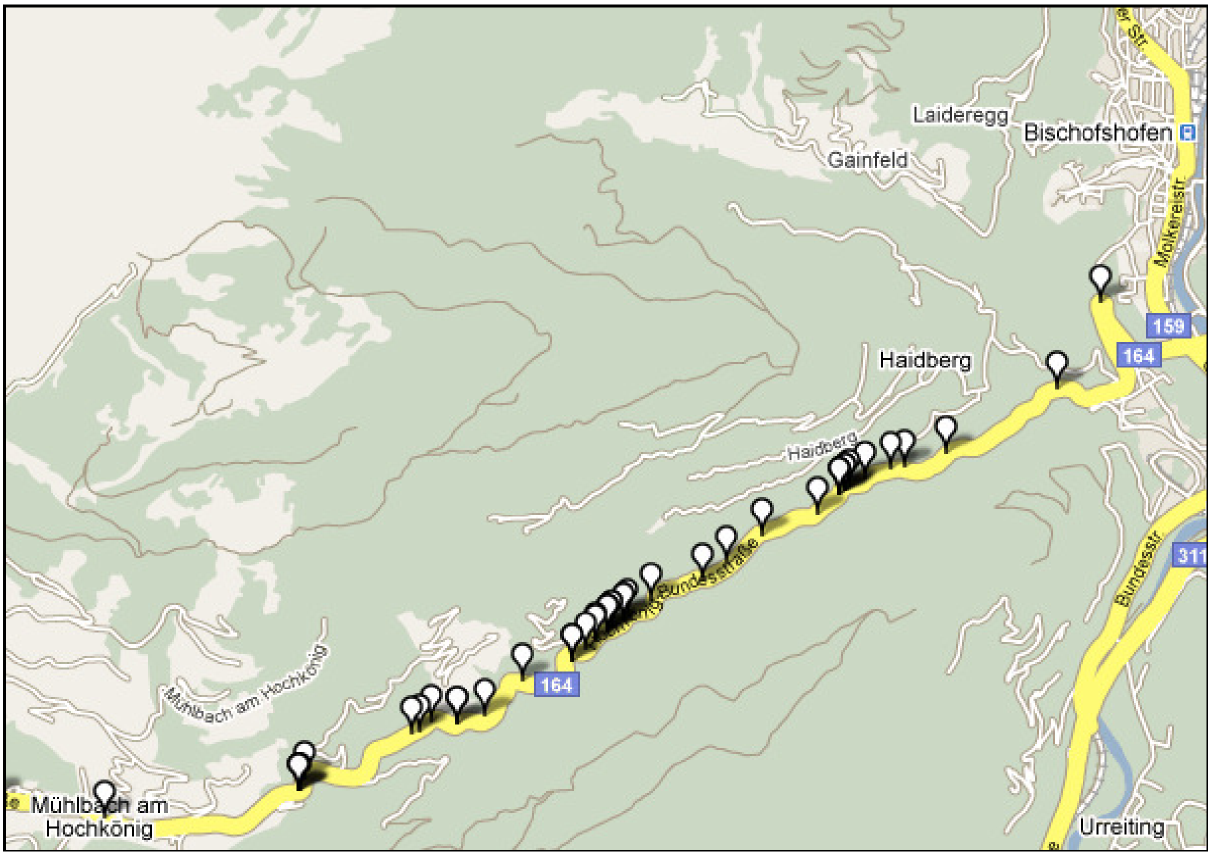


Figure 58: Road section B164 - “Bischofshofen – Mühlbach am Hochkönig”.

The map of road section “Bischofshofen – Mühlbach a. Hochkönig” is shown in Figure 58. Table 124 shows general information about the road section.

This road section is the one with the second highest account of PTW accidents. The geometry of the trace seems to be harmonic. The accidents are equally distributed along the whole road section length.

Findings on Road section B164 "Bischofshofen – Mühlbach am Hochkönig"

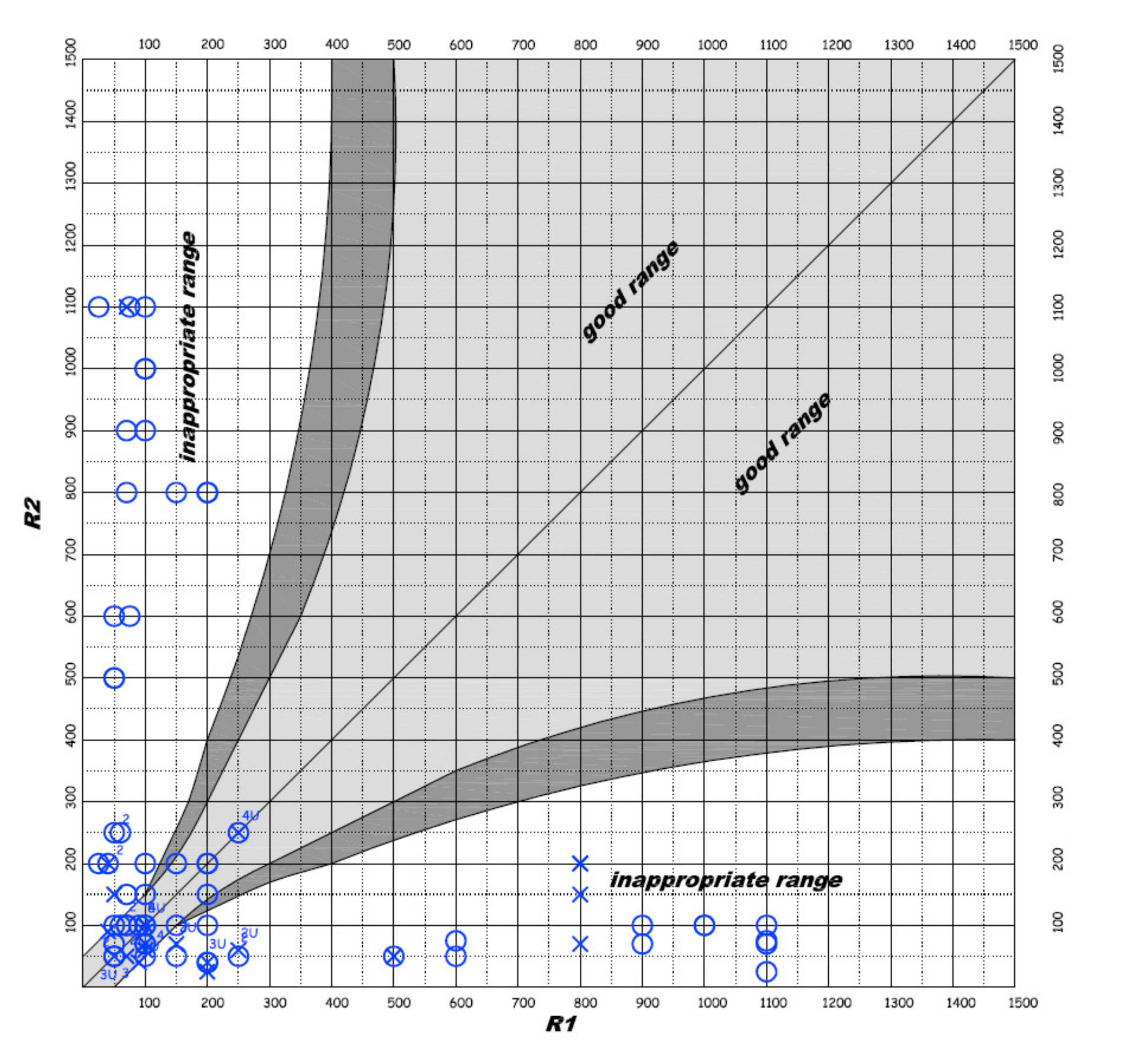


Figure 59: Result of analysed radii relation at "Bischofshofen – Mühlbach a. Hochkönig".

Results of analysis based on the radii relation (see Figure 59):

- *The most PTW accidents happen in radii relations R1:R2 larger than 1.0.*
- *The most PTW accidents happen in the range, with a curve radius R2 smaller than 200m.*
- *Areas with other accident participations are not so dangerous for PTWs. Other road sections show a better correlation of PTW and other accident participations.*

4.2.6.2. Summary of Key Findings (all selected road sections)

172 PTW accidents were found on all seven road section.

140 PTW accidents are registered for the analyses of radii relations.

Table 125: Summary of all road sections.

B*	Road Section	Length [km]	Length [m]	Number of PTW accidents
B 20	Türnitz - Annaberg	13,87	13870	16
B 20	Reith - Mitterbach a. Erlaufsee	11,66	11660	17
B 27	L134 - Hirschwang a.d. Rax	14,82	14820	43
B 72	St. Kathrein - Krieglach	12,80	12800	16
B 95	Reichenau - Turracherhöhe	9,10	9100	27
B 127	Rottenegg - Lacken	4,49	4490	13
B 164	Bischofshofen - Mühlbach a. Hochkönig	8,30	8300	40

		PTW riders		
B*	Road Section	killed	severe injured	slight injured
B 20	Türnitz - Annaberg	1	7	8
B 20	Reith - Mitterbach a. Erlaufsee	0	8	8
B 27	L134 - Hirschwang a.d. Rax	1	63	18
B 72	St. Kathrein - Krieglach	0	29	10
B 95	Reichenau - Turracherhöhe	0	31	11
B 127	Rottenegg - Lacken	1	29	14
B 164	Bischofshofen - Mühlbach a. Hochkönig	1	22	20

		Accident density	Economic costs of PTW accidents		
B*	Road Section		Entire road section	/km	/km *a
B 20	Türnitz - Annaberg	0,144	€ 1.425.300	€ 102.761,36	€ 12.845,17
B 20	Reith - Mitterbach a. Erlaufsee	0,182	€ 472.800	€ 40.548,89	€ 5.068,61
B 27	L134 - Hirschwang a.d. Rax	0,363	€ 4.523.300	€ 305.215,92	€ 38.151,99
B 72	St. Kathrein - Krieglach	0,156	€ 1.626.500	€ 127.070,31	€ 15.883,79
B 95	Reichenau - Turracherhöhe	0,371	€ 1.740.100	€ 191.219,78	€ 23.902,47
B 127	Rottenegg - Lacken	0,362	€ 2.651.900	€ 590.623,61	€ 73.827,95
B 164	Bischofshofen - Mühlbach a. Hochkönig	0,602	€ 2.298.000	€ 276.867,47	€ 34.608,43

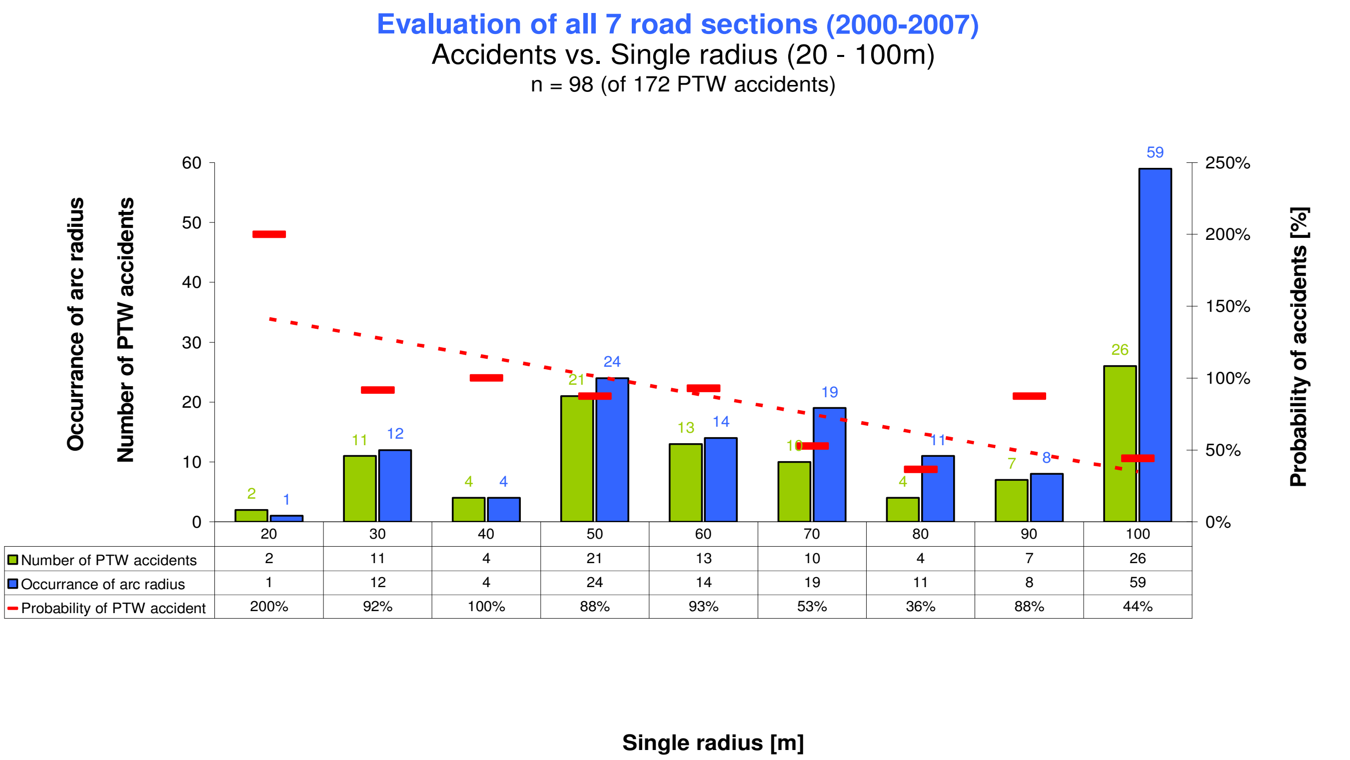
In terms of economic costs of PTW accidents, Table 125 shows the summary of all seven road sections. The rates for the economic costs are 1.007 Mio € for a fatal injured, 56.000 € for a severe injured victim and 4.600 € for a slight injured rider. Following parameters are calculated for each road section:

- Length of road section
- Number of PTW accidents
- Numbers of killed, severely injured and slightly injured PTW riders
- Accident density = Number of PTW accidents / (length * years)
- Economic costs for:
    - The entire road section
    - Per kilometre
    - Per kilometre and year

The economic costs of accident events are a qualified method to validate accident hot spots and the risk value of specific sections (like shown above) and also useful for a cost benefit analyses of accidents preventative measures. In Table 125, e.g. the road section “Rottenegg - Lacken”, the shortest section of all, has the highest economical cost per kilometre and per kilometre*year.

A modification (active or passive measures) of the road section in terms of road safety will cost a certain amount, but these improvements can lead to lower accident numbers and also decrease the severity rate – so that the cost benefit calculations are positive.

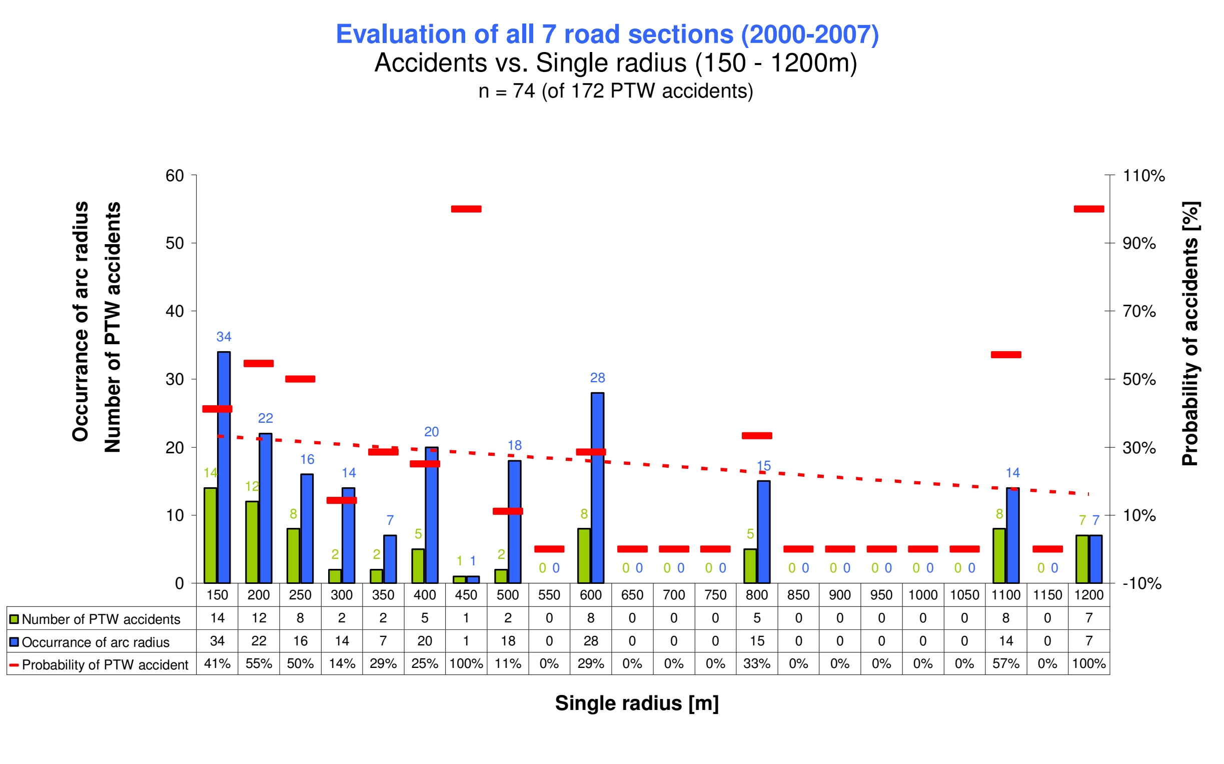
Examples are so called “underriders”: Especially when the PTW user has lost control of his vehicle can have consequences which vary very much on what type (if any) of road restraint system is installed on that particular road section. Some of the most serious PTW accidents happen when the rider, sliding on the road bed, passes under the road restraint system, simultaneously impacting with one of its supporting posts. A solution is the installation of underride guards, which are designed and tested to minimise the risks to the sliding PTW rider, preventing him from going under the barrier and impacting its support posts, whilst at the same time cushioning his slide to minimise the risk of sustaining severe or fatal injuries.



	20	30	40	50	60	70	80	90	100
Number of PTW accidents	2	11	4	21	13	10	4	7	26
Occurrance of arc radius	1	12	4	24	14	19	11	8	59
Probability of PTW accident	200%	92%	100%	88%	93%	53%	36%	88%	44%

Figure 60: PTW accidents vs. single radius (20 – 100m).

Figure 60 shows the results of analysis PTW accidents versus single radius at the range between 20 and 100m. The figure above shows the relation number of PTW accidents and the occurrence of arc radius of all seven road sections. It appears that the probability of happening PTW accidents decrease with increasing radii. The most accidents happen at radius 100m, but the occurrence of this radius is also higher, which gives the absolute accident number a lower weight. So the relative risk or probability of a crash is less than in e.g. radius 50m.



Single radius [m]	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
Number of PTW accidents	14	12	8	2	2	5	1	2	0	8	0	0	0	5	0	0	0	0	0	8	0	7
Occurrance of arc radius	34	22	16	14	7	20	1	18	0	28	0	0	0	15	0	0	0	0	0	14	0	7
Probability of PTW accident	41%	55%	50%	14%	29%	25%	100%	11%	0%	29%	0%	0%	0%	33%	0%	0%	0%	0%	0%	57%	0%	100%

Figure 61: PTW accidents vs. single radius (150 – 1200m).

Figure 61 shows similar results in terms of single radius, but for the range of 150 to 1200m. The probability of happening PTW accidents also decrease with increasing radius.

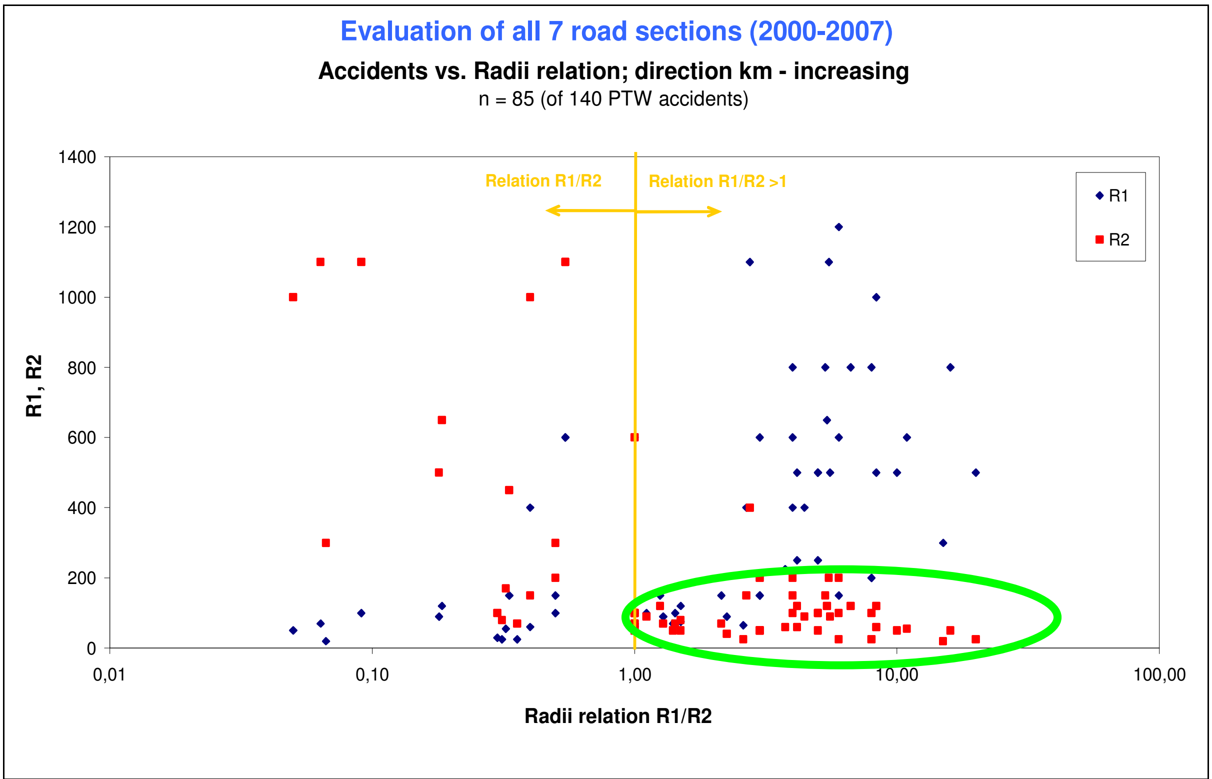


Figure 62: PTW accidents vs. radii relations; increasing km.

In order to figure out any other possible influences of curve radii and their relations on PTW accidents, specific cross tabulations of the relation itself with the single radii have been carried out.

In this second part of analyses the following results are shown in Figure 62. It presents the correlation of R1 and R2 to the relation R1 divided by R2. A ratio larger than 1.0 means that, the accident occurs in smaller radius, followed after a larger one and vice versa for a ratio smaller than 1.0. Figure 62 shows all PTW accidents of all road sections in increasing driving direction.

It is apparent that the most PTW accidents are situated at relations higher than 1.0 and in a range "R2" smaller than 200m (see green ellipse).

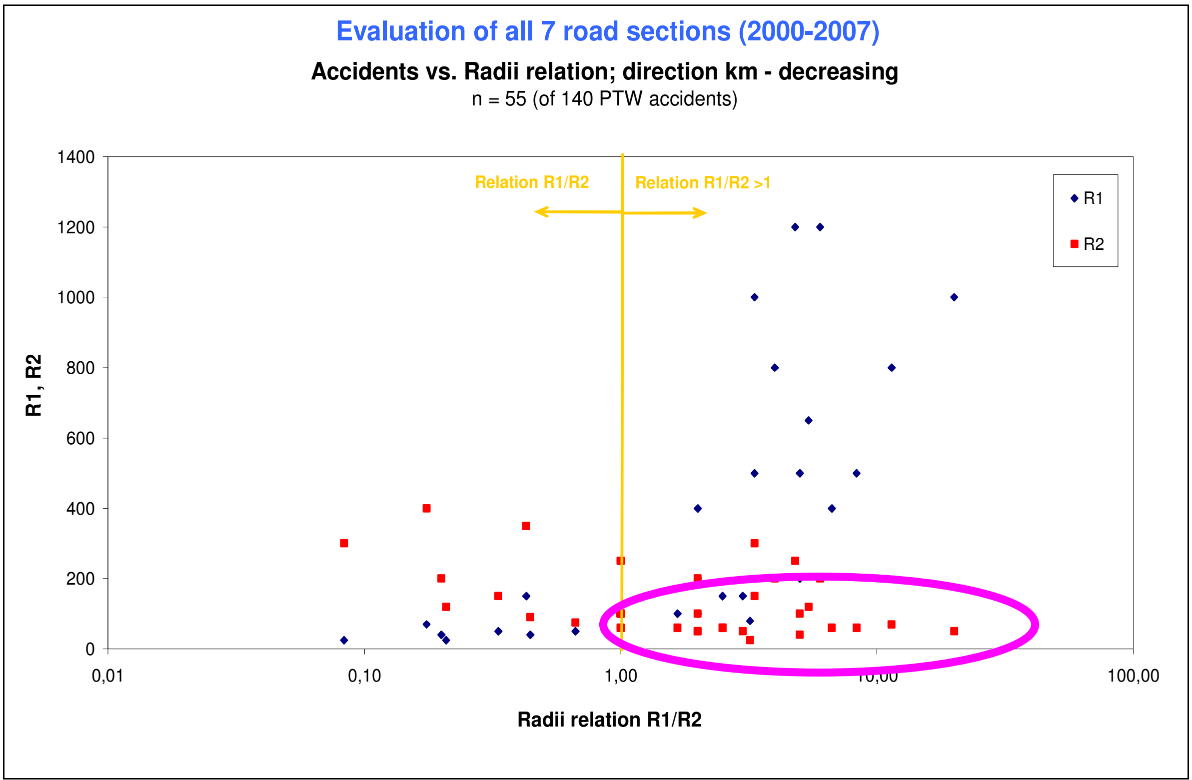


Figure 63: PTW accidents vs. radii relations; decreasing km.

Figure 63 shows all PTW accidents of all seven road sections in decreasing driving direction. Also the most PTW accidents are situated at radii relation higher than 1.0 (see magenta ellipse) and inside a range of R2 smaller than 200m.

4.2.7. Conclusions for the microscopic analysis in Austria

Road safety in general and especially regarding PTW accidents are the aim for all European members, in respect to reach the goal of halving the accident numbers on European roads. The facts of raising PTW riders in Austria, the increasing rate of registered PTWs and therefore the critical numbers of crashes and injured people needs an improvement of road safety measures for motorcyclists.

In this research report, a microscopic view on possible crash causes of PTW accidents, based on the interaction of PTW accident and road infrastructure, have been carried out. The road infrastructure input data are measurement parameters of high quality, regarding the road surface characteristics and road geometry elements.

Several analyses of different correlations between road surface condition and trace parameters together with localised PTW accident events show the following results.

Crashes in bends are the most severe ones on federal roads in Austria. Especially the investigation of radii relation gives interesting outputs. A significant correlation between PTW accidents and the relation of following curve radii was detected. Primarily curves with small radius have a higher accident rate.

Main results of this analysis are shown in the following key findings:

- *A radii relation larger than 1.0 is more dangerous than a relation smaller than 1.0.*
- *In terms of single radius the results show that the probability of an occurring PTW accident decreases with increasing radius.*
- *The most accidents happen in relation with R2 smaller than 200m.*
- *Mainly the relation of curve with large radius, or a straight lane following by a curve with smaller radius are more dangerous than others.*
- *The statement that areas with other accident participation (truck, passenger car…) are also dangerous for PTWs is highlighted in many parts of the analyses.*

The analysis in terms of other road geometry parameters and road condition characteristics, measured by the device RoadSTAR, shows the following results:

- *In terms of longitudinal gradient the most PTW accidents happen at 1 to 2 %.*
- *In terms of crossfall the most accidents happen at a range between 2 and 4 %.*
- *In terms of skid resistance the most PTW accidents happen at quality classes "very good" ($\mu > 0.75$) and "good" ($0.75 \geq \mu > 0.59$).*
- *With reference to the parameter IRI for longitudinal evenness, the most PTW accidents happen at quality classes "average" ($1.8 \leq IRI < 3.0$) and "good"($1.0 \leq IRI < 1.8$).*
- *The results of analysis regarding to parameter MPD for the texture, the most accidents happen in quality class "poor" ($0.6 \geq MPD > 0.3$).*
- *In terms of rut depth the most PTW accidents happen in "good" ($5.0 \leq t_s < 10.0$) and "very good" ($0.0 \leq t_s < 5.0$).*
- *With reference to theoretical water depth the most PTW accidents happen at quality classes "good" ($0.0 \leq t_w < 1.0$).*

As those results show first trends in specific correlation of road alignment characteristics to PTW accident, further research questions have to focus on PTW accident types (like run-off crashes in curves) and the usage of vehicle-infrastructure-interaction-simulation to survey the combined approach of influencing road condition and geometry data.

4.3. Interaction between Powered Two-Wheeler Accidents and Infrastructure in Spain

4.3.1. Methodology – Spanish Data Base and Available Data

This report provides the deliverable in respect of the activity 1.2, comprising the analysis of the in-depth accident database, DIANA. The objective of this activity is to investigate which road infrastructure elements (road design elements and road surface parameters) have an influence on PTW accidents.

DIANA database contains the information collected by an accident investigation team who travels on the spot to the accident scene and works in close cooperation with police forces and medical services. DIANA incorporates huge amounts of data relating to multiple variables for each incident, comprising the three key factors of traffic accidents: vehicle, occupants and infrastructure. The database contains accidents from years 2003-2009.

After applying the accident selection criteria on DIANA database, a sample of 67 motorcycle accidents is extracted. This sample is not representative; therefore, results based on it should be interpreted carefully.

4.3.2. Descriptive analysis of DIANA database

This descriptive analysis intends to provide an overall view of the accidents. It is necessary to remark that since the selected sample is not representative the results can differ considerably from those drawn for the national scene.

In contrast to the national distribution of accidents by area, it has been found that most of the accidents selected are collected outside urban area (82,1%).

Express roads are shown (Figure 64) to be the dominant road type for PTW accidents, representing three out of four accidents collected (76%).

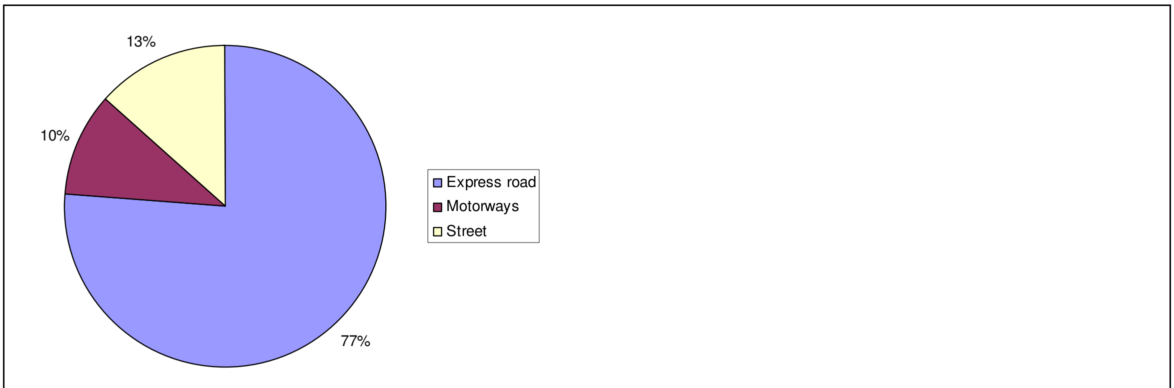


Figure 64: Type of road (n=67 PTW accidents).

Besides, the severity associated to these roads (Figure 65) is higher than for the rest of the roads because they are less equipped, roadside hazards are often not protected, and roadside geometry is generally more harmful. For this reason, it is suggested to focus further investigation on accidents on these roads.

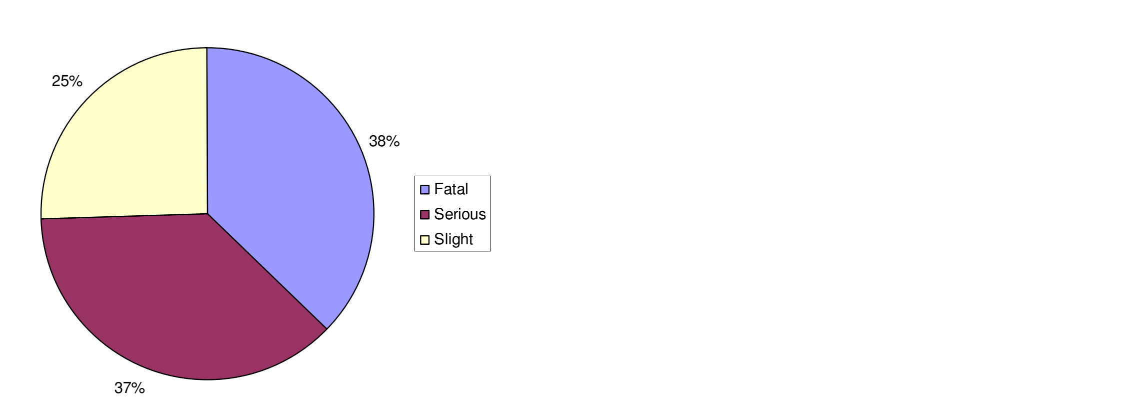


Figure 65: Severity associated to express roads (n=51 PTW accidents).

The vast majority of accidents occur during daylight hours and good weather conditions, likely to be an indication of generally higher traffic volumes during the day and without adverse conditions. As with those related to weather, dry conditions dominate (86,6%) the accident figures.

Figure 66 shows the dominance of run-off-road accidents, representing more than half of the accidents. Front-to-side collisions account for more than 20% of all accidents selected.

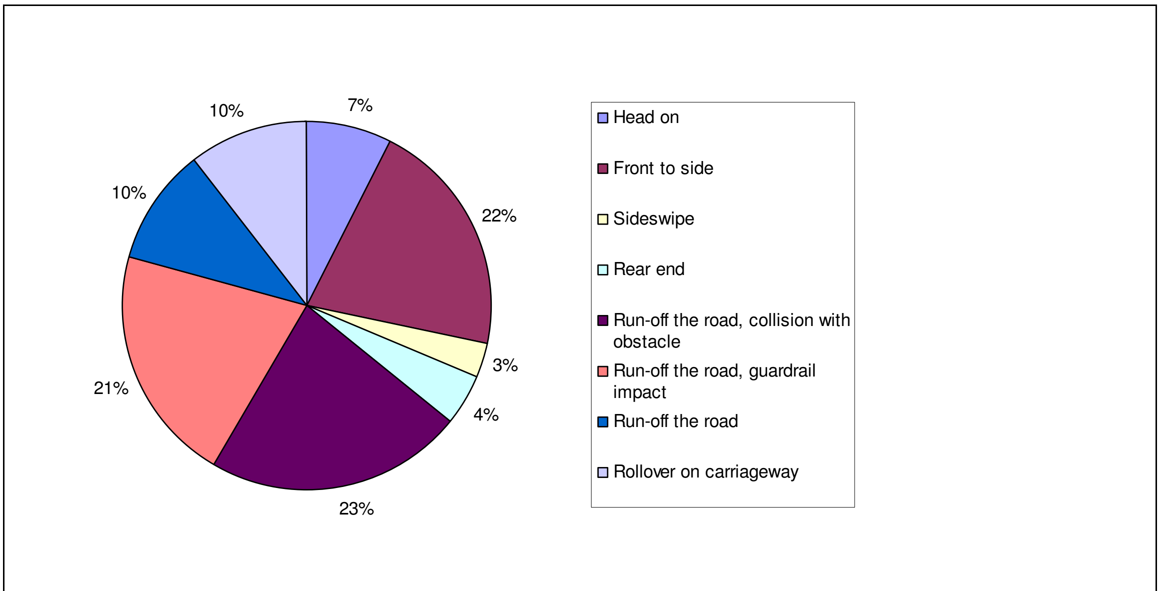


Figure 66: Typology of accidents (n=67 motorcycle accidents).

Related to the dominance of run-off-road accidents, the selected accidents are more likely to occur at bends (55%) than on straight roads (45%). Considering only run-off-road accidents, more than 80% of these accidents occur at bends.

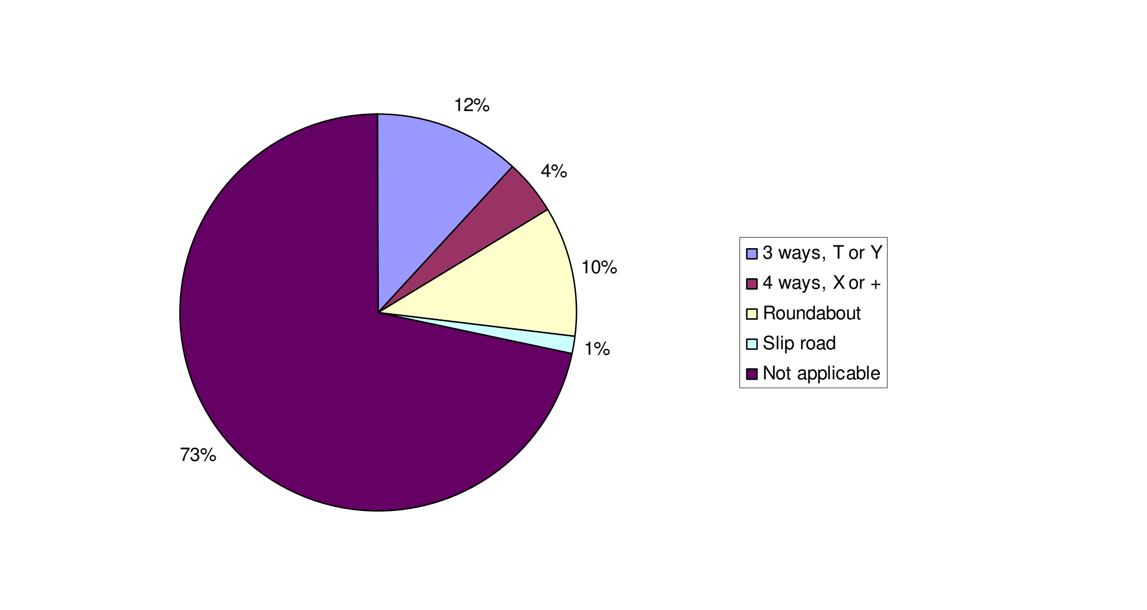


Figure 67: Type of intersection (n=67 accidents).

Almost three quarters of the accidents are located away from junctions (Figure 67). Those no-junction accidents are more likely to occur at bends (67%) than on straight roads. Among the accidents occurred at junctions, the most common type of intersection is the “3 ways, T or Y” (44%), and roundabouts are the second most prevalent type (37%).

Considering only riders and PTW passengers in the analysis of injuries severity (Table 126), it has been found that the severity associated to the sample of accidents selected (28,8% fatalities, 38,8% seriously injured) is considerably higher than the one obtained for the national accidents involving PTW’s (2% fatalities, 16% seriously injured).

Table 126: Injury severity (n=80 riders and motorcycle passengers).

Injury severity	Casualty count	Percentage (%)
Fatal	23	28,8
Seriously injured	31	38,8
Slightly injured	22	27,4
No injury	4	5

4.3.3. Specific queries (cross-tables between categories)

Cross table comparisons could be made between almost any two different factors, giving many possible combinations. The queries presented in the following intended to detect the most revealing factors related to infrastructure, with the aim of identifying possible countermeasures focused on the mitigation of the consequences of the accidents. In order to evaluate these factors related to infrastructure, two different analyses have been carried out separating the cases occurred at intersections and those away from intersections.

4.3.3.1. Accident away from junctions

Among these accidents it is necessary to differentiate between two situations regarding the road alignment:

- Accidents at bends (67%)
- Accidents in straight sections of road (33%)

A) Accidents at bends.

Most of the accidents collected occurred at left hand bends (72%). PTW **accidents are more likely to occur at left hand bands** because it is easier for the motorcyclist to survey a right hand turn. For a better navigation through the curve, the motorcyclist fixes his eyes along the line of the inner curve to a point on the horizon. In right hand turns, the course of the PTW also lies in the inner curve. Therefore possible hazards such as potholes or other unevenness lie in the field of vision of the motorcyclist. In left hand turns the eyes of the motorcyclist are also fixed on the inner curve. The course he follows, however, lies in the outer curve and therefore possible hazards do not appear immediately in his field of vision.

It is also remarkable that three out of four accidents located at bend occurred at roads with descendent gradient and without hard shoulder or with impassable shoulder. Thus, a prevalent situation among these accidents is '*run-off road at a left hand bend with descendent gradient along a road without shoulders or with impassable shoulders*'.

- *Type of accident by Driving Speed*

Table 127: Accidents occurred away from junction. Type of accident by Driving speed (n=29).

		Driving Speed (km/h)				Total
		30<Speed<60	60<Speed<90	90<Speed<120	Speed>120	
Type of accident	Head on	0 (0%)	2 (7%)	1 (3,5%)	0 (0%)	**3 (10%)**
	Run-off the road, collision with obstacle	0 (0%)	2 (7%)	3 (10,5%)	1 (3,5%)	**6 (21%)**
	Run-off the road, guardrail impact	0 (0%)	6 (21%)	8 (28%)	0 (0%)	**14 (49%)**
	Run-off the road	1 (3,5%)	1 (3,5%)	1 (3,5%)	0 (0%)	**4 (10%)**
	Rollover on carriageway	0 (0%)	1 (3,5%)	2 (7%)	0 (0%)	**3 (10%)**
Total		**1 (3,5%)**	**12 (41%)**	**15 (52%)**	**1 (3,5%)**	**29 (100%)**

Table 127 shows that almost half of the accidents are run-off-road accidents involving a **roadside barrier** and that the **driving speed** of the motorcycles in these accidents is likely to be **higher than 90 km/h**. Since the severity associated to these impacts is generally fairly high, it has been considered necessary to analyse this specific type of accident more deeply.

- *Curve radius by Driving Speed*

According to Table 128, most of the accidents collected occurred on roads with a curvature radius below 70 meters and at driving speeds between 60 and 120 km/h. Accidents on roads with a curvature radius above 300 meters are not observed at driving speeds below 90 km/h.

Table 128: Accidents occurred away from junction. Curve radius by Driving speed (n=29).

		Driving speed				
		30<Speed<60	60<Speed<90	90<Speed<120	Speed>120	Total
Radius	R<70	1 (3,5%)	8 (28%)	9 (31%)	0 (0%)	**18 (62,5%)**
	70<R<150	0 (0%)	3 (10,5%)	3 (10,5%)	0 (0%)	**6 (20%)**
	150<R<300	0 (0%)	1 (3,5%)	1 (3,5%)	1 (3,5%)	**3 10,5%)**
	R>300	0 (0%)	0 (0%)	2 (7%)	0 (0%)	**2 (7%)**
Total		**1 (3,5%)**	**12 (42%)**	**15 (51%)**	**1 (3,5%)**	**29 (100%)**

- *"Curve radius by Rollover on carriageway" and "Crossfall by Rollover on carriageway"*

Within PTW accidents involving infrastructure elements, there are two different situations which need to be evaluated separately in order to determine possible countermeasures for each. It is necessary to differentiate between accidents where the PTW impacts the barrier or roadside object whilst the rider is still operating the vehicle (*upright position*) and the situation where rider and vehicle have become separated beforehand and are both sliding along the surface (*sliding position*) towards the obstacle.

Thus, it has been considered necessary to evaluate the influence of the road geometry on the dynamics (two situations defined previously) of the PTW accidents.

Table 129: Accidents occurred away from junction. Curve radius by Rollover on carriageway (n=29).

		Rollover on carriageway before collision		
		No	Yes	Total
Curve Radius	R<70	14 (48%)	4 (14%)	**18 (62%)**
	70<R<150	3 (10,5%)	3 (10,5%)	**6 (21%)**
	150<R<300	2 (7%)	1 (3,5%)	**3 (10%)**
	R>300	1 (3,5%)	1 (3,5%)	**2 (7%)**
Total		**20 (69%)**	**9 (31%)**	**29 (100%)**

Table 130: Accidents occurred away from junction. Crossfall by Rollover on carriageway (n=29).

		Rollover on carriageway before collision		Total
		No	Yes	
Crossfall	Crossfall < 2%	6 (23%)	2 (8%)	**8** **(31%)**
	2% < Crossfall < 4%	5 (19%)	1 (4%)	**6** **(23%)**
	4% < Crossfall < 6%	4 (15%)	3 (11,5%)	**7** **(26,5%)**
	6% < Crossfall < 8%	2 (8%)	3 (11,5%)	**5** **(19,5%)**
Total		**17** **(65%)**	**9** **(35%)**	**26** **(100%)**

As an overall conclusion, **riders are almost twice as likely to impact in an upright position** as in a sliding position.

Table 129 and Table 130 show that crossfall of road appears to be a relevant infrastructure factor since higher values of crossfall result in fewer run-off road accidents. Nevertheless, rollovers on carriageway do not occur less frequently at higher values of crossfall of the road. Regarding the curve radius, sliding impacts after rollovers on carriageway are not more frequent at decreasing values of radius, so **neither crossfall nor radius are determining factors by themselves on the dynamics of PTW single accidents**.

As these factors are not found to be determining by themselves, further analyses are needed to identify which combination of factors are most revealing. Thus, "Driving speed" has been introduced into the following tables in order to evaluate its influence on the two infrastructure factors previously analyzed.

Table 131: Accidents away from junction. Rollover on carriageway by radius and speed (n=29).

Rollover on carriageway			Curve Radius				Total
			R<70	70<R<150	150<R<300	R>300	
No	Driving speed	30<Speed<60	1 (3,5%)	0 (0%)	0 (0%)	0 (0%)	**1** **(3,5%)**
		60<Speed<90	6 (21%)	2 (7%)	1 (3,5%)	0 (0%)	**9** **(31,5%)**
		90<Speed<120	7 (24%)	1 (3,5%)	1 (3,5%)	1 (3,5%)	**10** **(34,5%)**
	Total		**14** **(48,5%)**	**3** **(10,5%)**	**2** **(7%)**	**1** **(3,5%)**	**20** **(68,5%)**
Yes	Driving speed	60<Speed<90	2 (7%)	1 (3,5%)	0 (0%)	0 (0%)	**3** **(10,5%)**
		90<Speed<120	2 (7%)	2 (7%)	0 (0%)	1 (3,5%)	**5** **(17,5%)**
		Speed>120	0 (0%)	0 (0%)	1 (3,5%)	0 (0%)	**1** **(3,5%)**
	Total		**4** **(14%)**	**3** **(10,5%)**	**1** **(3,5%)**	**1** **(3,5%)**	**9** **(31,5%)**

The most prevalent situation is a "***rider who travelled along a curved section of road (R=70 meters) at speeds between 90 and 120 km/h impacting in an upright position***" (Table 131). In the case of riders who rolled over on the carriageway before the collision, the most common values of driving speeds and radius curve are above 60 km/h and below 150 meters respectively.

Table 132: Accidents away from junction. Rollover on carriageway by crossfall and speed (n=29).

Rollover on carriageway before collision			Driving Speed 30<Speed<60	60<Speed<90	90<Speed<120	Speed>120	Total
No	Crossfall	Crossfall < 2%	0 (0%)	2 (9%)	4 (17%)		**6 (26%)**
		2% < Crossfall < 4%	1 (4%)	2 (9%)	1 (4%)		**4 (18%)**
		4% < Crossfall < 6%	0 (0%)	2 (9%)	1 (4%)		**3 (13%)**
		6% < Crossfall < 8%	0 (0%)	1 (4%)	1 (4%)		**2 (9%)**
	Total		1 (4%)	7 (31%)	7 (31%)		**15 (66%)**
Yes	Crossfall	Crossfall < 2%		1 (4%)	1 (4%)	0 (0%)	**2 (8%)**
		2% < Crossfall < 4%		0 (0%)	0 (0%)	1 (4%)	**1 (4%)**
		4% < Crossfall < 6%		0 (0%)	2 (9%)	0 (0%)	**2 (9%)**
		6% < Crossfall < 8%		2 (9%)	1 (4%)	0 (0%)	**3 (13%)**
	Total			**3 (13%)**	**4 (17%)**	**1 (4%)**	**8 (34%)**

As shown in Table 132, the most frequent situation is a "***rider impacting in an upright position who travelled along a curved section of road (crossfall < 2%) at speeds between 90 and 120 km/h***". For riders who slide along the road surface before impacting the object (rollover on carriageway), the most common values of driving speeds and crossfall are above 60 km/h and 4% respectively.
In accordance with the previous tables, it could be stated that accidents are more likely to occur at higher speeds and lower values of curve radius, although in the vast majority of the accidents the rider impacts in an upright position. Therefore, probably the most **frequent situation among run-off-road accidents** is "*riders who travel at inappropriately high speeds relative to their forward visibility and perceive the real geometry of the road when they are inside the curve (some curves have not a predictable geometry) but they are not able to moderate the speed and negotiate the curve properly; consequently, they run off the road keeping an upright position*". Thus, the accidents could be attributed to a prevalence of a **perception failure** of the riders, and probably to significant **collision avoidance problems**.

- *Severity by Type of object hit in carriageway*

In Table 133, it can be seen that a kerb was hit in every fatal accident in which an object was hit in carriageway, collected in DIANA database. These kerbs were placed mainly in roundabouts within outside urban settings, so impact speeds are higher than those registered in urban settings (traffic lights). The huge fatality rate associated to **kerb** impacts could be due to this fact; anyway this cross sectional element **could be identified as a safety hazard** mainly if its design is potentially harmful. Therefore, further analyses on "safety kerbs" should be undertaken (low rise, bevelled edges…).

Table 133: Run-off-road accident hitting an object on carriageway. Severity by Type of object (n=9 riders and motorcycle passengers).

		Object hit in carriageway		Total
		Kerb	Traffic light	
Severity	Fatal	5 (56%)	0 (0%)	**5 (56%)**
	Serious	0 (0%)	1 (11%)	**1 (11%)**
	Slight	2 (22%)	1 (11%)	**3 (33%)**
Total		**7 (78%)**	**2 (22%)**	**9 (100%)**

Related to this fact, the distribution of accidents by injury and shape of object is analyzed and it is concluded that a round object was the most frequently struck (79%) and the severity of injury was fairly distributed. An edge object, for example a **kerbstone**, was the least likely to be struck (4%) but **the most likely to cause a severe (AIS 5) injury**. A flat object was struck in 9% of causes but was the least likely to cause an injury.

- *Severity by Type of object hit off carriageway*

Barriers are by far the most dominant roadside elements hit by riders and also have a large number of fatalities associated (Table 134). Fatality rates are headed by slope (stone), lamp post and mainly drainage pipes though, since all accidents collected involving these elements result in at least one death.

Table 134: Run-off road hitting an object off carriageway. Severity by Type of object (n=32 riders and motorcycle passengers).

		Object hit off the carriageway							Total
		Barrier	Drainage pipe	Lamp post	No collision	Other	Slope/ Embank ment	Wall	
Severity	Fatal	5 (16%)	3 (9%)	1 (3%)	0 (0%)	0 (0%)	1 (3%)	0 (0%)	**10 (31%)**
	Serious	8 (25%)	0 (0%)	0 (0%)	5 (16%)	0 (0%)	0 (0%)	1 (3%)	**14 (44%)**
	Slight	5 (16%)	0 (0%)	0 (0%)	1 (3%)	2 (6%)	0 (0%)	0 (0%)	**8 (25%)**
Total		**18 (57%)**	**3 (9%)**	**1 (3%)**	**6 (19%)**	**2 (6%)**	**1 (3%)**	**1 (3%)**	**32 (100%)**

- **SAFETY BARRIER IMPACTS**

As mentioned previously, it has been considered essential to study the interaction between riders and safety barriers separately. The following figures give an overall view of the accidents involving these elements.

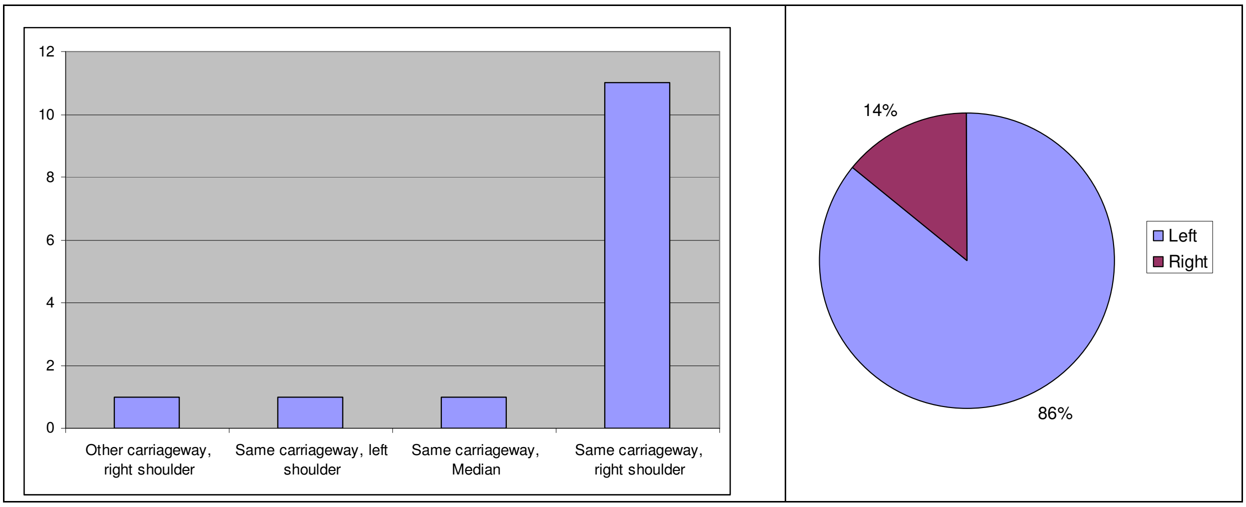


Figure 68: Barrier location and curve orientation (n=14 accidents).

Figure 68: Barrier location and curve orientation (n=14 accidents) Figure 68 shows that the most prevalent situation is a loss of control of the rider along a **left hand bend** and a subsequent collision into a safety barrier located in the right roadside of the carriageway.

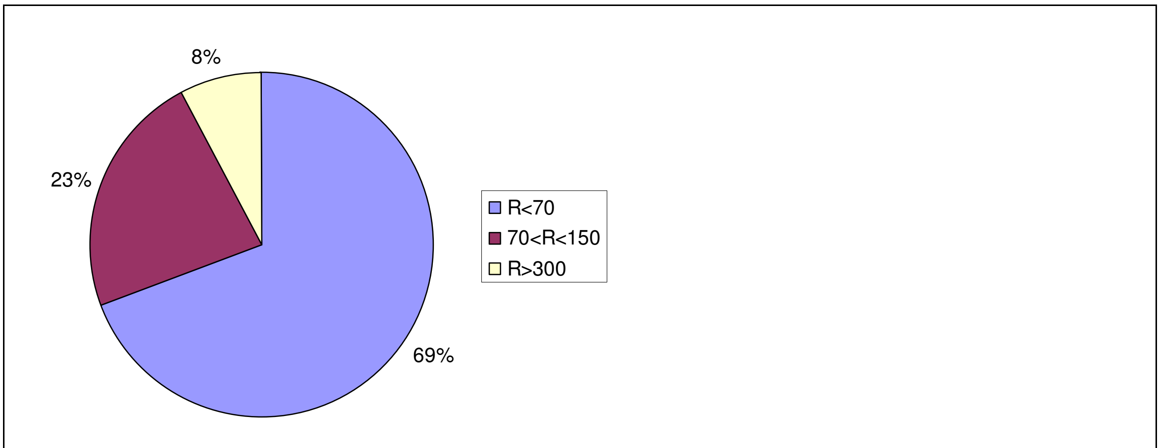


Figure 69: Curve Radius (n=14 accidents).

Almost 70% of accidents involving roadside barriers occurred at bends with radius below 70 meters (Figure 69).

The following figures show that the **vast majority of riders impact in an upright position** (64%; **Figure 70**) and in 79% the **impact angle is below 20º** (**Figure 71**).

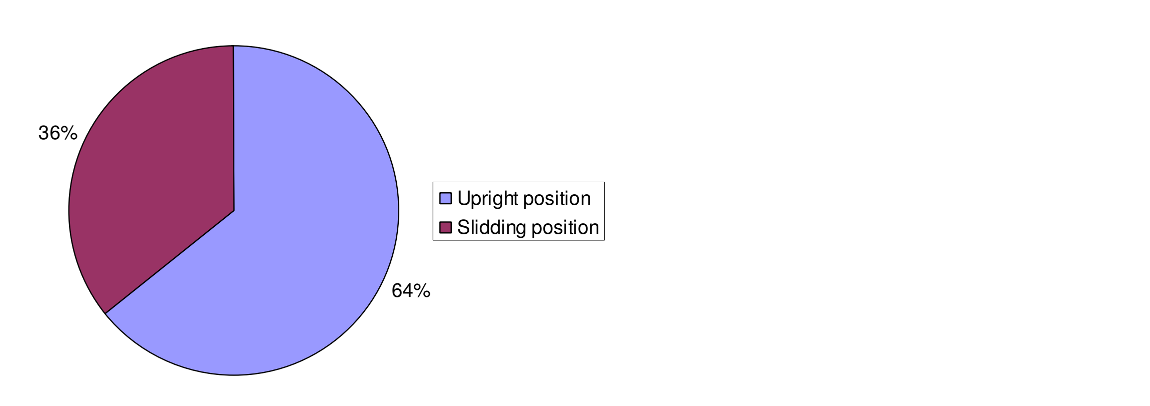


Figure 70: Position of impact (n=14 accidents).

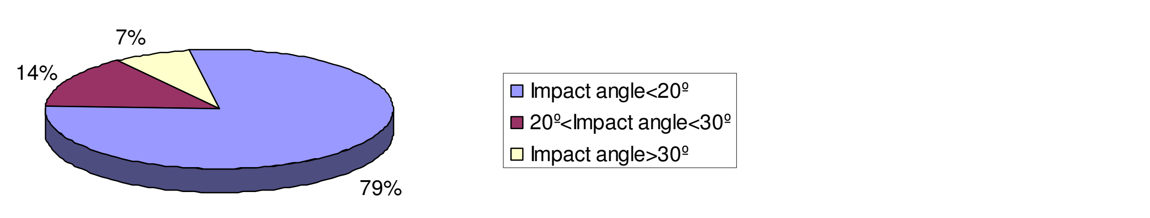


Figure 71: Impact angle (n=14 accidents).

Most of the accidents occur in the impact speed range between 30 and 60 km/h (Figure 72), and the impact speed average is around 55 km/h.

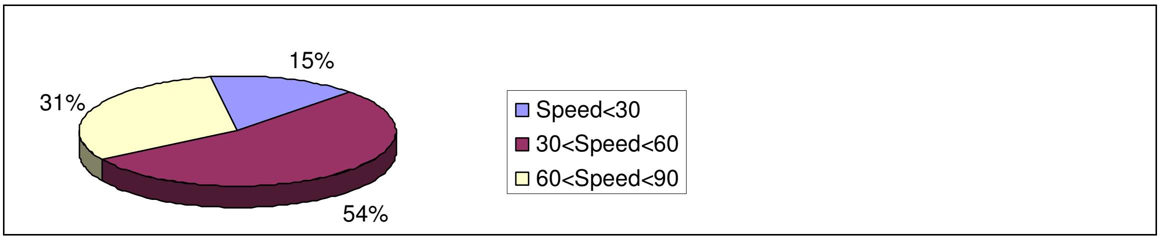


Figure 72: Impact speed (n=14 accidents).

The UNE 135900 standard specifies performance requirements and defines levels in passive safety terms intended to reduce the severity of injury to the riders of motorcycles impacting into motorcyclist protection systems installed along roadside barriers. Test methods for determining the level of performance under various conditions of impact are given. In summary, test conditions defined in the standard are shown in Figure 73.

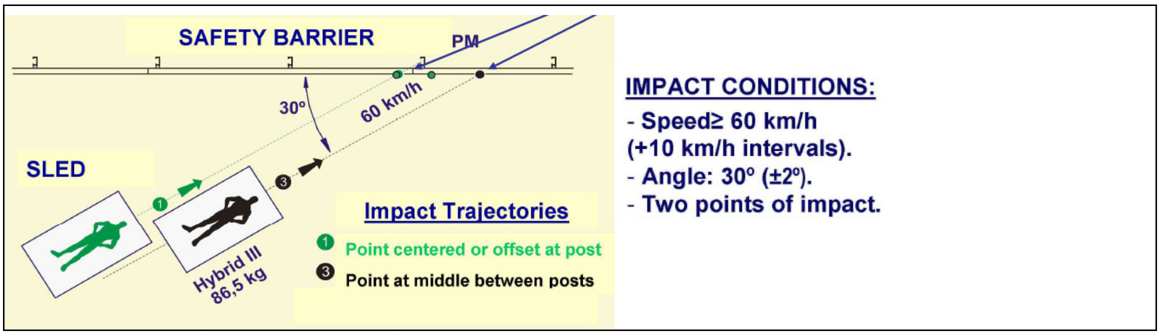


Figure 73: Test impact conditions.

The test simulates a rider sliding on the road surface and impacting the protection system at 30º. The test rider impact speed shall be 60 km/h. If these impact conditions are compared with those defined by the accident analysis, it is found that the test impact angle could be overestimated, and although the sliding position does not account for the majority of collisions, the most severe of both is sliding and upright position. Test impact speed (60 km/h) and the average impact speed (55 km/h) of these accidents are quite similar.

It is important to remark that none of the analyzed safety barriers was equipped with a motorcyclist protection system, and its effectiveness therefore could not be studied.

Regarding accident severity, all the riders involved in crashes into safety barriers sustained at least one injury (Table 135). Furthermore, riders sustaining fatal or serious injuries account for more than 60%.

Table 135: Safety barrier collisions. Severity of accidents (n=14).

Injury severity	Casualty count	Percentage (%)
Fatal	4	28
Seriously injured	5	36
Slightly injured	5	36
No injury	0	0

As it can be observed in Table 136, riders impacting in a sliding position are more likely to sustain more severe injuries than those impacting in an upright position. Riders impacting in a sliding position sustained serious injuries at impact speeds below 30 km/h, while all riders impacting in an upright position at speeds below 30 km/h only sustained slight injuries.

The whole of riders (n=5) who fell off their PTW impacted into the supporting posts of the roadside safety barrier. Furthermore, riders impacting double-T shaped posts sustained fatal injuries, while the remaining two riders who sustained serious injuries impacted into C-shaped posts. Thus, it can be concluded that the sharper edges of double-T shaped posts are more harmful than the C-shaped, so it is **strongly recommended to protect these posts or even to replace them with C-shaped**.

Table 136: Safety barrier collisions. Severity by rollover on carriageway and impact speed (n=14)

Rollover on carriageway previous to barrier impact			Severity			Total
			Fatal	Serious	Slight	
No	Impact speed	Speed<30	0 (0%)	0 (0%)	2 (14%)	2 (14%)
		30<Speed<60	0 (0%)	2 (14%)	3 (21%)	5 (36%)
		60<Speed<90	1 (7%)	1 (7%)	0 (0%)	2 (14%)
	Total		1 (7%)	3 (21%)	5 (36%)	9 (64%)
Yes	Impact speed	Speed<30	0 (0%)	1 (7%)	0 (0%)	1 (7%)
		30<Speed<60	2 (14%)	0 (0%)	0 (0%)	2 (14%)
		60<Speed<90	1 (7%)	1 (7%)	0 (0%)	2 (14%)
	Total		3 (21%)	2 (14%)	0 (0%)	5 (36%)

B) Accidents in straight sections of roads.

Most of the accidents (65%) collected in straight sections were motor vehicle collisions between a passenger car and a PTW. Almost half of accidents occurred at darkness suggesting a problem of visibility.

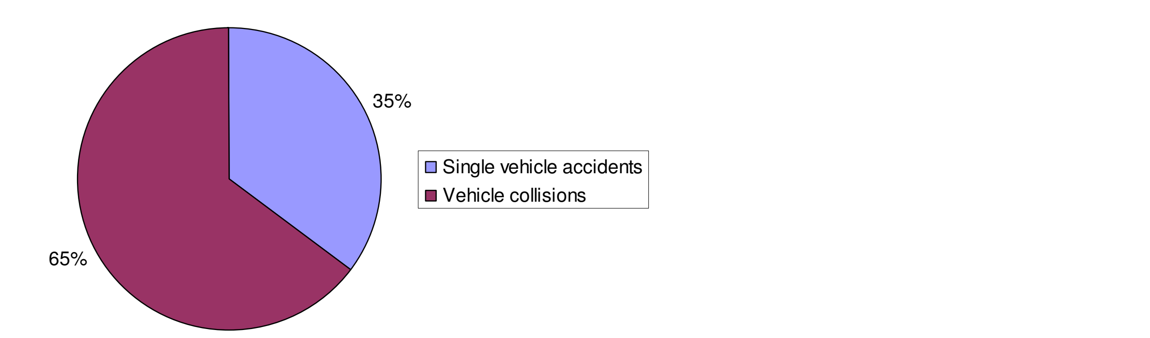


Figure 74: Type of accident (n=16).

Head on and front to side accidents are the most severe accident types (100% of fatal accidents), and all single vehicle accidents (run-off road, rollover, etc.) resulted in slight injured people, except for one serious accident. Thus, it could be concluded that **single vehicle accidents occurred at bends are more likely to result in fatal or seriously injured people than those occurred at straight sections of road.**

Table 137: Type of accident by severity (n=16).

		Severity			Total
		Fatal	Serious	Slight	
Type of accident	Head on	2 (12,5%)	0 (0%)	0 (0%)	**2 (12,5%)**
	Front to side	2 (12,5%)	2 (12,5%)	1 (6,25%)	**5 (31,25%)**
	Rear end	0 (0%)	0 (0%)	2 (12,5%)	**2 (12,5%)**
	Sideswipe	0 (0%)	1 (6,25%)	0 (0%)	**1 (6,25%)**
	Run-off the road, collision with obstacle	0 (0%)	0 (0%)	2 (12,5%)	**2 (12,5%)**
	Run-off the road, guardrail impact	0 (0%)	0 (0%)	1 (6,25%)	**1 (6,25%)**
	Run-off the road	0 (0%)	1 (6,25%)	0 (0%)	**1 (6,25%)**
	Rollover on carriageway	0 (0%)	0 (0%)	2 (12,5%)	**2 (12,5%)**
Total		**4 (25%)**	**4 (25%)**	**8 (50%)**	**16 (100%)**

PTW front-to-side accidents usually do not occur in straight sections away from junctions. Three of the registered accidents occurred after a wrong manoeuvre of drivers of the passenger cars when they were **leaving a parking place (inside urban) and did not notice the presence of the PTW**. The remaining two front-to-side accidents occurred outside urban areas, one of them after the driver had lost the control of his vehicle and went into the opposite lane, and the other one after the rider had made a wrong U-turn at low speed.

Regarding single vehicle accidents (run-off road and rollover), the road markings induced instability in half of them (n=3), and the lack of maintenance of the road (road works) was the cause of one accident. Thus, it could be stated that **road surface condition was a relevant factor** in these accidents, and particularly **road marking** is identified as a potential hazard to PTW users.

Table 138: Approach speed by Driving speed and Speed limit. (n=16)

Speed limit	Driving Speed	Type of accident								Total
		Head on	Front to side	Sideswipe	Rear end	Run-off the road, collision with obstacle	Run-off the road, guardrail impact	Run-off the road	Rollover on carriageway	
30	30<Speed<60						1			1
45	30<Speed<60		1		1	1				3
50	30<Speed<60					1		1	1	3
	90<Speed<120		2							2
80	60<Speed<90								1	1
90	Speed<30		1							1
	90<Speed<120	1	1							2
100	60<Speed<90	1								1
	Speed>120			1						1
120	Speed>120				1					1

Speed excess is registered in half of the accidents, but it is **not identified as a primary contributing factor** or main cause of the accident in any of them.

4.3.3.2. Accident at intersections

Among these accidents it is necessary to differentiate between two situations regarding the number of vehicles involved:

- Single vehicle accident. Run-off the road or rollover on carriageway of motorcycles at intersections.
- Collisions involving two vehicles (at least one motorcycle).

A) Single vehicle accidents

The most frequent type of intersection where accidents occurred is a roundabout (7 out of 8), and just one of them is located inside an urban setting. Among these accidents, a problem of perception/ conspicuity of the junction (roundabout) could be detected, since 70% of these accidents occurred without daylight conditions.

- *Severity by Type of intersection*

As it is shown in Figure 75, all fatal accidents collected occurred at roundabouts. The object most frequently hit among these fatal accidents (3 out of 4) was the kerbstone of the roundabouts. The object hit in the remaining accident was a lamp post located inside the roundabout, after the vehicle had impacted with the kerbstone.

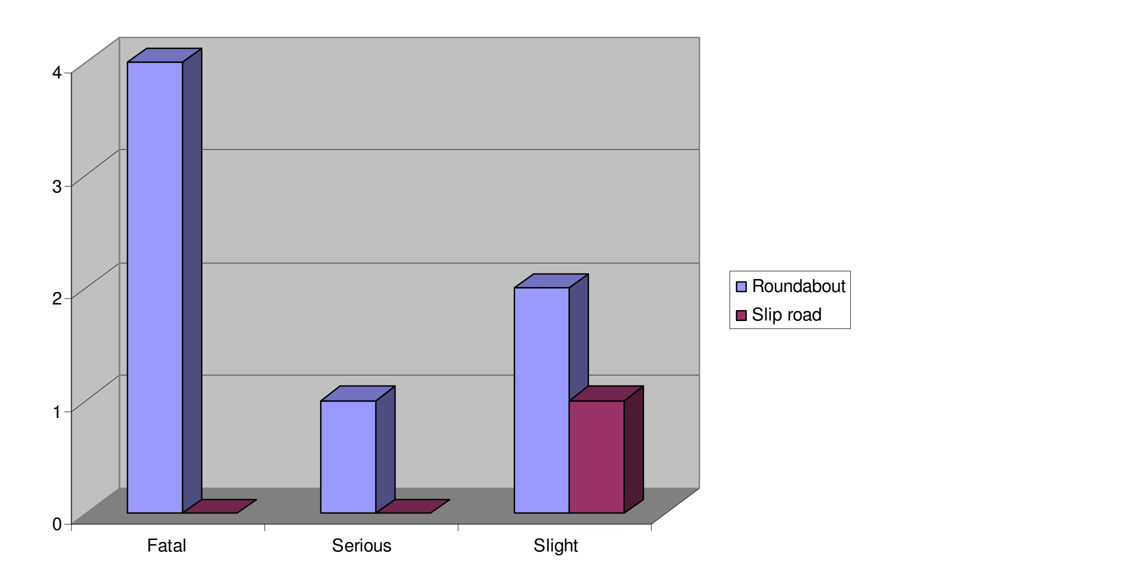


Figure 75: Severity by Type of accident (n=8 accidents).

- *Approach speed by Speed limit*

According to Table 139**, approaching speeds to junctions are clearly over speed limit** in all accidents, except for those involving mopeds (n=2) which rolled over on the carriageway.

Table 139: Approach speed by Speed limit (n=8).

Approach speed	Speed limit	
	40 km/h	50 km/h
30<Speed<60	2 (25%)	0 (0%)
60<Speed<90	1 (12,5%)	1 (12,5%)
90<Speed<120	2 (25%)	0 (0%)
Speed>120	2 (25%)	0 (0%)

It is remarkable that all the junctions were equipped properly. Road signs located at junctions complied with national regulations and recommendations, showing good levels of retroreflectance and visibility. Therefore, it could be stated that **road signing was completely adequate** and consequently it could **not be considered as a contributing factor**.

B) Collisions involving two vehicles.

Figure 76 represents the distribution of traffic control at junctions. The most frequent types are traffic lights (37%) and not controlled intersections (27%).

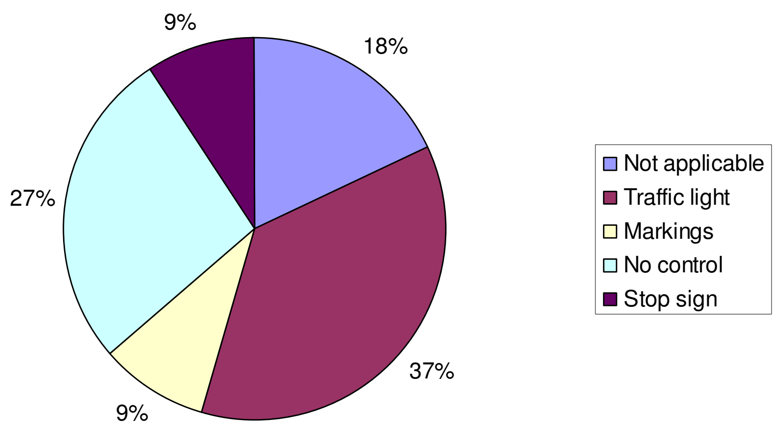


Figure 76: Traffic control (n=11 accidents).

Five of all riders were responsible for the accident, while drivers resulted to be responsible for six accidents. Traffic control violation was reported in three accidents (driver n=3, rider n=1), failure to give way (driver n=1, rider n=3) was the cause of three accidents and an improper turn was reported in two accidents (driver n=2). Speed excess was registered in 4 accidents (driver n=2, rider n=2).

Visibility was impaired in just one accident due to vegetation, and a low conspicuity was also present in another accident (at night) due to the rider's misuse of the dipped headlights.

Lack of visibility at the junction was present in just one of the accidents. The visibility was impaired due to vegetation, and the moped moved off from a path (no control, and not paved) at left roadside. The passenger car travelled over speed limit and could not avoid the collision with the moped.

Although it was not a junction controlled, **it is recommended to properly maintain the visibility at all intersections** removing or displacing those elements which reduce it.

As drivers stated, in many cases they not noticed the PTW. Therefore, it is also **recommended to increase the conspicuity of riders** using reflective clothing, white or light coloured helmets, and daytime headlights.

4.3.4. Conclusions for the microscopic analysis in Spain

Within this report the DIANA accident data was analysed in different ways, providing valuable information on several factors underlying PTW accidents. The aim of this report is to identify which are the most relevant factors related to infrastructure involved in the accidents involving this specific type of users.

The following is a summary of the key findings:

- Weather is not identified as a common primary contributing factor.
- Absence of traffic signs and impaired visibility are not detected as relevant factors.
- Run-off-road accidents involving PTW are more likely to occur in left hand bends than in right hand bends.
- A prevalent situation among accidents at curves is the '*run-off road at a left hand bend with descendent gradient along a road without shoulders or with impassable shoulders*'.
- Regarding run-off-road accidents, riders are almost twice as likely to impact in an upright position as in a sliding position.
- Not-predictable road geometry is identified as a relevant factor. Improving good forward visibility and the use of indication signs could improve the anticipation of the ongoing road geometry by the riders.
- Crossfall and curve radius are considered as relevant factors in combination with approach speed of the PTW.
- The kerbstone is identified as a potential safety hazard. It is proposed to conduct further "safety design" studies.
- The severity of injuries sustained by riders impacting roadside barriers without motorcyclist protection system (continuous additional rail) has been found to be extremely high.
- The main cause of death after roadside barrier impacts is the collision with exposed posts.
- The sharper edges of double-T shaped posts are more harmful than the C-shaped, and consequently are more likely to result in severe or fatal injuries. Therefore, it is strongly recommended to protect these posts or even to replace them with C-shaped.
- Among the accidents involving a roadside barrier, the vast majority of riders impact in an upright position and with impact angles below 20º. This fact shows the importance of clear zones which are free of obstacles behind the roadside barrier, in order to avoid possible collisions with them in case that rider cross over the guardrail system.
- Accidents which occurred in straight road sections are less likely to result in fatal or seriously injured people than those occurred at bends.
- Slippery road marking are identified as potential hazards, because they have lower skid resistance than the road surface.
- Speed excess is not identified as a primary contributing factor among accidents located at straight roads.
- Roundabouts are identified as a potentially hazardous type of intersection. Most of the accidents collected in these junctions occurred without daylight conditions so it could be suggested that kerbs should be painted with the aim of raising their conspicuity.
- Approaching speeds to junctions are frequently above the speed limit.
- A problem of conspicuity is detected among accidents occurred at junctions. Therefore it is recommendable to increase the conspicuity of riders using reflective clothing, white or brightly coloured helmets, and daytime headlights.

4.4. Interaction between Powered Two-Wheeler Accidents and Infrastructure in Germany

4.4.1. Methodology – German Data Base and Available Data

According to the official road crash statistics there were 327,984 injury crashes in Germany in 2006, 10% (32,933) thereof involving a powered two-wheeler. Of these 32,933 crashes 63% (20,692) occurred on urban roads, 34% (11,296) on rural roads (roads outside urban areas without motorways) and, 3% (945) on motorways. Overall, 793 powered two-wheeler users (riders and passengers) were killed in a crash, 25% (201) of them on an urban road, 69% (544) on a rural road, and 6% (48) on a motorway. These figures clearly indicate that the majority of powered two-wheeler crashes occur on urban roads; these crashes, however, are characterised by a relatively low crash severity. In contrast, the relatively fewer powered two-wheeler crashes on rural roads are characterized by a high crash severity. Against this background, this study focuses on powered two-wheeler crashes on rural roads.

This study considered only motorcycle crashes. Crashes of mopeds, motor-assisted bicycles and bicycles fitted with an auxiliary motor with an engine capacity not exceeding 50 cc (maximum design speed not exceeding 50 km/h) were not taken into account. The main reason for excluding these categories of powered two-wheelers is the fact that their maximum speed is much lower than the speed limit on rural roads of 100 km/h. For this reason, these categories were involved in less crashes (also because of their low mileage) and in different crash types than motorcycles.

Since we know that there is a very high number of unreported motorcycle crashes with material damage only (especially single motorcycle crashes), solely motorcycle crashes with personal injury were considered.

Therefore, this investigation focuses exclusively on injury motorcycle crashes on rural roads.

This investigation is divided into three parts. Within the first part, the relationship between the density of injury motorcycle crashes and the average daily traffic (ADT) of powered two-wheelers was investigated. As data base for this part served the 2005 road traffic census data and the crash data of injury motorcycle crashes on rural federal trunk and state roads in the federal state of Bavaria from 2002 to 2006.

The second part concentrated on the relationship between crashes, where the motorcyclist lost control of his bike and various infrastructure parameters. Therefore, investigation sections with approximately the same ADT of powered two-wheeler, but different crash situation (safe sections with no crashes versus unsafe sections with more than three crashes of the aforementioned type), were selected in three different regions. Using a measurement vehicle of the Dresden University of Technology relevant road infrastructure parameters were recorded for these selected road sections.

The aim of the third part was taking an in-depth look at the influence of the road surface condition on injury motorcycle crashes on rural trunk roads in the federal state of North Rhine-Westphalia. For this investigation, road surface condition data and crash data from 2003 has been used.

4.4.1. Influence of the ADT of powered two-wheelers on the density of injury motorcycle crashes

It is already known that there is a strong relationship between the ADT and the crash density. Whether there is also a strong relationship between the <u>ADT of powered two-wheelers</u> and the density of injury motorcycle crashes had to be proven. For this reason, the data of the 2005 road traffic census and data of injury motorcycle crashes on rural federal trunk and state roads in Bavaria between 2002 and 2006 was used for such analysis. Since the traffic census data did not differentiate between different types of powered two-wheeler, it was not possible to determine the relationship between the <u>ADT of motorcycles</u> and the density of injury motorcycle crashes. However, as the officially registered number of scooter and moped crashes is extremely low due to their low mileage on these kinds of roads, it is legitimate to compare the <u>ADT of powered two-wheelers</u> with the density of injury motorcycle crashes.

Overall, for 3,403 sections of rural federal trunk and state roads in Bavaria information on the ADT of powered two-wheelers was available. On 822 of these 3,403 sections there was at least one motorcycle crash involving personal injury. As the consideration of road section without a motorcycle crash involving personal injury have only a negligible influence on the relationship between the density of injury motorcycle crashes and the ADT of powered two-wheeler, but the result can be shown clearly without them, the following investigation was restricted to these 822 road sections.

Due to the fact that for road sections with an ADT above 500 motorcycles per day meaningful grouping for the subsequent investigation was impossible, road sections with an ADT above 500 powered two-wheelers per 24 h were not included (this applies to 10 road sections). The following investigation was therefore restricted to 812 road sections (mean section length: 3,900 m).

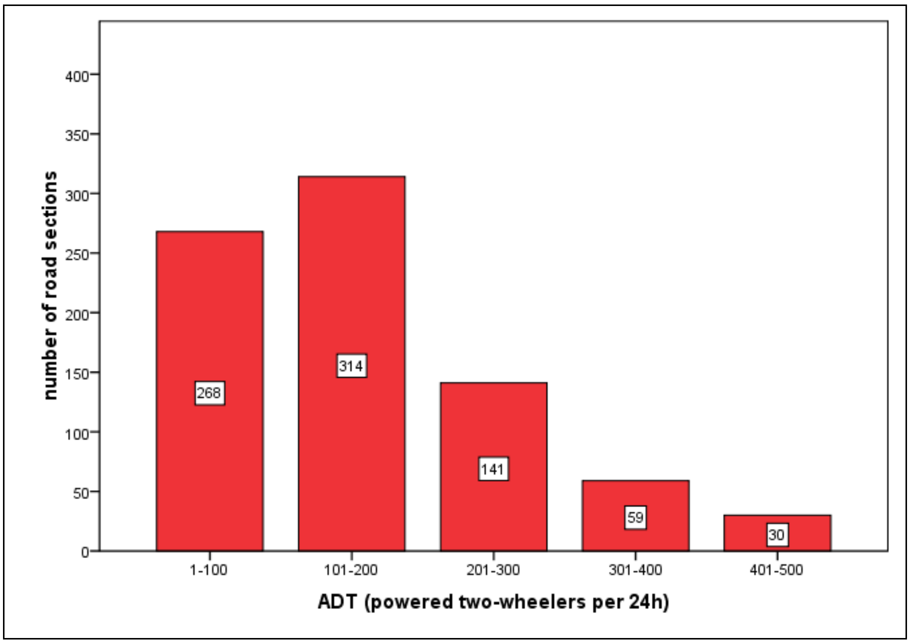


Figure 77: ADT of powered two-wheelers and number of investigated road sections in Bavaria.

The number of sections as a function of 5 ADT classes with a uniform class width is shown in Figure 77. As can be seen the majority of road sections have an ADT between 101 and 200 powered two-wheelers per 24h (39%). By contrast, road sections with an above average ADT between 401 and 500 powered two-wheelers per 24h have a much smaller proportion (4%).

In the next step, the crash density was calculated for all 812 road sections. The crash density is a unit which expresses the relationship between crash occurrence and the examined length in kilometers of a road. Figure 78 shows the relationship between the ADT of powered two-wheelers and the density of injury motorcycle crashes as a box and whisker plot.

A box and whisker plot is a convenient way of graphically depicting groups of numerical data. The bottom and top of the red box are the 25th and 75th percentile (the lower and upper quartiles), and the black line near the middle of the box is always the 50th percentile (the median). The ends of the whiskers represent in this case the lowest datum still within 1.5 interquartile range of the lower quartile, and the highest datum still within 1.5 interquartile range of the upper quartile. Any data not included between the whiskers is plotted as an outlier with a dot or plotted as an extreme outlier with a star.

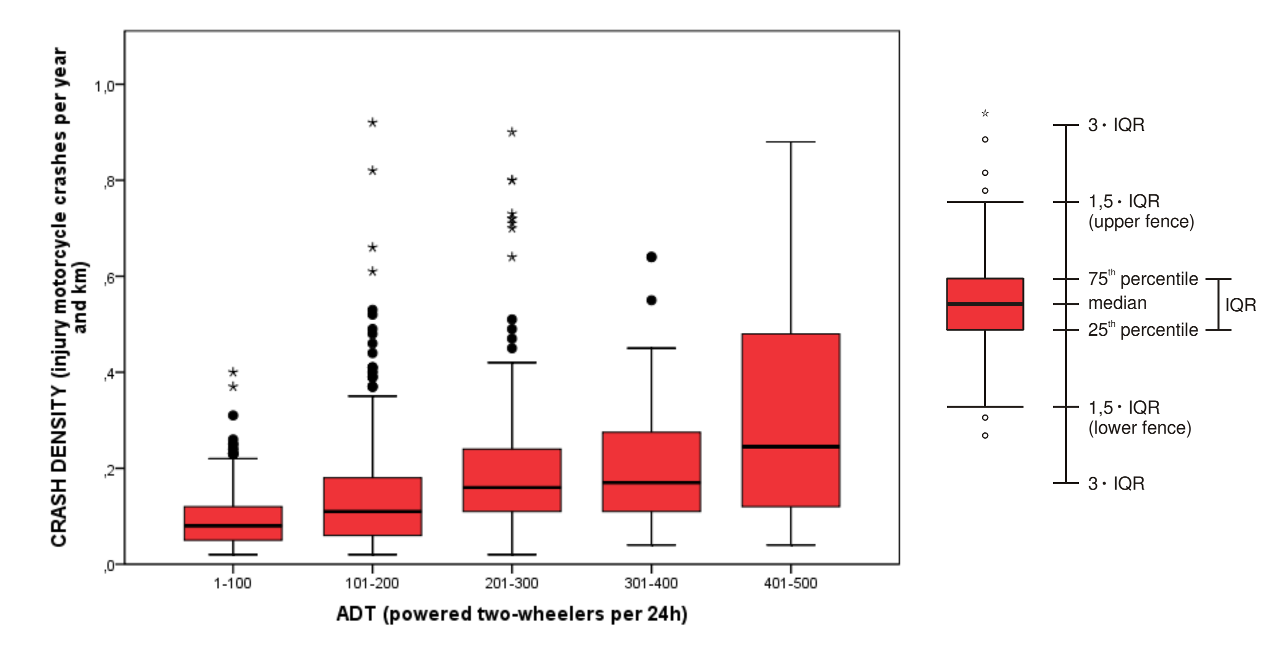


Figure 78: Relationship between the ADT of powered two-wheelers and the density of injury motorcycle crashes.

In Figure 78 it becomes particularly evident that with an increasing ADT of powered two-wheelers, the density of injury motorcycle crashes also increases. This context is clearly, shown by the median. The density of injury motorcycle crashes on road sections with an ADT between 1 and 100 powered two-wheelers per day is about 0.1 injury motorcycle crashes per year and km, whereas the density of injury motorcycle crashes on road sections with an ADT between 401 and 500 powered two-wheelers per day is slightly above 0.2 injury motorcycle crashes per year and km. Thus the crash density on heavily loaded sections is about twice as high as on the weak loaded sections.

The crash density of injury motorcycle crashes is crucially dependent on the ADT of powered two wheelers. The information on the ADT of powered two-wheelers is therefore necessary within the following road section related investigation of a possible relationship between road infrastructure parameters and single injury motorcycle crashes.

4.4.2. Influence of road infrastructure parameters on injury motorcycle crashes

Which infrastructure parameters have an impact on injury motorcycle crashes can best be shown in a comparison of safe road sections (no single injury motorcycle crashes) with unsafe road sections (many single injury motorcycle crashes). For example, if the unsafe road section is characterised by a bad road surface condition, which is on the safe road section is not the case, it is possible that crashes happen due to that particular characteristic.

Different possible investigation areas with a high proportion of motorcycle crashes were analysed using a map of Germany, which illustrates the share of injury motorcycle crashes of any injury crash on rural roads in 2006 (see Figure 79 – red indicates a proportion of more than 20%). According to the map, there is a particularly high proportion of injury motorcycle crashes in the federal states of North Rhine-Westphalia, Rhineland-Palatinate and Bavaria. This is because there are extensive mountainous areas in these federal states, which are particularly attractive to motorcyclists. For this reason the further investigation is limited to rural roads in the federal states of North Rhine-Westphalia, Rhineland-Palatinate and Bavaria.

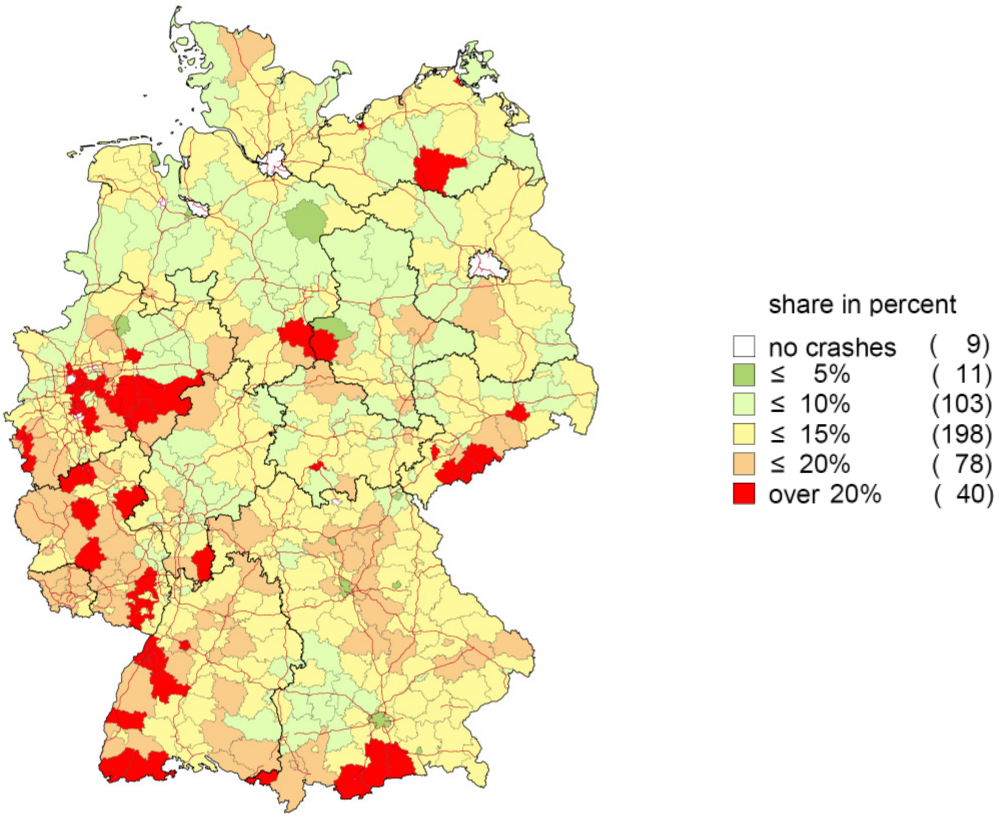


Figure 79: Share of motorcycle crashes with personal injuries of any personal injury crash on rural roads in 2006.

Next the crash density was calculated for road sections where the ADT of powered two-wheelers was available and also higher than 100 powered two-wheelers per day. For calculating the crash density, only injury motorcycles crashes between 2002 and 2006, where the motorcyclist lost control over his bike (hereinafter referred to as "injury motorcycle driving crash") were considered. It was assumed that all other types of crashes were not or only marginally affected by road infrastructure parameters (except crashes on intersections).

Depending on the calculated crash density, the road sections were then divided into two categories. Road sections with a calculated crash density of zero (no injury motorcycle driving crash) were assigned to the first category (safe road sections), whereas road sections with a high crash density were assigned to the second category (unsafe road sections with more than three injury motorcycle driving crashes).

Using a measurement vehicle of the Dresden University of Technology (see Figure 80) different road infrastructure parameters were recorded for randomly chosen road sections of those two road section categories in 2009. The measured infrastructure parameters included road geometry data (design elements of the horizontal and vertical alignment), road cross-sectional data (number of lanes, lane width, roadside design, crossfall), road equipment (marking, traffic signs and safety devices) and road condition data (network cracks, flick posts and rut depth).

Figure 80: Measurement vehicle of the Dresden University of Technology.

The aforementioned infrastructure parameters were collected by the measuring vehicle for 32 safe and 27 unsafe road sections. Against the background that there are significantly safer road sections in the road network, the total number of safe road sections was slightly higher in comparison to the unsafe road sections (see Table 140). As can further be seen in Table 140, the average ADT of powered two-wheelers per day is almost identical and equally distributed for both road categories. Hence, the influence of the ADT of powered two-wheelers per day can be excluded.

Table 140: Comparison of safe and unsafe road sections.

	Safe road sections	Unsafe road sections
Number of road sections	32	27
Average section length [m]	4288	4712
ADT [powered two-wheelers per day]	247	245
Number of injury motorcycle driving crashes	0	254
Crash density [injury motorcycle driving crashes per year and km]	0	0,48

Subsequently, various infrastructure parameters which are expected to have an influence on injury motorcycle driving crashes were examined with the software tool “RoadVIEW”.

4.4.2.1. Curvature Change Rate

Figure 79 already shows that the share of injury motorcycle crashes of any injury crash on rural roads is particularly high in mountainous regions. In mountainous areas, the alignment of the roads is generally strongly adapted to the landscape. Due to this fact, it is expected, that the curvature change rate has a significant influence on motorcycle crashes.

The curvature change rate is defined as follows: The curvature change rate is the sum of angle changes in the curve divided by the length of the road section. The sum of absolute angle changes consists here of the angle changes from the circular and the transition curve.

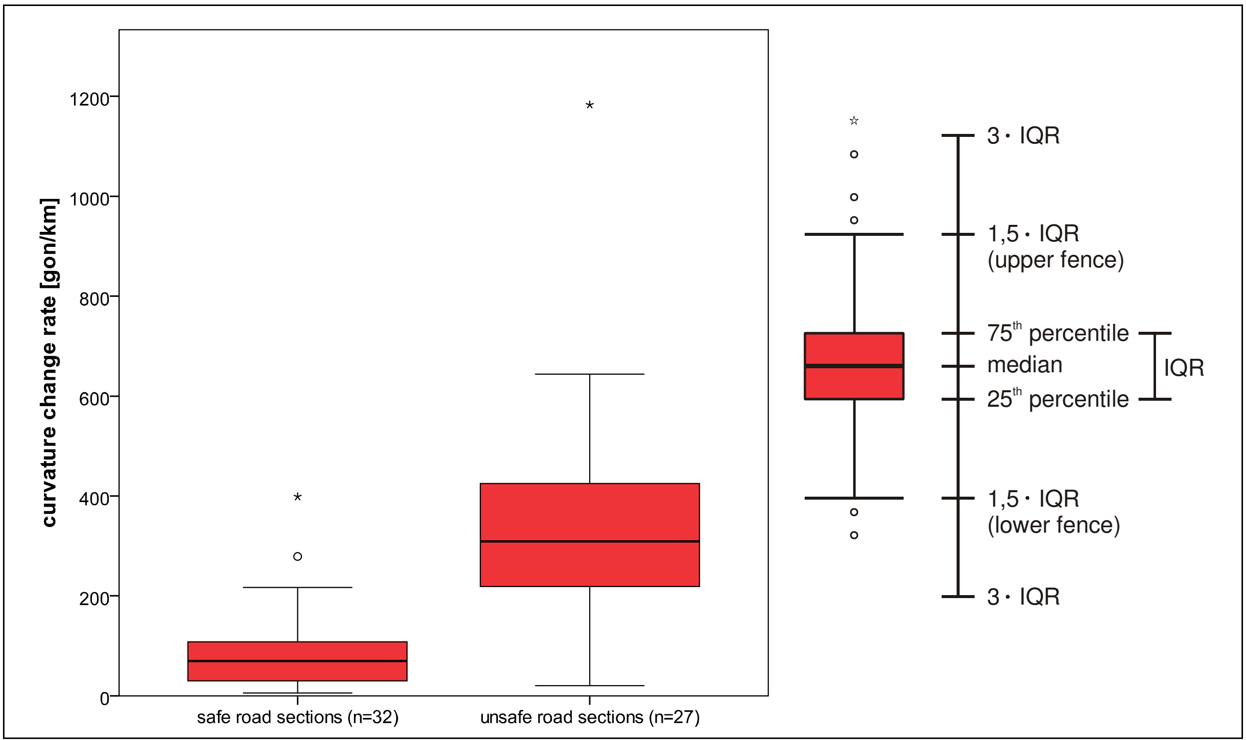


Figure 81: Curvature change rate.

Figure 81 shows that the curvature change rate [gon/km] is higher on unsafe road sections than on safe road sections. On safe road sections the curvature change rate is approximately 70 gon/km (median) whereas with over 300 gon/km (median) the curvature change rate on unsafe road sections is more than fourfold. This means that the curvature change rate and thus the vertical alignment have an influence on injury motorcycle driving crashes.

In this context, the alignment just before and at the crash scene of injury motorcycle driving crashes was investigated. As a result it was found that the vast majority of these crashes occurred in curves. These curves are usually characterized by very small curve radii (< 50 m). Moreover, they are usually in sections with a bad radii relation (unbalanced ratio of successive radii or radii on adjacent straight).

4.4.2.2. Road surface condition

Due to their design, the driving stability of motorcycles can be significantly restricted under bad road surface conditions. The question of the subsequent investigation is, if defects in road surface condition affect injury motorcycle driving crashes.

As part of the measurement of infrastructure parameters on the safe and unsafe road sections, the following road surface condition parameters were collected:

- Rut depth (mm)
- Network cracks (%)
- Flick posts (%)

These recorded road surface condition parameters were turned into a condition grade from 1.0 to 5.0 with the following range of value:

- Condition grade 1.0 to smaller than 1.5 (very good)
- Condition grade 1.5 to smaller than 3.5 (good/medium)
- Condition grade 3.5 to smaller than 4.5 (bad)
- Condition grade 4.5 to 5.0 (very bad)

For the final evaluation of a road section, the single road surface condition parameters (rut depth, network cracks and flick posts) were grouped according to the "working paper for the road surface analysis and assessment of the road surface of roads (ZEB)" to an "overall value" for sections of 20 m.

Figure 82 shows the road surface condition as overall value for the safe and unsafe road sections. According to this, the road surface condition is practically identical on the safe and unsafe road sections.

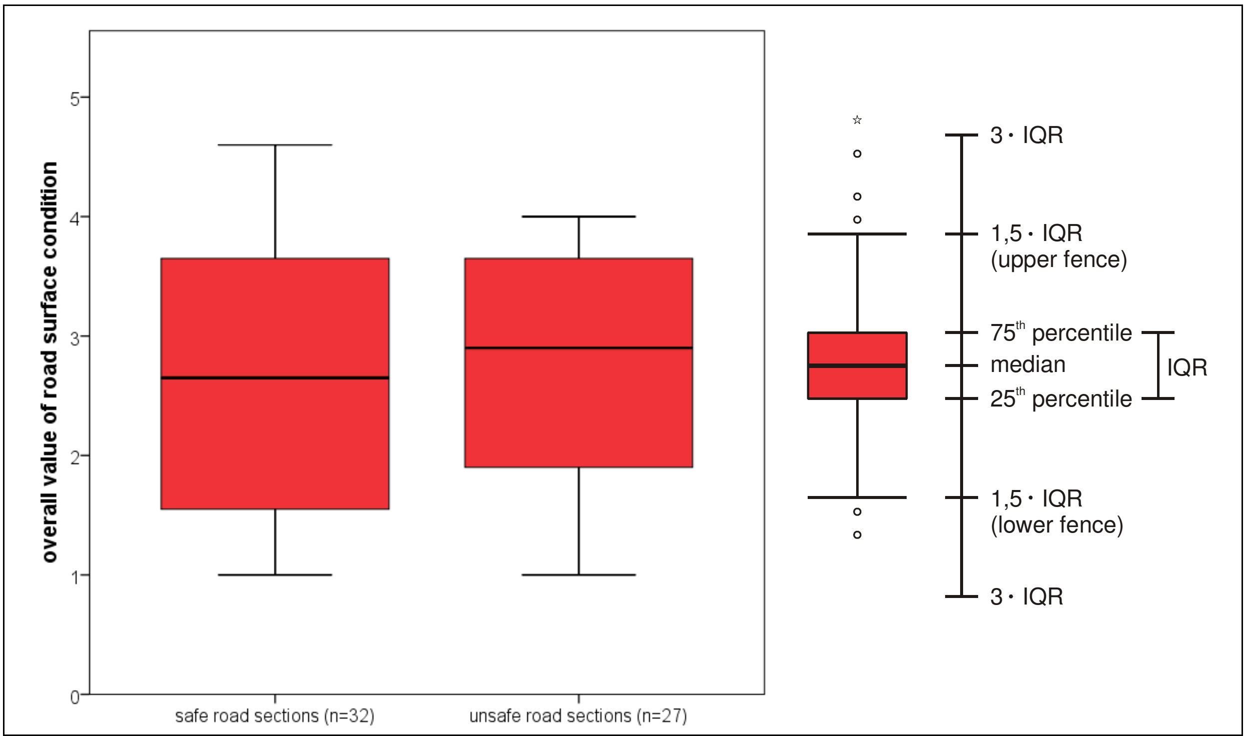


Figure 82: Overall value of road surface condition.

That safe road sections do not as expected have better road surface conditions, might be caused by the following points:

- The overall value was averaged over the entire road section. Thus the road surface condition is not directly associated with the crash.
- As data base for the study injury motorcycle driving crashes from the period 2002-2006 were used. However, the road surface conditions were recorded in 2009. It is

assumed that the road surface conditions from the year 2009 differ from the road surface conditions between 2002 and 2006.

Due to these circumstances and against the background that the measurement vehicle of Dresden University of Technology could not record all road surface condition parameter according to ZEB (e.g. skid resistance), the next chapter will be investigating the influence of different road surface condition parameters on road safety of motorcyclists in detail.

4.4.3. Influence of road surface condition on injury motorcycle driving crashes

In Germany, the road surface condition parameters general unevenness, ruts, friction, network cracks, flick posts and other surface damages are measured on the federal roads every four years. Beside these relevant road surface condition parameters additional characterising parameters (e.g. accumulations of binder) are recorded. The road surface condition parameters are collected by fast moving measurement vehicles and assigned to the road network system.

In the process of road surface assessment, the road condition parameters, which have been determined from condition data collected locally with physical dimensions, are first converted into normalized non-dimensional condition grades for sections with a regular length of 100 meters and then as part of a value synthesis linked to different sub goals values and an total value. The rating of condition values follows the range of value as described in chapter 4.4.2.2.

As part of the subsequent investigation, the relevant road surface condition data of the federal rural roads (no motorways) in North Rhine-Westphalia from 2003 were directly linked to the data of injury motorcycle driving crashes of the same year. Since the crash is caused ahead of the final position of the bike or the rider, the road surface condition parameter of the preceding 100 meters section has been linked to the crash. A total of 106 injury motorcycle driving crashes could be linked with road surface parameters. To assess the road surface conditions at the crash scene, the road surface condition parameters of a large part of the federal rural road network (no motorways) in North Rhine-Westphalia (total of 2107 sections á 100 meters) were used as a comparison.

4.4.3.1. Longitudinal unevenness – general unevenness

The longitudinal evenness indicates the compliance of the actual shape of the surface layer (actual surface) with the shape of the projected surface layer (target surface) in longitudinal direction (parallel to the road axis). Unevenness in longitudinal direction is geometrical irregularities of the road surface in form of height deviations from the planned shape of the surface layer, which are not part of the texture.

Unevenness in longitudinal direction may affect driving safety due to reduced frictional connection of dynamic variation of wheel forces. Also, the rider fitness and comfort may be reduced due to vertical accelerations.

The longitudinal unevenness is measured on the right-hand lane of each directional carriageway. A rigid measuring beam is installed under the vehicle and decoupled from it, in the rolling track of the right-hand wheels. Five triangulation laser sensors are attached to this beam which constantly scans the distance to the road surface.

From the parameter group "longitudinal unevenness" 3 different condition parameters (general unevenness, single obstacles and periodic unevenness) are determined. Of these 3 condition parameters, however, the general unevenness is the only one relevant for the calculation of the overall value. For this reason, only the general unevenness has been examined here.

Figure 83: General Unevenness (road surface wave and pothole).

Figure 83 shows examples for general unevenness which can occur as road surface waves as well as potholes (separation of parts of the road surface due to traffic, weathering, or weather influence).

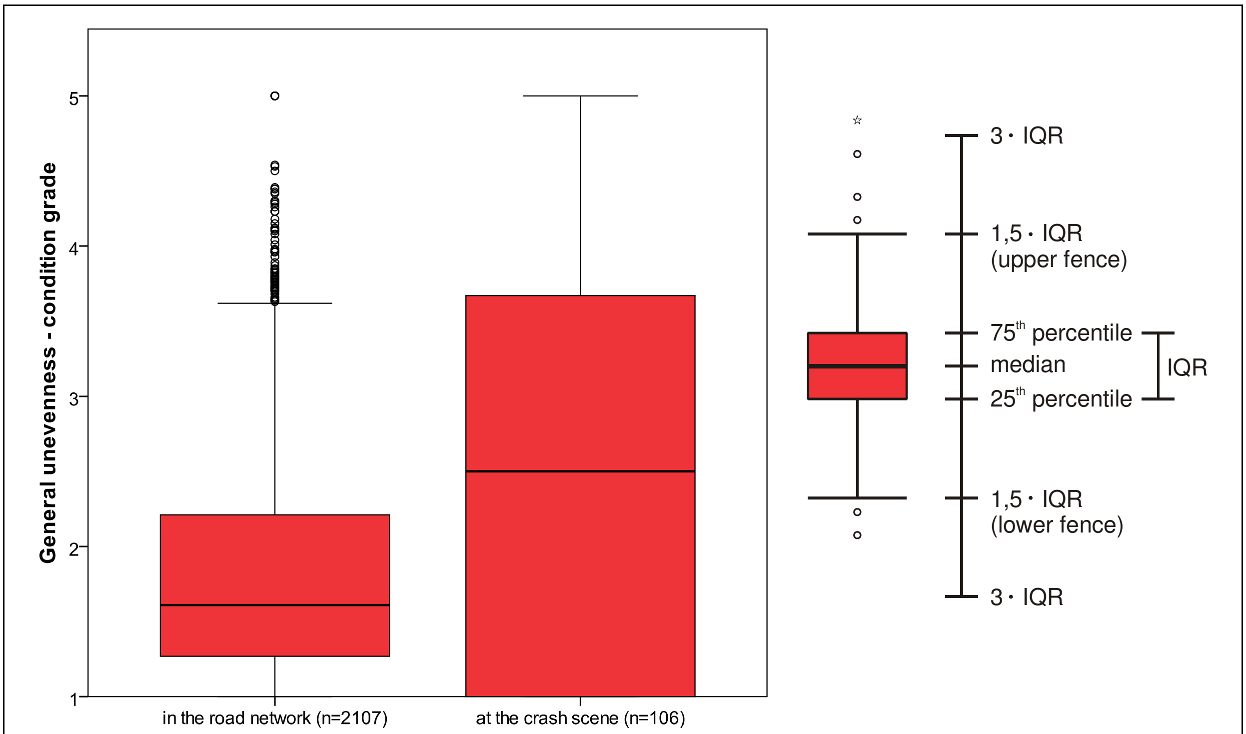


Figure 84: General unevenness.

As shown in Figure 84, the actual condition grade of the general unevenness in the road network is much lower than at crash scenes. The median of the actual condition grade in the road network is still in the very good range (smaller 1.5), in contrast to a good/medium range (around 2.5) at the crash scene. This means that the actual condition grade of the general unevenness at the crash scene is much worse than is the case in the road network. Therefore, the deficits concerning the general unevenness have an impact on injury motorcycle driving crashes.

4.4.3.2. Transverse unevenness – rut depth and theoretical water depth

The transverse unevenness indicates the compliance of the actual shape of the road surface layer (actual surface) with the shape of the projected surface layer (target surface) in transverse direction (rectangular to the axis of the road). The transverse unevenness is therefore the deviation of the actual shape of the surface layer from the shape of the target surface layer.

Transverse unevenness may affect traffic safety by reducing the traction between road surface and vehicle tires due to deteriorated water drainage. By affecting the direction of travel they can also influence the lane keeping of motorcyclists and strain the rider additionally.

The transversal evenness is measured with 41 triangulation laser sensors mounted on a rigid beam. This beam is installed behind the rear axle, decoupled from the vehicle. To achieve a measuring width of 4 m given a device width of 2.4m, the outer 9 laser sensors on each side are inclined at angles of up to 63° and arranged vertically to a height of 1.7 m.

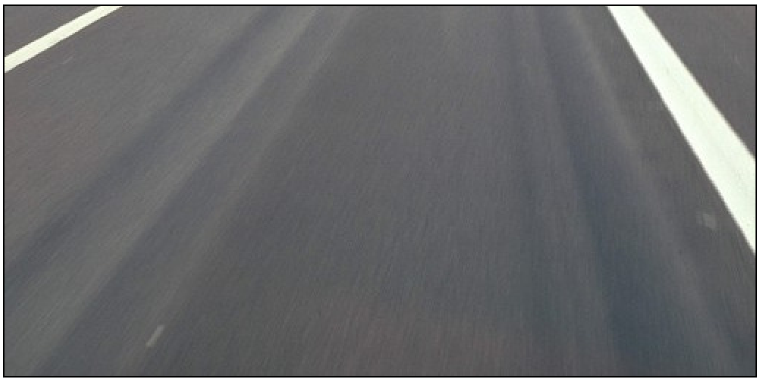


Figure 85: Transverse Unevenness (ruts).

The transverse evenness is registered using the condition parameter "ruts" (see Figure 85). According to ZEB, the condition grades were calculated for the corresponding condition parameters rut depth and theoretical water depth.

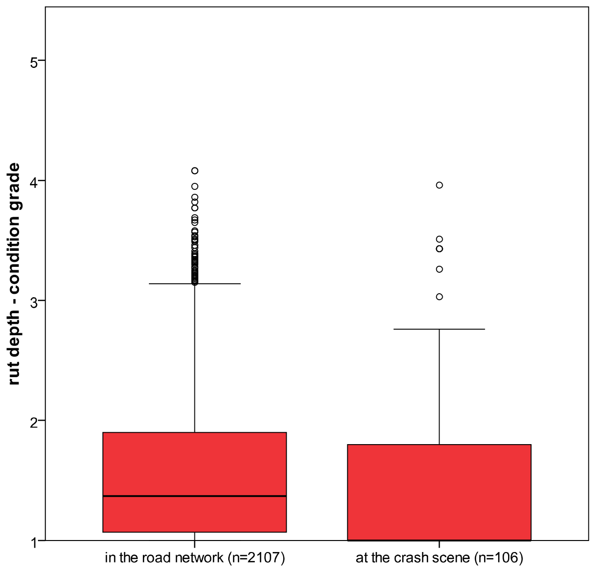


Figure 86: Rut depth.

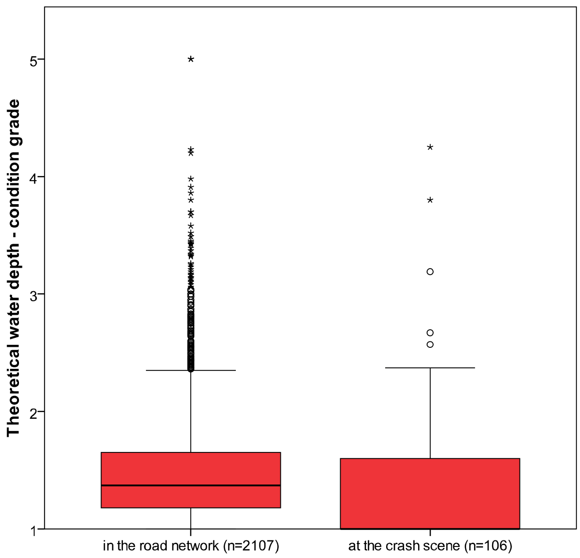


Figure 87: Theoretical water depth.

The rut depth is determined by the largest possible depth gauge in transversal axis of a road profile below a 2 meters latch. All possible positions are investigated to find the maximum depth gauge for the right and left half of lane.

Figure 86 shows that the median of the actual condition grade rut depth is in a very good range (smaller than 1.5) both in the road network and at the crash scenes. At the crash scenes the median is even below the condition grade of 1. This means that ruts were not present at more than 50% of crash scenes. Against the background that the median of the condition grade rut depth in the road network is above the value 1, it can be concluded, that deficits concerning the rut depth have no influence on injury motorcycle driving crashes.

The theoretical water depth is determined on the basis of the possible theoretical accumulation of water in a rut. Figure 87 shows the actual condition grade for the theoretical water depth. The result is comparable to the result of the actual condition grade of rut depth. Accordingly, an influence of deficits concerning the theoretical water depth can be excluded in injury motorcycle driving crashes.

That deficits regarding both, the rut depth as well as the theoretical water depth have no influence on injury motorcycle driving crashes, may possibly be due to the fact that these two parameters are generally in a very good range on road sections of federal rural roads.

4.4.3.3. Friction – friction value

Friction characterises the effect texture and material composition of the road surface have on the traction between motorcycle tires and roadway under defined conditions. Friction forces for the acceleration, deceleration and lane keeping of a motorcycle are transferred through the road surfaces. By measuring the skid resistance coefficient between a measuring wheel and a wetted road surface of the right wheel tracks friction is recorded.

We already know that friction has an influence on driving safety and that there is a direct connection with the crash rate under wet conditions.

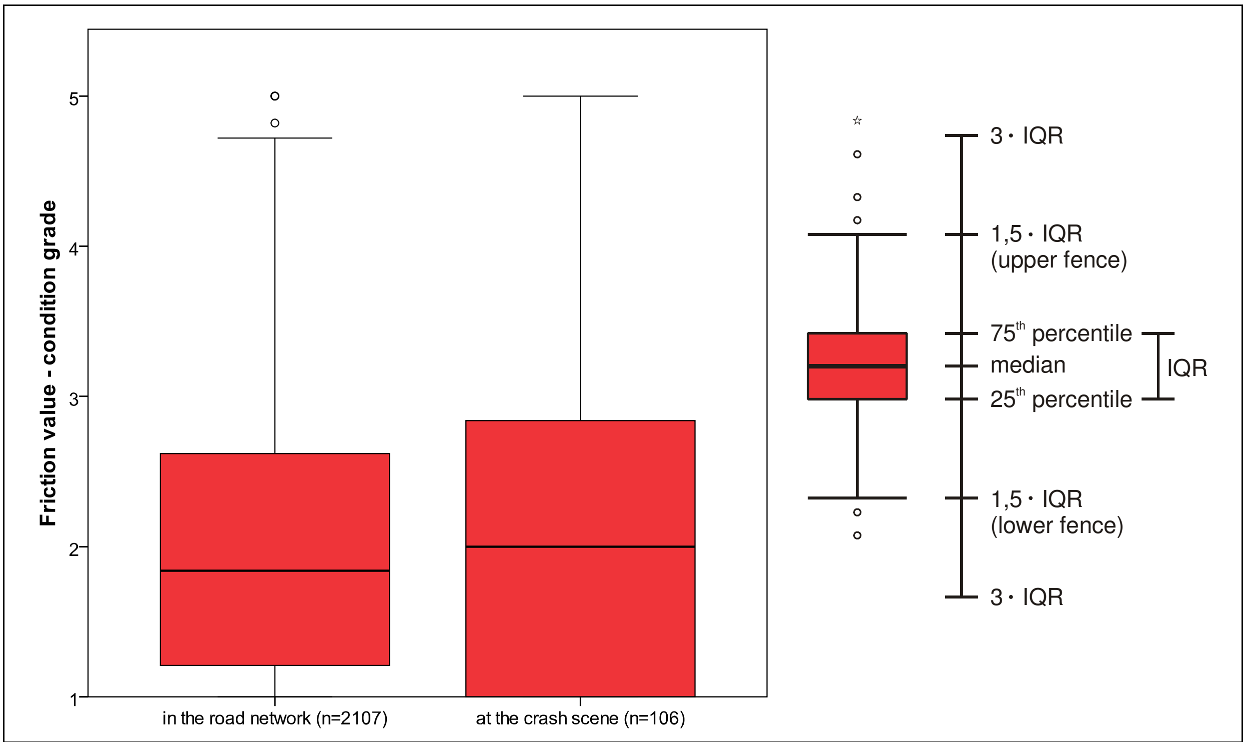


Figure 88: Friction value.

Figure 88 shows the results of the friction value. According to this, the friction value is practically identical at the crash scene and in the road network.

The friction value at the crash scene is not, as could be expected, significantly worse than in the road network. A possible reason is that the friction may have a critical influence only under wet conditions. The overall motorcycle crash statistics shows that the share of motorcycle crashes under wet conditions is very small. The reason is that most motorcyclists try to avoid riding under bad weather conditions.

4.4.3.4. Substance – Network cracks, flick posts and accumulation of bituminous binder

The condition characteristic "substance" (surface profile) indicates visible structural road surface damages of the pavement. The condition parameters of the road surface are recorded on the basis of technical video components. The assessment is based on a surface grid, which has a size of 1/3 of the lane width in transverse direction and a size of 1 metre in the longitudinal direction. The occurrence of corresponding damage is recorded for each grid. This process is then used to determine the average relative frequency of damages.

Figure 89: Substance parameter (Network cracks, flick posts, accumulation of bituminous binder).

Condition parameters recorded are single cracks, network cracks, flick posts, potholes and accumulations of bituminous binder. Since only network cracks and flick posts are relevant for the calculation of the overall value, only these condition parameters were analysed. However, it is also believed that accumulations of binder may have an influence on injury motorcycle driving crashes. For this reason, this condition parameter was also investigated.

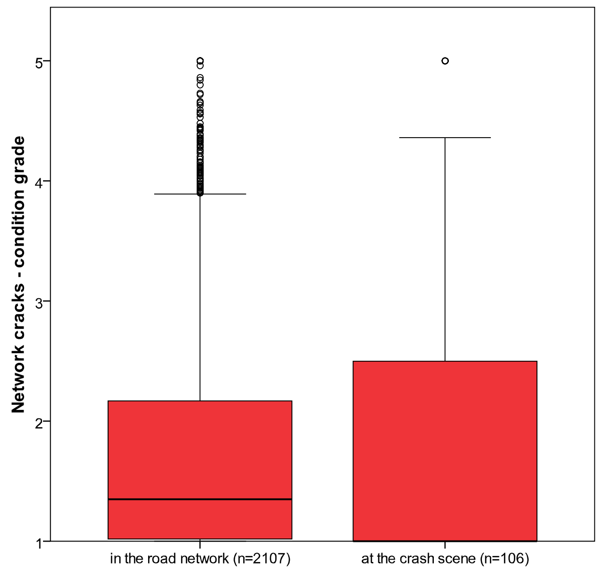


Figure 90: Network cracks.

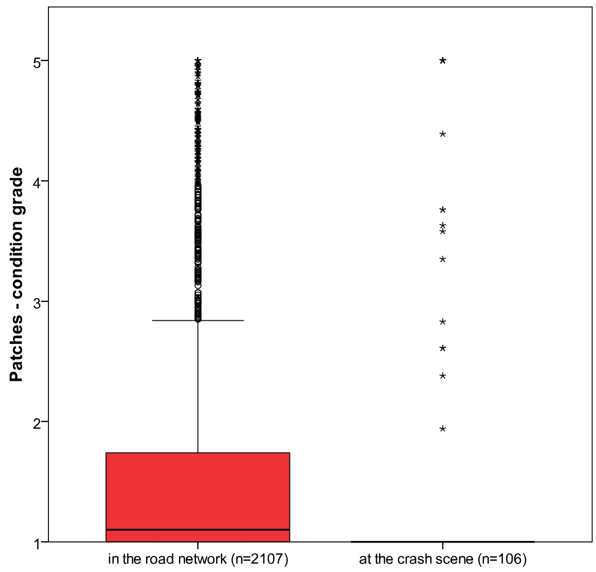


Figure 91: Flick posts.

Figure 90 and Figure 91 show the condition grade of network cracks and flick posts. The median of the two condition parameters at the crash scene is below the state value of 1, in case of the flick posts even below the 75th percentile. In comparison, the median in the road network is just above 1. This means that network cracks and flick posts have no detectable influence on injury motorcycle driving crashes.

The accumulation of bituminous binders on the road surface could only be detected on a few sections in the road network, however, not at any crash scene. Accumulations of bituminous binder increase the stopping distance and reduce the maximum sloping position in curves. Because of these characteristics, accumulations of bituminous binder expose a high crash potential for motorcyclists.

4.4.3.5. Overall value

The individual condition grades (general unevenness, rut depth, theoretical water depth, friction value, network cracks and flick posts) are combined in a value synthesis to two so-called sub values. The two sub goals road safety and traffic ability are summarized in a utility value (first sub value), which should characterise the quality of service for the road user. The second sub value is the substance value, which is calculated on the basis of the condition characteristic substance (surface profile). The overall value is equal to the poorer of the two sub values.

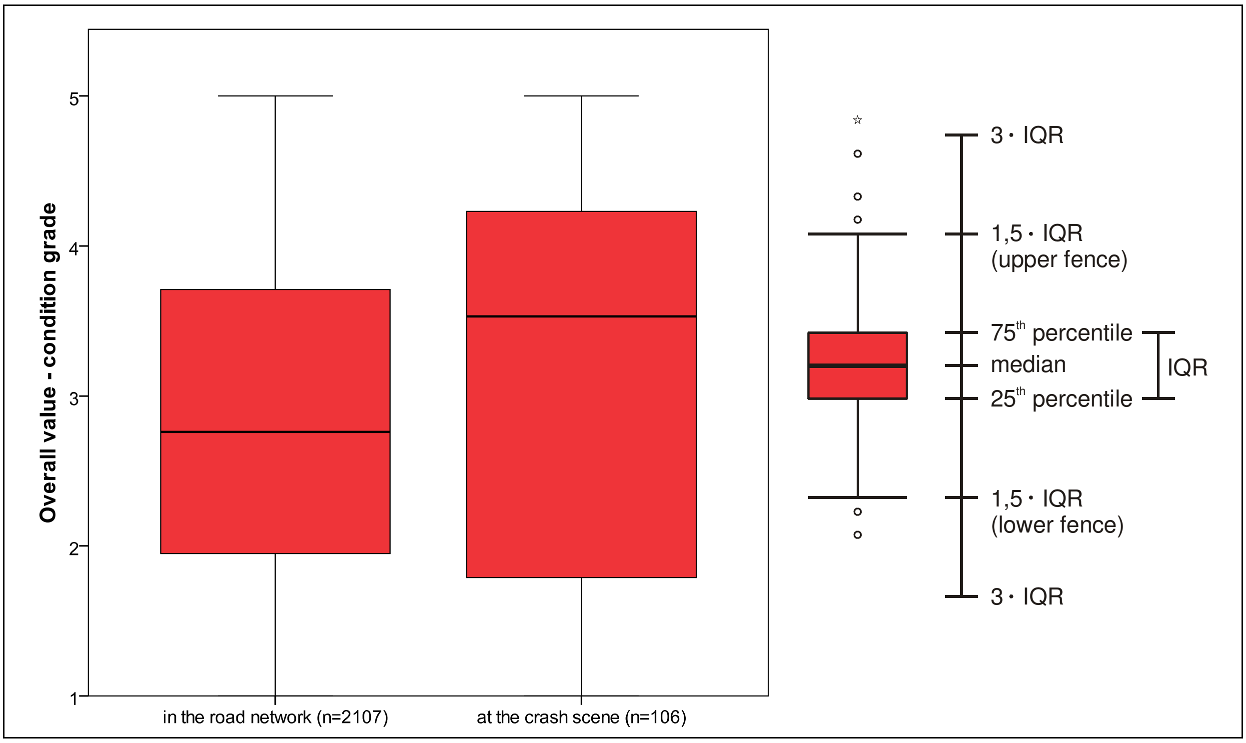


Figure 92: Overall value.

Figure 92 shows the overall value of road surface condition in the road network and at the crash scene. It becomes obvious that the median of the overall value in the road network is much lower and therefore better than at the crash scene. The median in the road network is at just above 2.5 in the good range (1.5 to 3.5), however, at the crash scene the median at just above 3.5 is already in a bad area (3.5 to 4.5). This means that the overall value for road surface condition at the crash scene is much worse than is the case for the road network. The overall value and hence the road surface condition has therefore an influence on injury motorcycle driving crashes.

4.4.4. Conclusions for the microscopic analysis in Germany

This investigation was divided into three parts and had the focus on injury motorcycle crashes on rural roads. Within the first part, the relationship between the density of motorcycle crashes and the average daily traffic (ADT) of powered two-wheelers was investigated. As a result it could be shown, that the crash density of injury motorcycle crashes is crucially dependent on the ADT of powered two wheelers. With an increasing ADT of powered two-wheelers, the density of injury motorcycle crashes also increases.

In the second part, the relationship between crashes, where the motorcyclist loses control of his bike (hereinafter referred to as "injury motorcycle driving crash"), and various infrastructure parameters was investigated. Therefore, investigation sections with approximately the same ADT of powered two-wheelers, but different crash situation (safe sections with no crashes versus unsafe sections with more than three crashes of the aforementioned type) were studied. It could be shown, that the curvature change rate is higher on unsafe road sections than on safe road sections. In this context, the alignment just before and at the crash scene of injury motorcycle driving crashes was investigated. As a result it was found that the vast majority of these crashes occurred in curves. These curves are usually characterized by very small curve radii (< 50 m). Moreover they are usually in sections with a bad radii relation.

Due to the investigation design, in contrast to the expectations it could not be shown that safe road sections have better road surface conditions then unsafe road sections. For this reason, the aim of the third part of this investigation was taking an in-depth look at the influence of the road surface condition on injury motorcycle driving crashes. For this investigation, road surface condition data and crash data from 2003 has been used. To assess the road surface conditions at the 106 crash scenes, the road surface condition from 2003 of a large part of the federal rural road network was used as a comparing size. Main results of this analysis are shown in the following key points:

- *Deficits concerning the general unevenness (longitudinal evenness including potholes) have an impact on injury motorcycle driving crashes.*
- *Deficits concerning rut depth as well as the theoretical water depth have no influence on injury motorcycle driving crashes. May possibly be due to the fact that the two parameters are in general in a very good range within the road network.*
- *In contrast to the expectations, the friction value at the crash scene is not significantly worse than in the road network. A possible reason is that friction may only have a critical influence under wet conditions. The overall motorcycle crash statistics shows that the share of motorcycle crashes under wet condition is very small. This is probably because most motorcyclists try to avoid riding under bad weather conditions.*
- *Network cracks and flick posts have no detectable influence on injury motorcycle driving crashes.*
- *The accumulation of bituminous binders on the road surface could only detected on a few sections in the road network, however, not at any crash scene. Still, accumulations of bituminous binder expose a high crash potential for motorcyclists.*

The overall value for road surface condition at the crash scene is much worse than it is the case in the road network. The overall value and hence the road surface condition has therefore an influence on injury motorcycle driving crashes.

5. Synopsis of Trends and Risk Factors

This chapter gives a short overview on the key results of the studies shown above; it is listing and describing the most critical trends and factors for PTW riders regarding the influences of road infrastructure. Results of the macroscopic analyses can mostly be interpreted as risk trends; outputs of the microscopic analyses can be seen as risk factors.

The **macroscopic analyses** have shown that a critical factor influencing PTW safety is the type of area (inside or outside urban areas). Results from Greece indicate that a significantly high percentage of both moped (88%) and motorcycle accidents (90%) occur inside urban areas. Moreover, rear end and head-on collisions are proportionately more common outside urban areas when compared to accidents inside urban areas. In Spain, PTW accidents inside urban areas account for three quarters of all accidents. UK results pointed that almost half of all incidents are reported in major travel corridors that may or may not reach motorway standards with speed limits ranging from 30 to 70 km/h.

The studies also revealed carriageway type as a determinant in PTW safety. Greece reports that, for collisions between mopeds and pedestrians, inside urban areas, almost half of crashes occur in single carriageways with at least one lane in each way (direction); for outside urban areas, this percentage rises to 88% (although the numbers are small). Inside urban areas on single carriageways with at least one lane in each way (direction), 69% of the accidents are lateral collisions, while 68% of the motorcycle accidents on one-way carriageways with one or more lanes are lateral collisions. In Spain, in half of all run-off-road accidents, carriageways are wider than 7 meters and lack hard shoulders. Spain also showed that accidents which happen in dual carriageway roads are the most severe, considering the number of fatalities with regard to the number of accidents. UK indicates that, by far, the most common combinations of infrastructure features in motorbike accidents are either A or unclassified roads, single carriageway and 30 mph speed limit. Italy reports that roads with one carriageway and two ways have the highest number of accidents.

Road Installations and stationary objects are found to be critical in PTW safety. Greece reported that 60% of moped accidents with stationary objects/vehicles occur at slopes inside urban areas. A similar percentage exists for motorcycle. The results were similar to Italian data. Moreover, most moped collisions with an vehicle in Greek road network are observed in uncontrolled junctions inside urban areas. Interestingly, in UK, only just under 6% of accidents involve a carriageway object (not including a moving vehicle) being hit. The majority of accidents involve a frontal impact, i.e. the motorcycle hitting a vehicle/object rather than being hit by another vehicle.

Pavement surface conditions have been proven to be critical in PTW safety especially when interacting with off-road accident type, riders' age and experience. Results from Greece show that, regardless from the type of area, PTW accidents are significantly increased during fine weather and dry pavement conditions. Spain reports dry road surface in more than 90% of run-off-road accidents. In UK, young riders are proportionally more likely to have an accident when the road is wet/damp than older riders. Moreover, prevailing conditions will, for the vast majority of the time, be during daylight hours with fine, dry weather and low winds. Finally, results from Italy demonstrate that the majority of accidents occur on dry roads (89%) and the largest share involves riders who received the driving license during the last decade; the number of accidents decreases with an increase in the length of time since the driving license has been made. Moreover, analysis on Italian data showed that accidents on wet and slippery roads are less severe than on dry roads (with the same pavement type) while uneven paved roads increase the accident severity.

Regarding weather conditions in the time of accident, in almost all countries, injuries and fatalities in accidents involving PTWs are mostly observed in dry weather conditions. Italy reports no correlation between weather conditions and the time of the accident, but the latter parameter is significant since the majority of accidents occur in the 15:30-21:29 range, but the most severe ones in the 23:30-6:29 range.UK reports that almost 85% of accidents occur during fine weather without high winds, and over 75% with dry road surface conditions.

Junction type was found to be critical in all countries examined. Greece reports that the percentage of motorcycle fatalities at junctions controlled by police are more than double comparing to similar moped accidents outside urban areas. In Spain, most fatal accidents occurred on Cross-roads and "T or Y" junctions and approximately 30% of rear-end accidents occur at intersections, mostly without traffic control. UK, on the relation of age with junction type, reported that up to their early to mid thirties the most likely location for riders to have an accident is at a T-junction. Moreover, older riders are also proportionally more likely to have an accident at a roundabout than younger riders. Finally, in Italy, the most relevant accident case is head-on side at cross roads, whereas, in case of no-junction the most relevant case is head-on side on straight road. Moreover, Italy reports higher accidents severity index in the case of one carriageway (two ways) and two carriageways for roads without traffic signs.

A critical risk factor was found to be the geometry specifications. In Greece, the percentage of motorcycle fatalities at straight road and slopes are low in both urban and interurban environment and lower than the moped fatalities. Moreover, narrow roads are found to be significantly more critical for motorcycles than mopeds regardless of the area type. Spain reports that, even though the number of accidents which occur in straight sections of roads is higher than the number of accidents which happen in bends, the first ones present a lower number of fatalities. Italy, combining age with geometry, suggests that 21-30 years old riders are more often involved in accidents; the most dangerous accident cases for this age group are at cross road and on a straight road.

Regarding the findings of the **microscopic analyses**, it could be shown that a radii relation bigger than 1.0 (coming form a larger radius to a smaller one) is more dangerous than a relation lower than 1.0. In general the in-depth investigation proves that most of the crashes occurring in curves happen in radii smaller than 200m. Black spots for passenger cars tend to be risky areas for PTW riders. Crossfall and curve radius are considered as relevant factors in combination with approach speed of the PTW. Run-off-road accidents involving PTW are more likely to occur in left hand bends than in right hand bends.

Risk factors for motorcyclists are road sections with a high curvature change rate. A comparison of safe sections with no crashes and unsafe sections with more than three injury motorcycle driving crashes shows, that the curvature change rate is higher on unsafe road sections than on safe road sections. This means that with an increasing curvature change rate the number of motorcycle crashes also increases. Other risk factors are an unbalanced ratio of successive radii or radii on adjacent straight (bad radii relation) as well as very small curve radii.

The results of analysis in Austria regarding to texture parameter MPD (Mean Profile Depth), show that the most accidents happen in quality class “poor”. Deficits concerning the general unevenness (longitudinal evenness and potholes) have an impact on PTW accidents (results of the survey in Germany). Examples for general unevenness are road surface waves as well as potholes (separation of parts of the road surface due to traffic, weathering, or weather influence). In contrast network cracks and flick posts are no risk factors for motorcyclists.

The friction value at the accident scene is not as expected significantly worse than in the road network. A possible reason is that the friction may have a critical influence under wet conditions only. The overall motorcycle crash statistics shows that share of motorcycle crashes under wet condition is very low. The reason for that is that most motorcyclists try to avoid riding under bad weather conditions. In terms of skid resistance values (μ) the most PTW accidents happen at quality classes “very good” ($\mu > 0.75$) and “good” ($0.75 \geq \mu > 0.59$). Slippery road marking are identified as potential hazards, because they have lower skid resistance than the road surface.

The accumulation of bituminous binders and ruts could only be detected on a few sections in the road network, however, not at any crash site. Still, accumulations of bituminous binder and ruts expose a risk factor for motorcyclists.

Not-predictable road geometry is identified as a relevant factor. Improving good forward visibility and the use of indication signs could improve the anticipation of the ongoing road geometry by the riders.

The overall value for road surface condition at the crash scene is much worse than this is the case of the general road network. The overall quality value and hence the road surface condition has therefore an influence on injury motorcycle driving crashes.

6. Conclusions

It is hoped that the results of the macro-analyses within Activity 1.2 will allow researchers to identify which combinations of infrastructure elements are most frequently involved in PTW accidents and therefore to target these in later work packages of the 2-BE-SAFE project. This should allow the study to target those accident types most frequently represented in the accident statistics, at the minimum cost.

The very often terrible consequences of accidents involving PTWs are a constant reminder that, much too often, infrastructure is not designed to ensure the maximum possible levels of safety for motorcycles and mopeds. There is hence a need to propose innovative solutions and to implement the already existing ones so that PTWs enjoy increasing levels of safety on European infrastructure. Europe is starting to take note of the problem, with European Commission Vice-President Antonio Tajani stating that “the problem of motorcycles must be tackled head on, as it represents 17% of deaths on the road” (II European Road Safety Day, Paris 13 October 2008).

The key findings of the analyses in Greece, Spain, Great Britain and Italy show that most of the basic risk factors (trends) regarding road infrastructure are in some points comparable. However lots of critical factors are specific for single countries, because of their rider’s habits and behaviour which will be studied within the 2-BE-SAFE project. Also road networks have different qualities in the participating countries. Disharmonic traces and sudden changes of the surface characteristics (road condition and/or road condition) lead to a higher risk potential for PTW safety.

Preventing loss of control of a PTW and mitigating the consequences of the possible accidents are two areas where infrastructure has a key role to play. Through better roads it is possible to avoid altogether accidents that would otherwise cause serious injuries on PTW riders. Also training and awareness of critical factors (especially situations at specific junction types or risky trace geometry of curves) for riders are useful preventative measures.

An in-depth view on the PTW accident events, a so-called microscopic analysis, is the final stage within that activity.

The Spanish database (DIANA) beside two software tools (RoadVIEW and MARVin), checking the German and Austrian PTW crash sites, have been used to investigate detailed correlation of infrastructure parameters and the crash risk. Measurement data of road surface characteristics have been used in the queries. The results show that a closer look to parameter combinations (e.g. curve radii, crossfall, texture, unevenness and skid resistance) is feasible.

The results of the microscopic analyses are better comparable than the ones of the macroscopic studies. It is the matter of facts, due to different national data bases, varying definitions of crash circumstances and especially different driver’s mentalities.

<u>Future Research:</u>

Surprising outcomes beside the core risk factors, shown in chapter 5, lead to new requests for further research which has to include exposure data. Without exposure data it is difficult to define real risks – that information should be available for all road safety researchers. The influence of skid resistance has to be discussed in future PTW safety research from another point of view, as it is expected that the macro texture of the road surface have an higher impact on PTW safety. Specifically a survey regarding risk multiplication due to the occurrence of several critical characteristics at the same area is needed.

Detailed analysis with simulation tools (vehicle-infrastructure-interaction simulation), as well as incorporation of data gathered in naturalistic driving studies, should take place in coming PTW related research projects.

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8. Annex (AIT, Microscopic Analysis)

8.1. Results of analyses based on the radii relations (See chapter 4.2.5.)

Table 141: Radii relation "good range".

Radii relation	Road number	PTW accidents	Sum of accidents	Rate [%]	Road section from	Road section to
100/100	B20	1	2	50,00	80647	81060
	B216	0	2	0,00	3454	3041
	B20	0	2	0,00	121985	122398
	B154	1	2	50,00	26864	27277
	B24	1	1	100,00	6588	6175
	B198	2	2	100,00	21277	21690
	B216	0	2	0,00	4743	4355
	B99	4	5	80,00	42443	42030
	B72	0	1	0,00	61392	60979
	B138	2	2	100,00	82119	82542
	B56	0	1	0,00	49406	49819
	sum	11	22	50,00	-	-
200/200	B50	1	3	33,33	123943	124722
	B72	1	8	12,50	43762	42984
	B37	1	9	11,11	30165	30944
	B310	2	9	22,22	20397	21176
	B171	1	27	3,70	104409	105188
	B130	0	2	0,00	11056	10273
	B119	0	0	0,00	39224	38445
	B20	1	4	25,00	32439	33215
	B126	1	2	50,00	31190	31969
	B30	0	1	0,00	58838	58054
	B130	0	1	0,00	10596	9813
	sum	8	66	12,12	-	-
300/300	B119	0	0	0,00	42595	41453
	B141	2	12	16,67	15704	16849
	B119	0	0	0,00	41710	40577
	B154	1	12	8,33	10979	12116
	B50	3	13	23,08	98819	99959
	B54	0	6	0,00	69214	68064
	B31	1	3	33,33	25558	26694
	B210	0	2	0,00	15830	14693
	B54	1	5	20,00	90164	89017
	B311	1	18	5,56	38722	39851
	B198	1	3	33,33	63137	64283
	B34	1	5	20,00	13357	14495
	B310	2	19	10,53	20139	21271
	sum	13	98	13,27	-	-

Table 142: Radii relation "moderate range".

Radii relation	Road number	PTW accidents	Sum of accidents	Rate [%]	Road section from	Road section to
100/150	B193	3	4	75,00	27819	28333
	B198	2	2	100,00	21251	21765
	B20	1	4	25,00	121894	122405
	B181	1	7	14,29	3047	3561
	B138	1	4	25,00	49299	49813
	B21	1	2	50,00	82795	83302
	B158	0	5	0,00	9683	10197
	B162	0	4	0,00	13637	14150
	B56	1	1	100,00	40875	41408
	B78	1	2	50,00	38147	38661
	B145	0	3	0,00	85821	85307
	B156	0	5	0,00	45619	46133
	B95	1	3	33,33	90257	89748
	B154	1	2	50,00	26739	27245
	B24	1	1	100,00	6638	6124
	B56	0	0	0,00	28679	29193
	B38	1	3	33,33	140382	140896
	B158	1	5	20,00	10073	10587
	Sum	16	57	28,07	-	-
160/250	B50	0	0	0,00	123193	124002
	B126	0	7	0,00	16757	17578
	B50	1	2	50,00	123953	124764
	B170	0	13	0,00	6557	7372
	B130	0	1	0,00	10479	9664
	B20	1	2	50,00	32505	33313
	B1	0	6	0,00	2059	2870
	B31	1	2	50,00	38581	39392
	B30	0	0	0,00	58798	57982
	B158	4	13	30,77	9903	10705
	B37	1	10	10,00	30122	30933
	B310	2	10	20,00	20243	21054
	B119	1	2	50,00	47297	46492
	B72	1	8	12,50	43802	42992
	B38	0	0	0,00	84303	85114
	B70	3	7	42,86	114656	113845
	B20	1	4	25,00	98140	98955
	B119	0	0	0,00	39224	38413
	B61	0	1	0,00	8235	9048
	Sum	16	88	18,18	-	-
200/300	B130	0	0	0,00	10549	9571
	B310	2	17	11,76	20132	21104
	B50	0	0	0,00	123140	124112
	B54	0	6	0,00	69046	68059
	B154	1	12	8,33	11119	12093
	B70	0	12	0,00	33944	32969
	B119	0	0	0,00	42654	41666
	B115	1	4	25,00	145257	144285

	B37	1	10	10,00	29991	30973
	B119	0	0	0,00	39294	38320
	B82	1	6	16,67	29266	30239
	B31	1	2	50,00	38508	39482
	B141	2	10	20,00	15767	16749
	B41	0	1	0,00	32790	31765
	B80	0	5	0,00	11637	12610
	B119	0	0	0,00	41790	40820
	B6	0	14	0,00	19908	20877
	B50	1	3	33,33	123833	124807
	B143	1	3	33,33	27476	28455
	Sum	11	105	10,48	-	-

Table 143: Radii relation "inappropriate range".

Radii relation	Road number	PTW accidents	Sum of accidents	Rate [%]	Road section from	to
50/150	B20	4	5	80,00	63609	64028
	B70	0	0	0,00	64839	64415
	B152	1	2	50,00	24999	24575
	B64	3	6	50,00	35994	36418
	B36	0	8	0,00	62815	63239
	B72	1	1	100,00	49524	49100
	B45	0	1	0,00	35836	36249
	B72	1	5	20,00	48589	48163
	B193	0	1	0,00	36501	36925
	B86	0	0	0,00	2777	2353
	B200	0	8	0,00	13429	13853
	B20	1	1	100,00	53557	53982
	B99	0	0	0,00	78847	78423
	B69	0	1	0,00	3463	3039
	B20	0	0	0,00	63747	64166
	B56	0	0	0,00	3492	3916
	B27	1	2	50,00	22988	22564
	B171	1	4	25,00	157160	157588
	B70	0	0	0,00	60265	59841
	B182	1	6	16,67	28142	28566
	Sum	14	51	27,45	-	-
100/200	B21	1	2	50,00	82707	83312
	B200	0	3	0,00	23740	24353
	B158	2	10	20,00	10053	10656
	B56	0	0	0,00	28649	29261
	B20	0	4	0,00	121506	122118
	B69	1	1	100,00	17111	16504
	B70	1	1	100,00	111748	111136
	B38	2	4	50,00	24822	25438
	B145	0	3	0,00	85841	85229
	B1	0	5	0,00	2139	2751
	B78	2	3	66,67	38089	38701
	B40	0	5	0,00	30231	29615

	B119	0	1	0,00	60071	59459
	B193	8	9	88,89	27739	28351
	B69	3	5	60,00	14151	13537
	B30	1	2	50,00	74745	74133
	B166	0	3	0,00	32946	33558
	B20	0	0	0,00	32655	33264
	B30	0	0	0,00	58758	58141
	B188	0	3	0,00	2079	2691
	Sum	21	64	32,81	-	-
100/300	B40	0	5	0,00	30435	29625
	B215	1	1	100,00	11041	10232
	B40	0	5	0,00	30906	30100
	B200	0	7	0,00	28517	29323
	B21	1	2	50,00	82543	83342
	B122	0	29	0,00	29016	28201
	B215	0	2	0,00	9164	8357
	B38	3	5	60,00	24668	25478
	B126	0	7	0,00	16767	17583
	B1	0	6	0,00	2089	2895
	B200	2	7	28,57	23646	24453
	B11	0	23	0,00	12121	12924
	B188	0	6	0,00	1405	2211
	B50	1	6	16,67	125799	126610
	B36	0	2	0,00	42704	43512
	B136	0	1	0,00	22099	22905
	B132	0	0	0,00	4520	5330
	B197	2	11	18,18	2566	3393
	B30	1	5	20,00	75373	74569
	B120	0	12	0,00	17316	16505
	Sum	11	142	7,75	-	-

8.2. Radii tulips of all road sections (PTW accidents) in both driving directions (See chapter 4.2.6.)

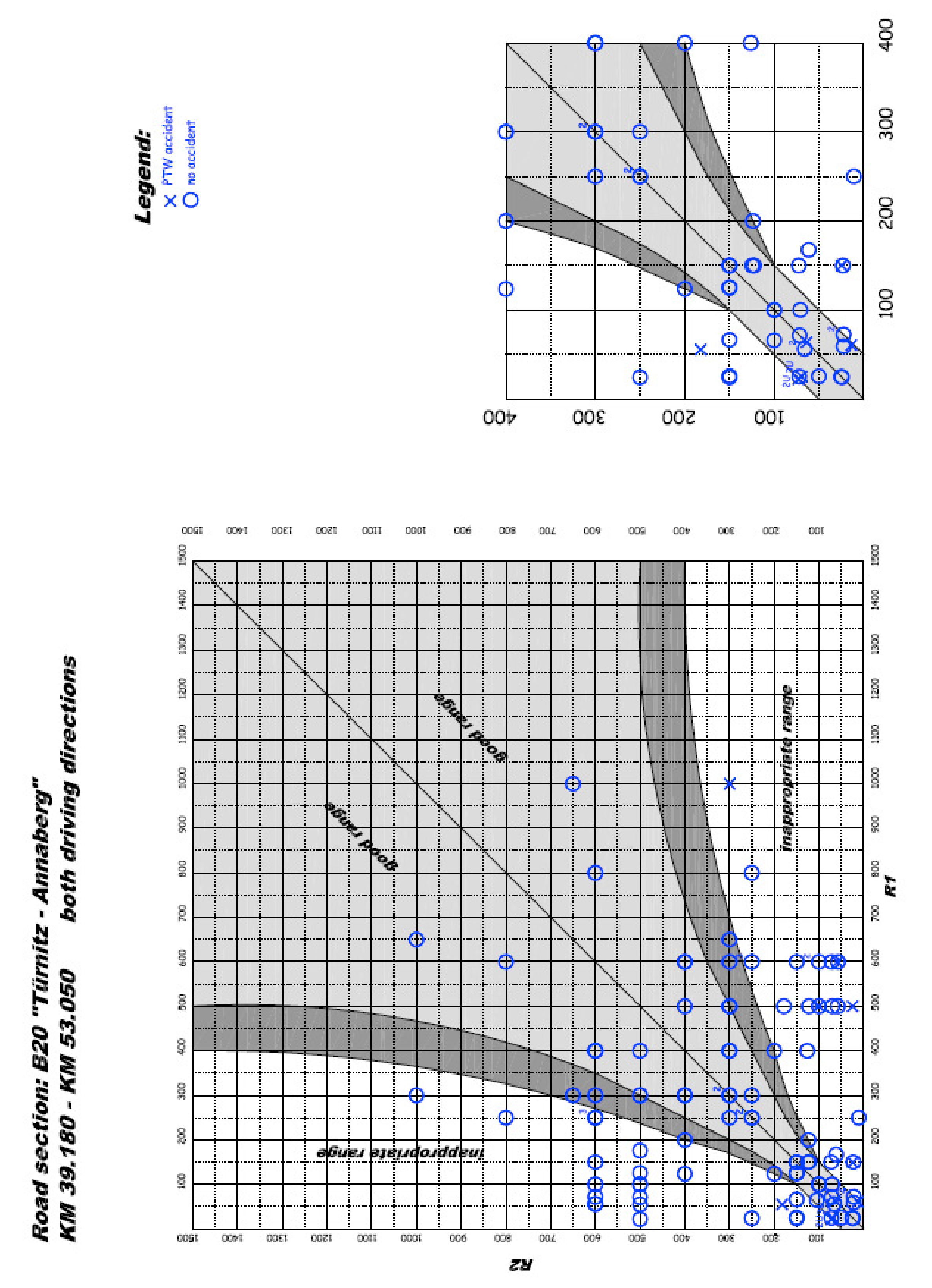

Figure 93: Radii tulip of road section B20 "Türnitz – Annaberg" – PTW accidents.

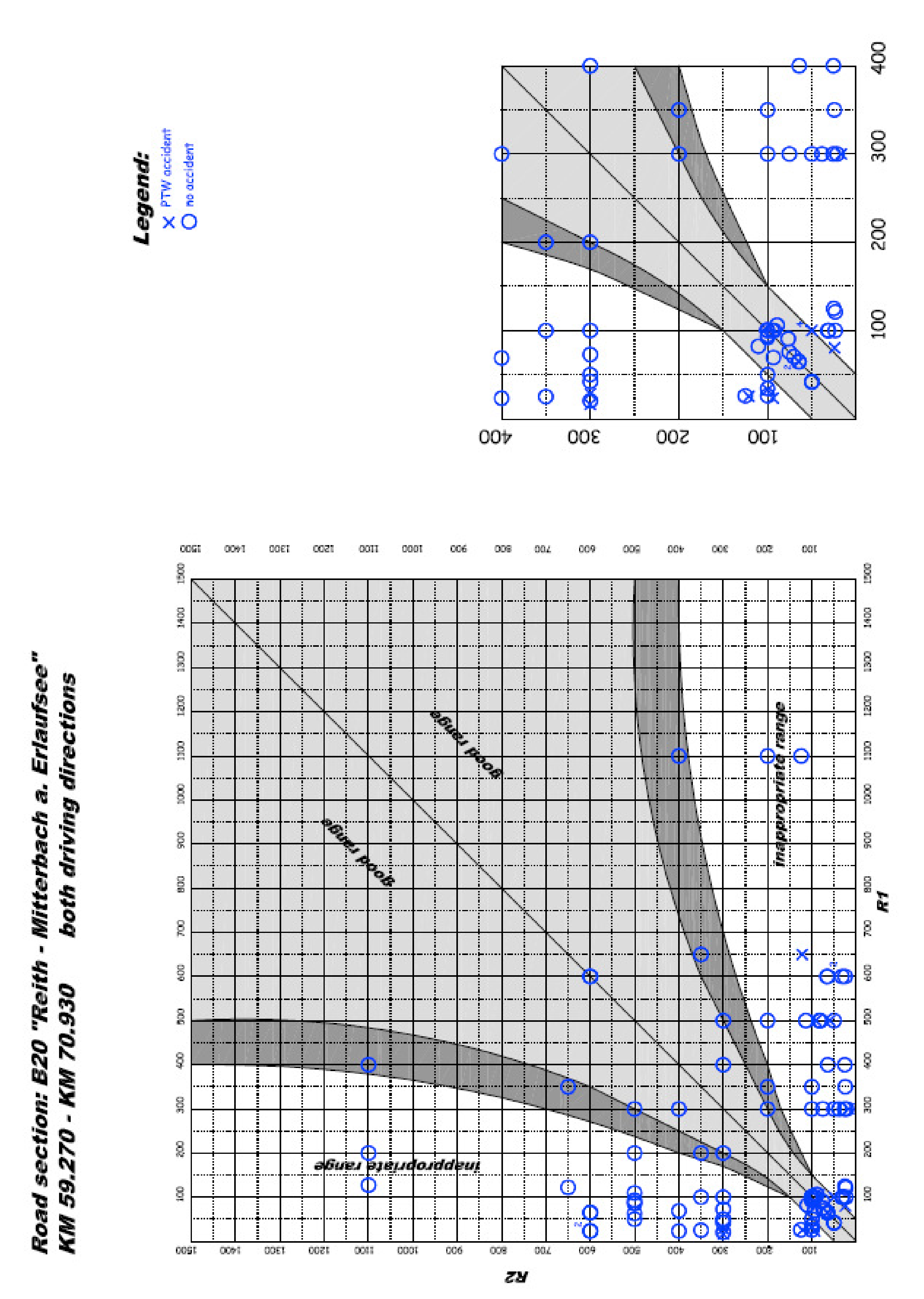

Figure 94: Radii tulip of road section B20 "Reith – Mitterbach a. Erlaufsee" – PTW accidents.

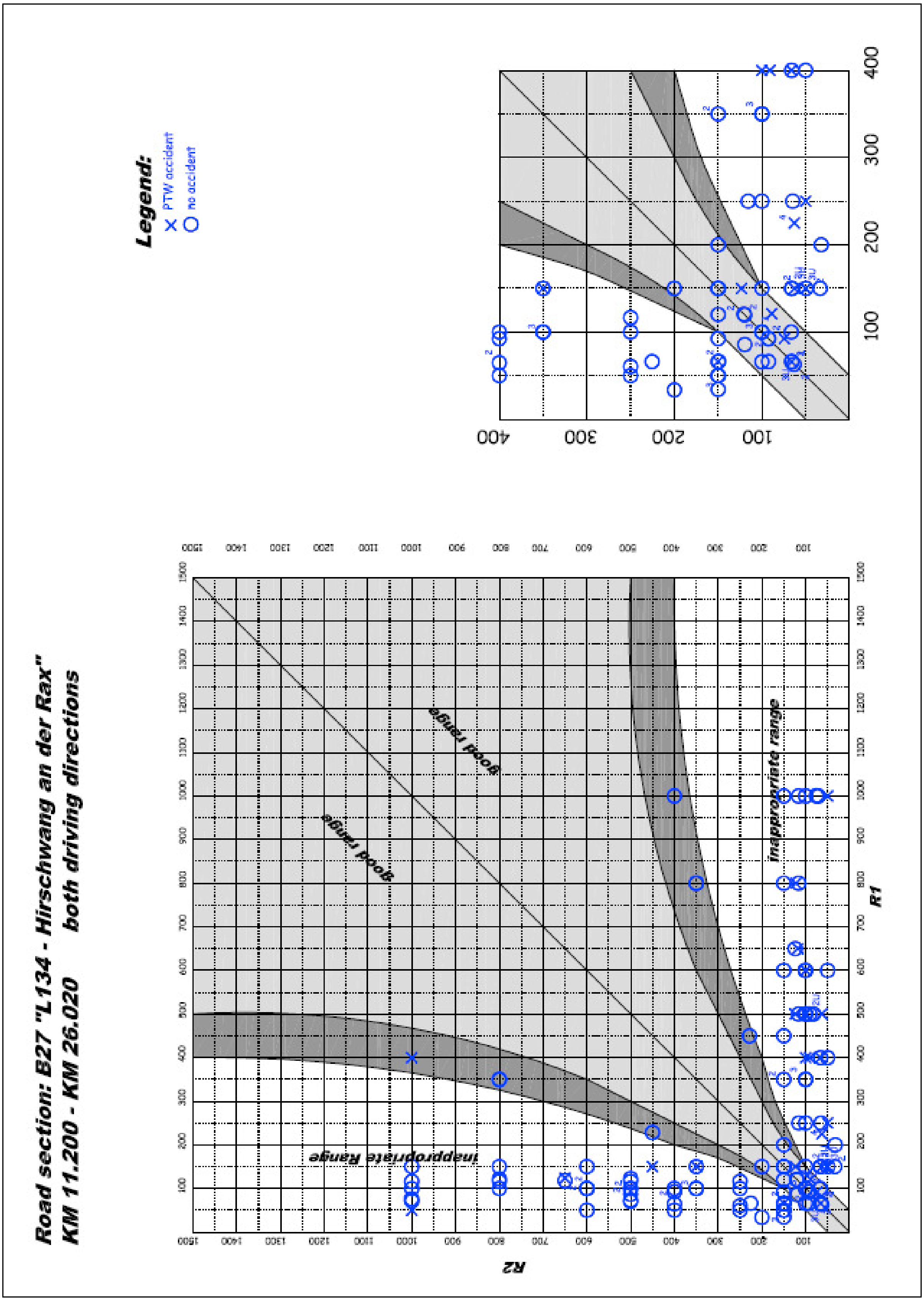

Figure 95: Radii tulip of road section B27 – PTW accidents.

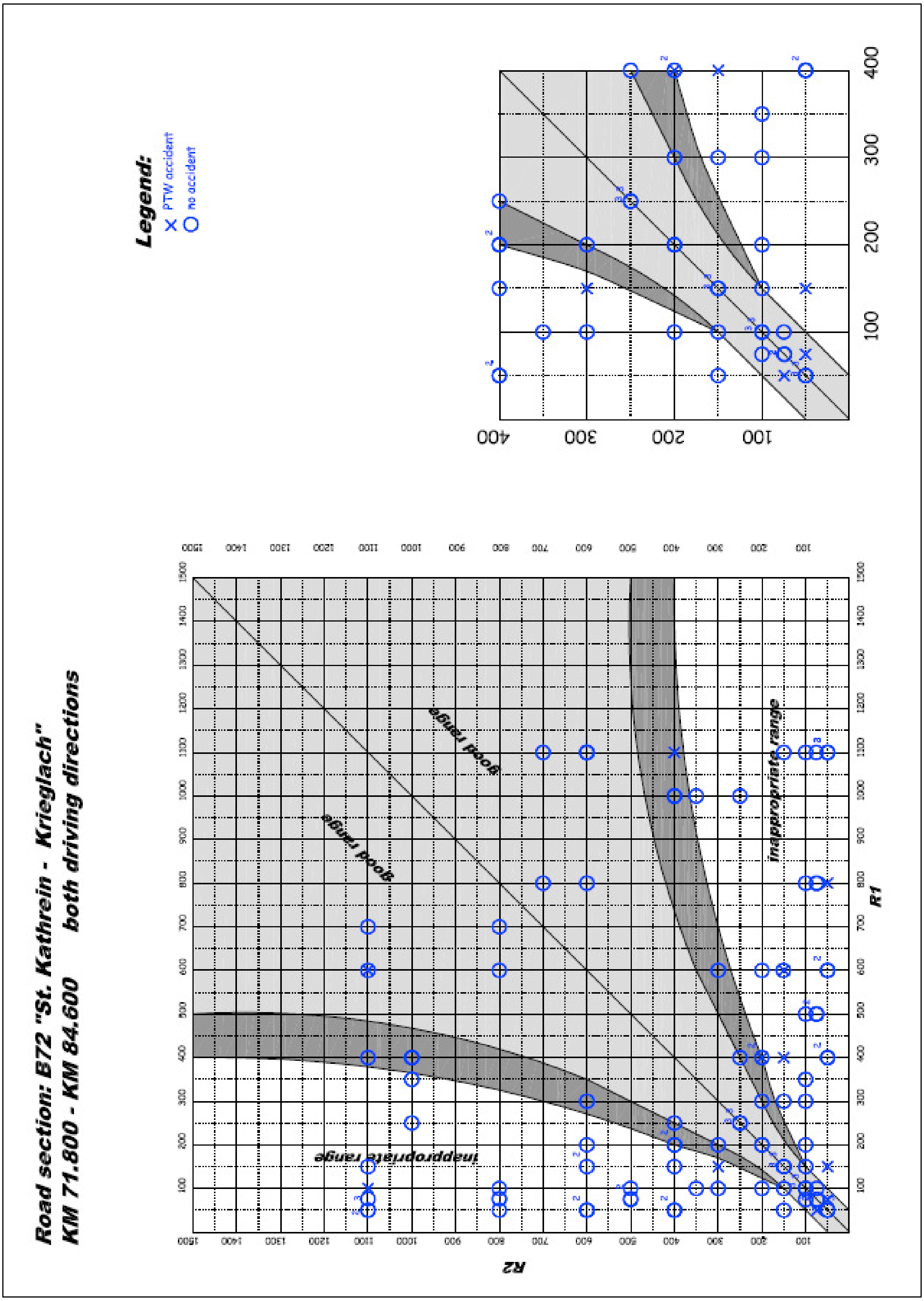

Figure 96: Radii tulip of road section B72 – PTW accidents.

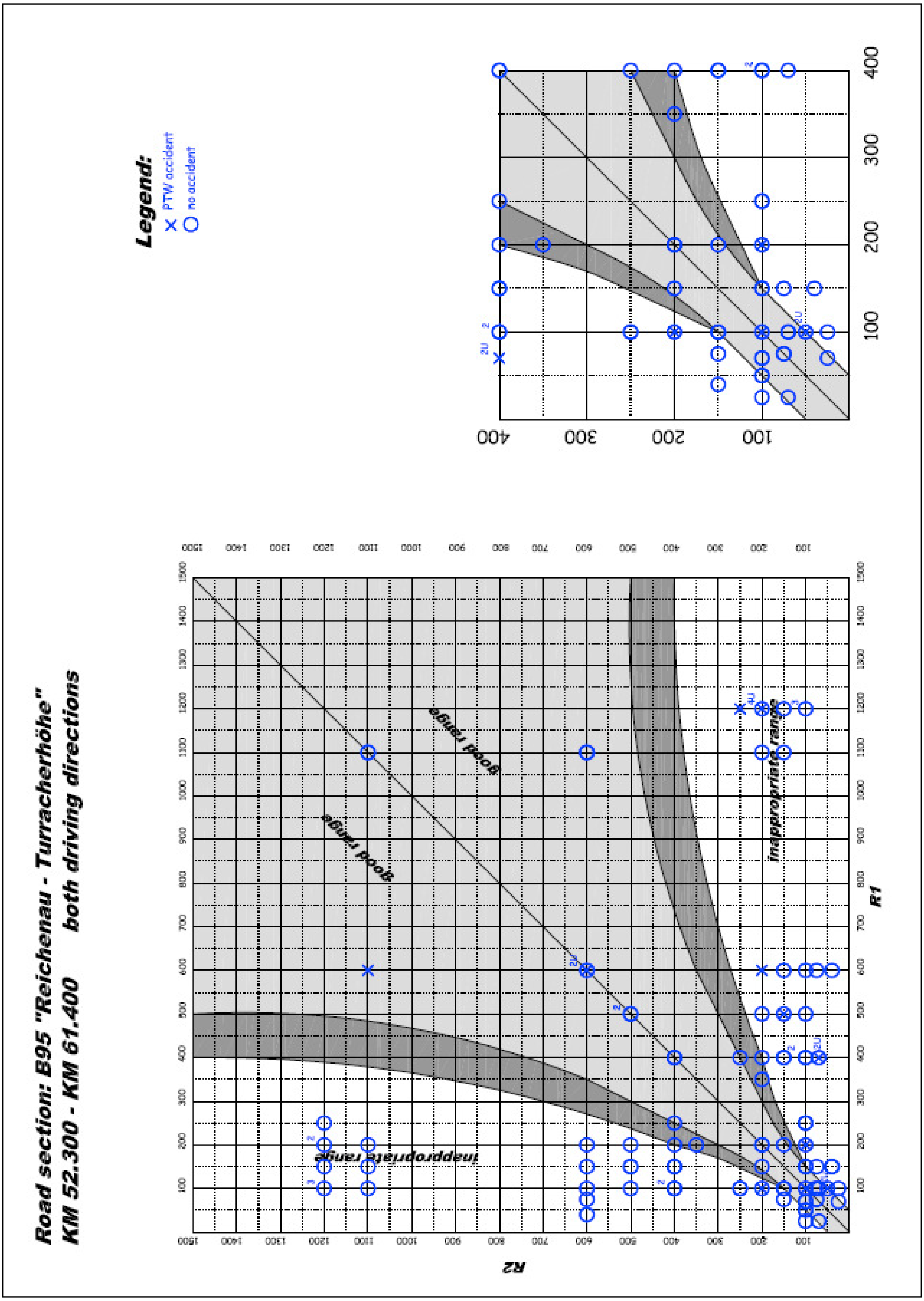

Figure 97: Radii tulip of road section B95 – PTW accidents.

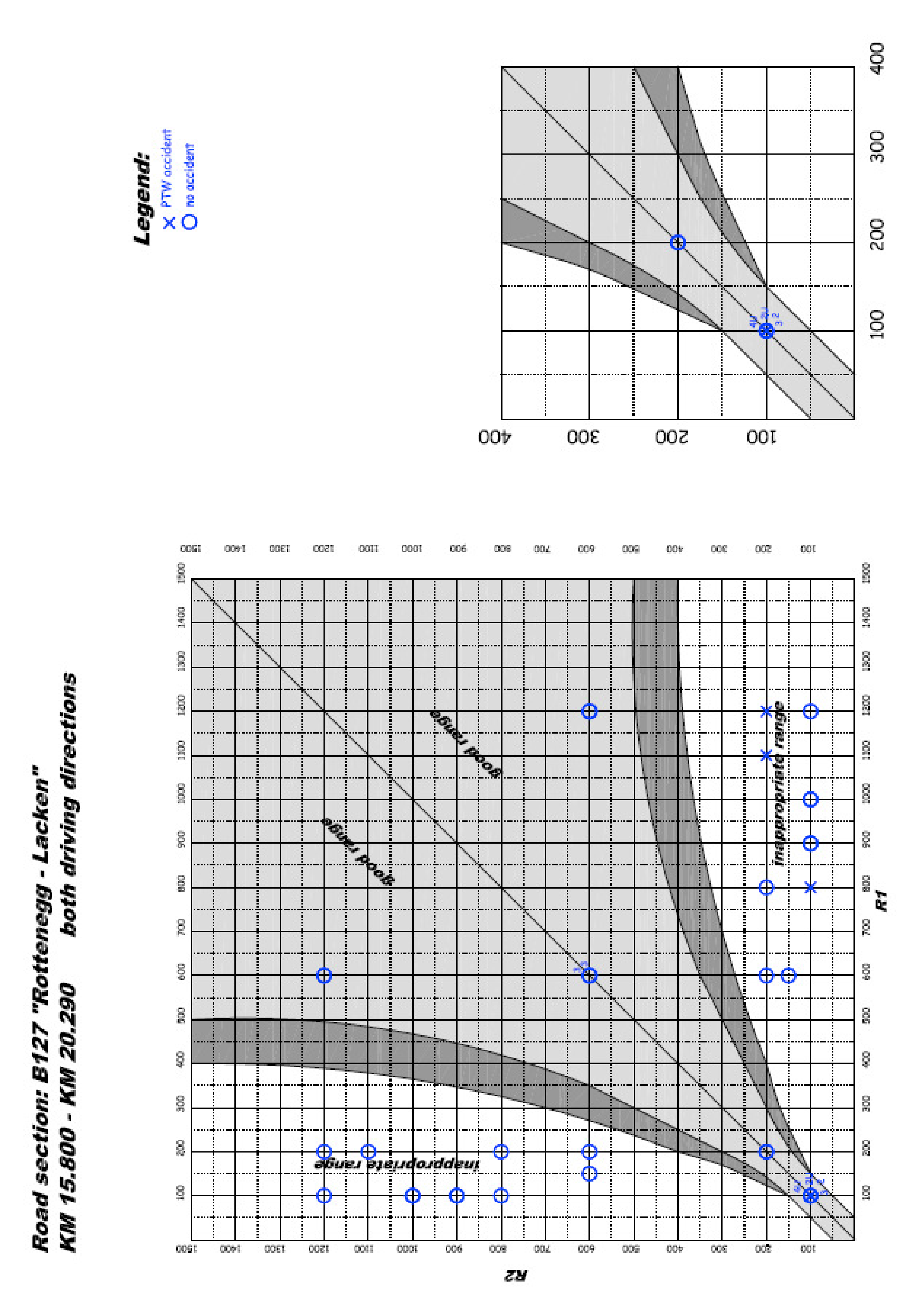

Figure 98: Radii tulip of road section B127 – PTW accidents.

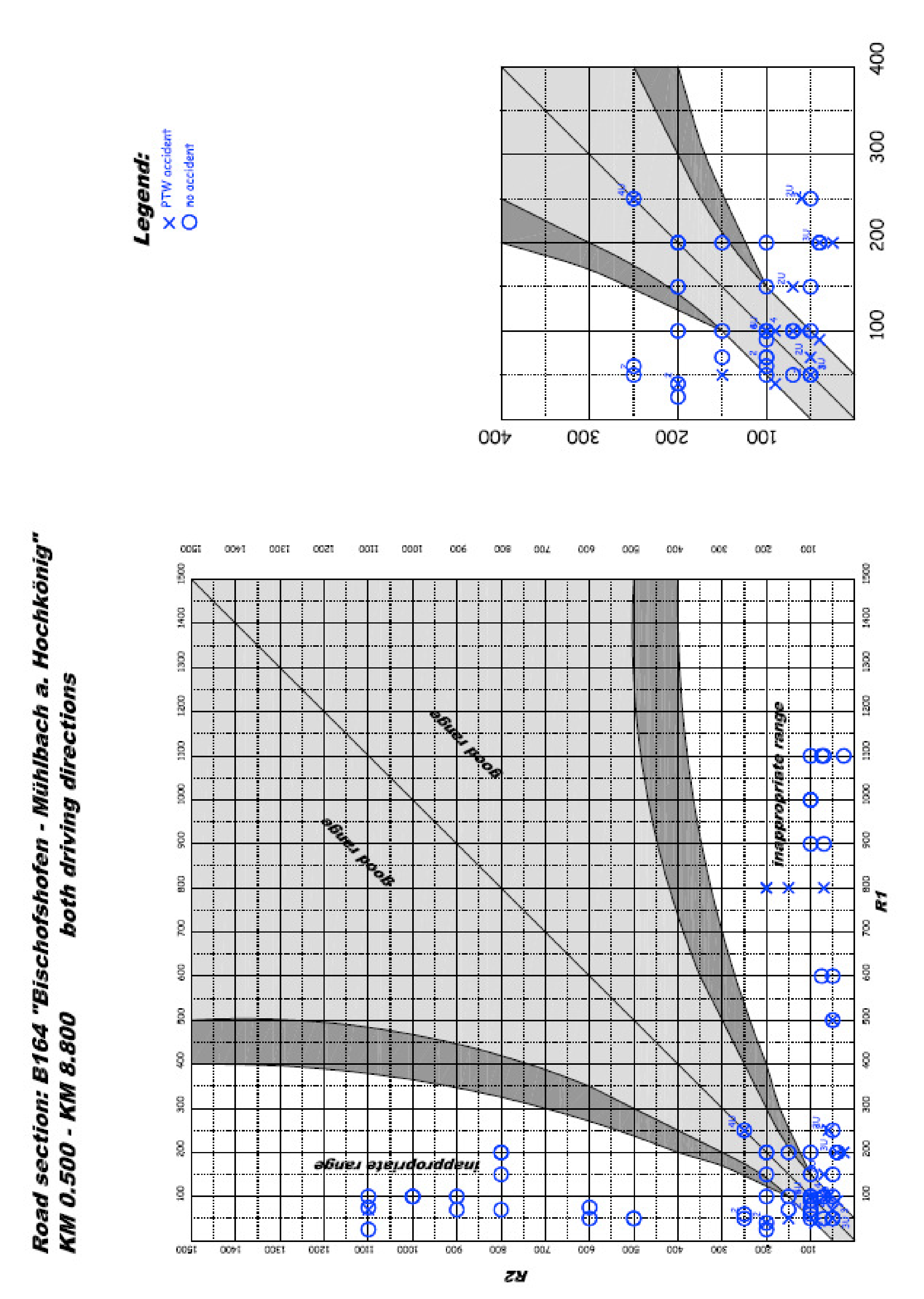

Figure 99: Radii tulip of road section B164 – PTW accidents.

8.3. Radii tulips of all road sections (all other accidents) in both directions (See chapter 4.2.6.)

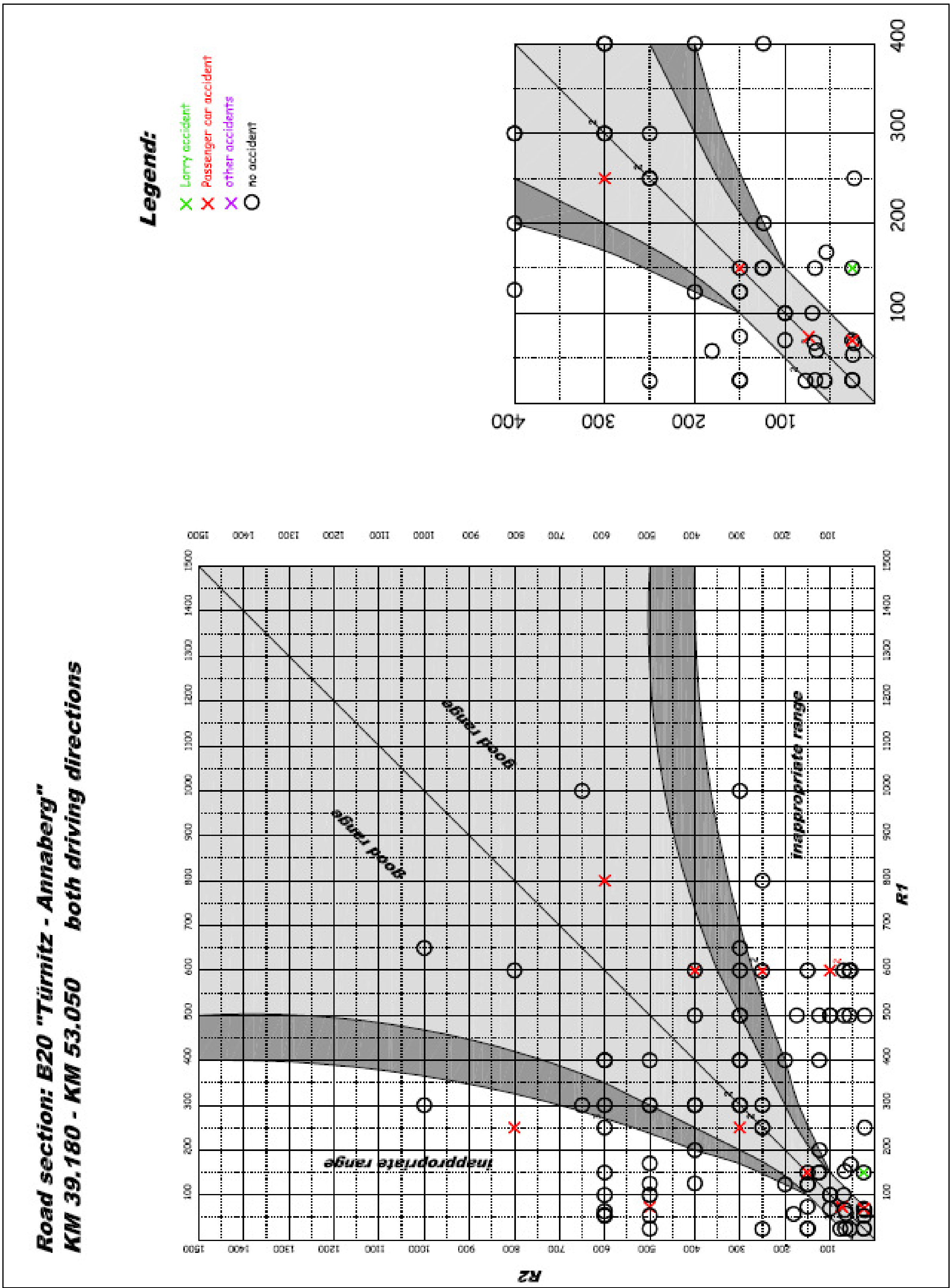

Figure 100: Radii tulip of road section B20 “Türnitz – Annaberg” – all other accidents.

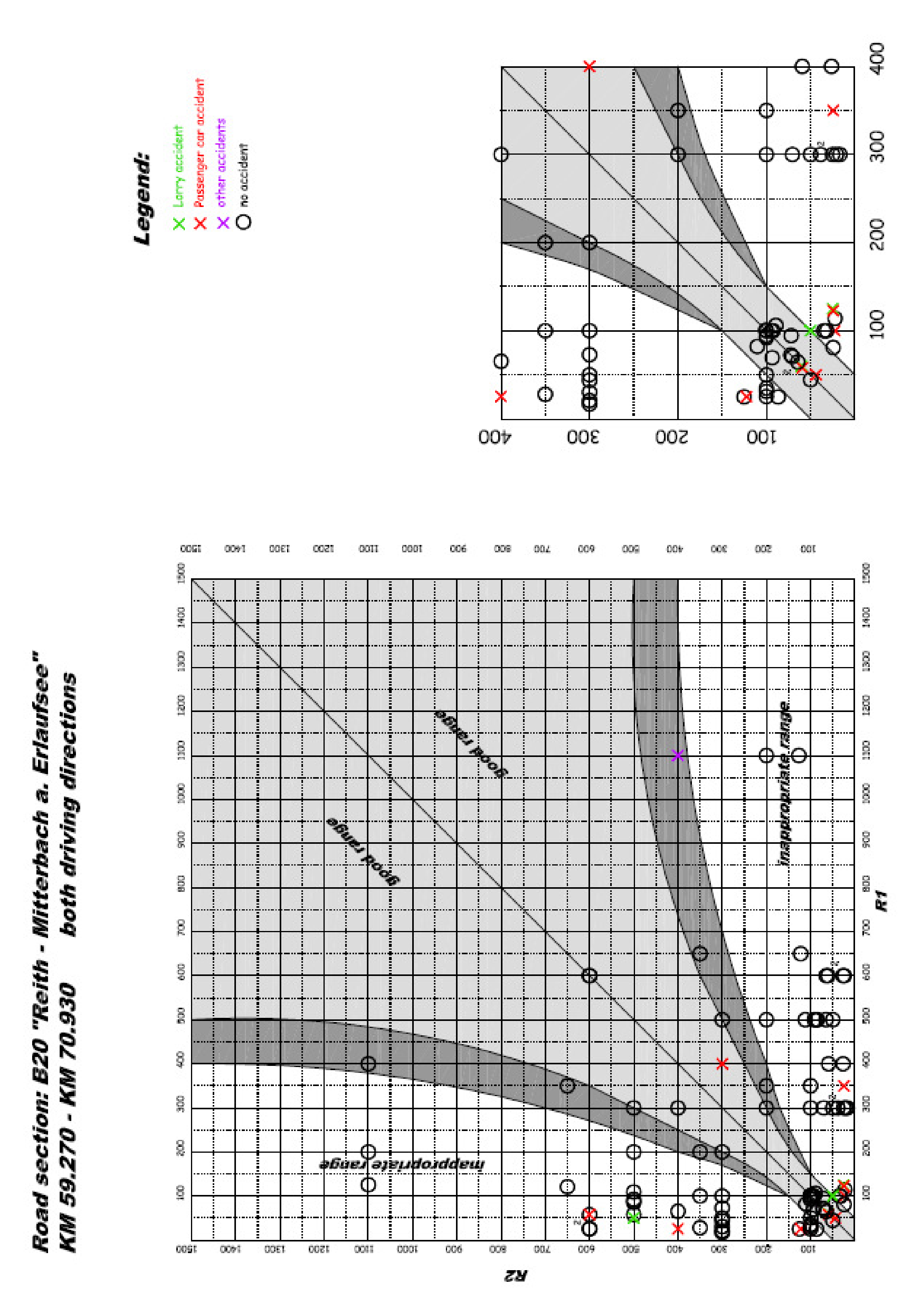

Figure 101: Radii tulip of road section B20 "Reith – Mitterbach a. Erlaufsee" – all other accidents.

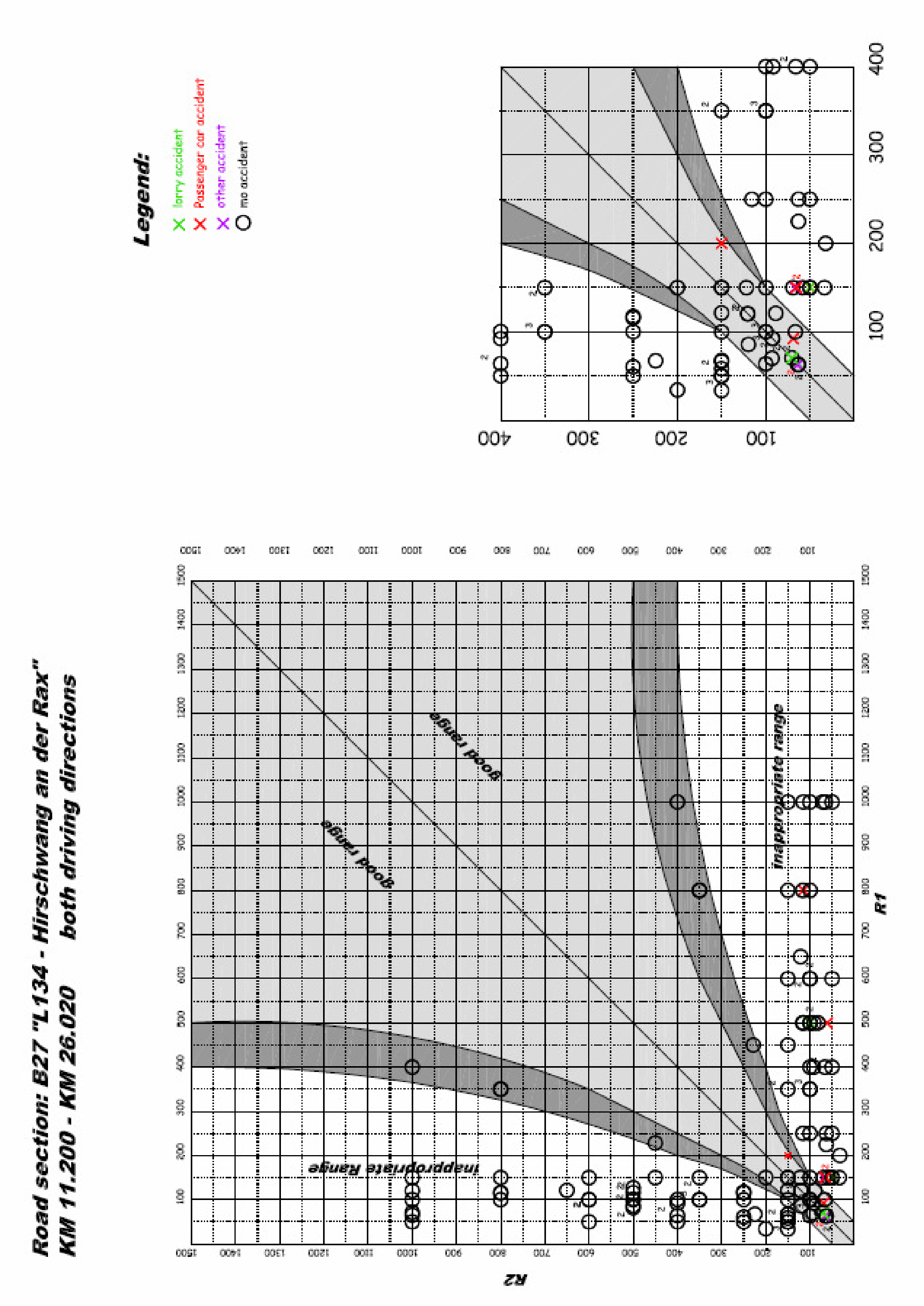

Figure 102: Radii tulip of road section B27 – all other accidents.

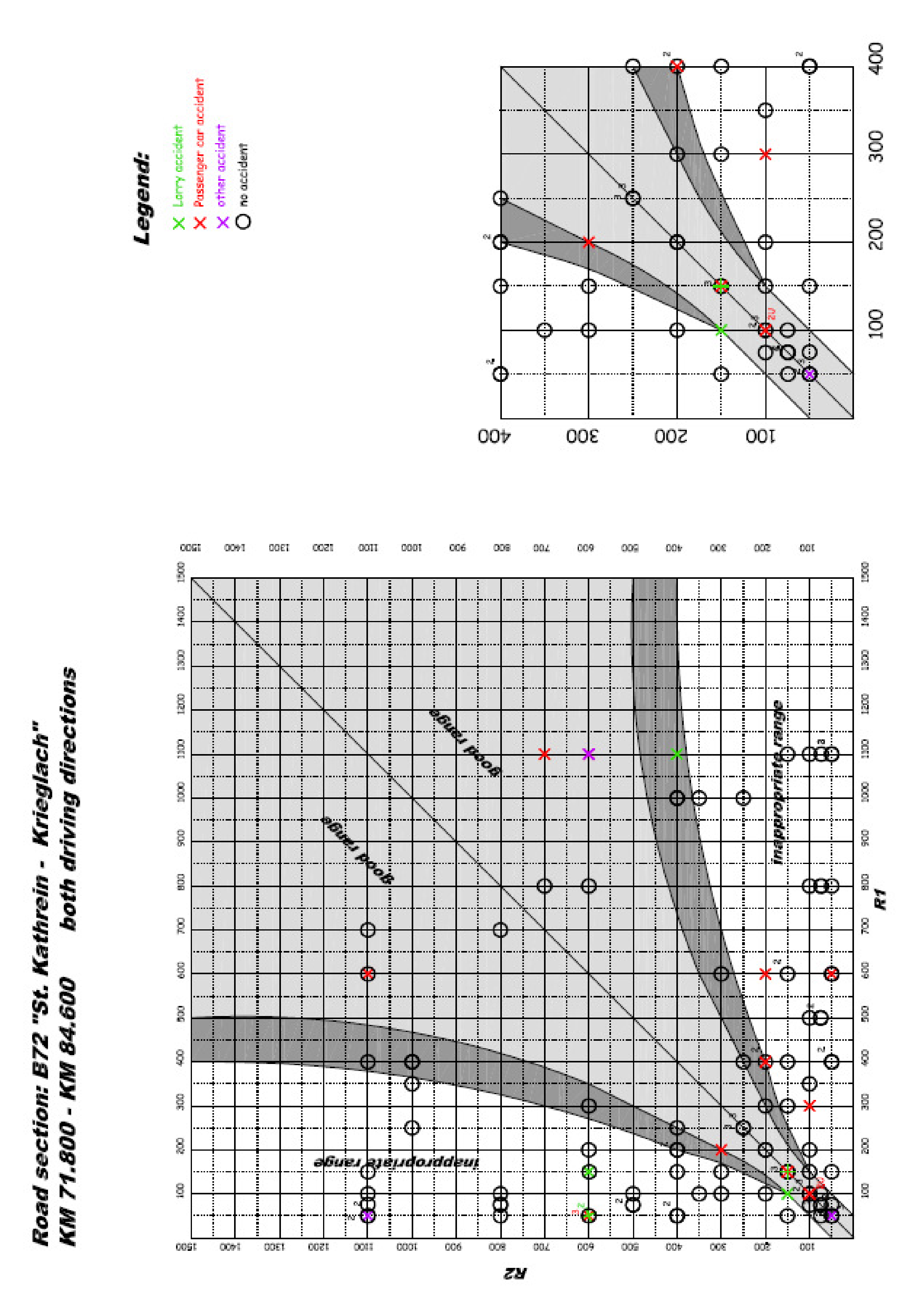

Figure 103: Radii tulip of road section B72 – all other accidents.

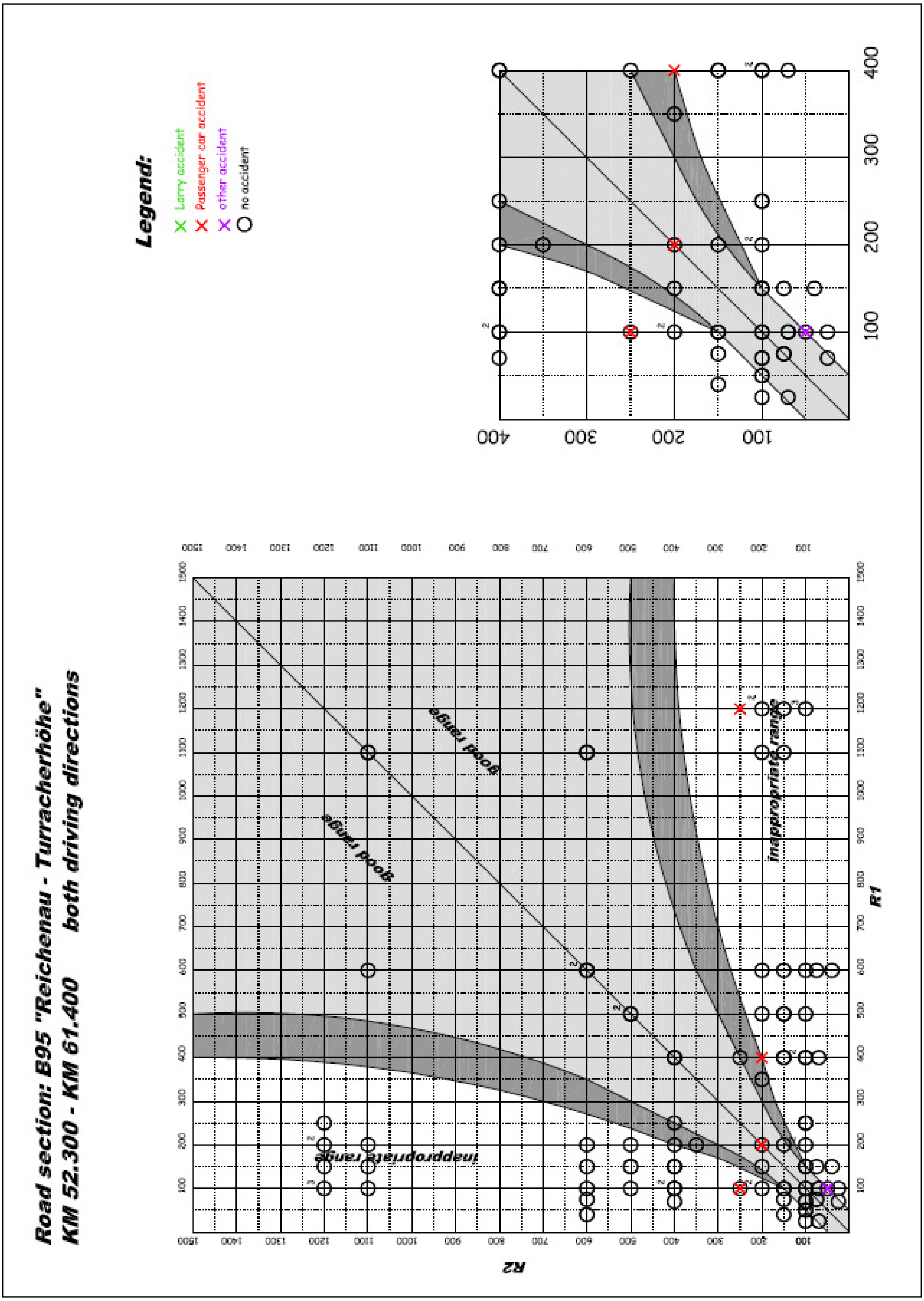

Figure 104: Radii tulip of road section B95 – all other accidents.

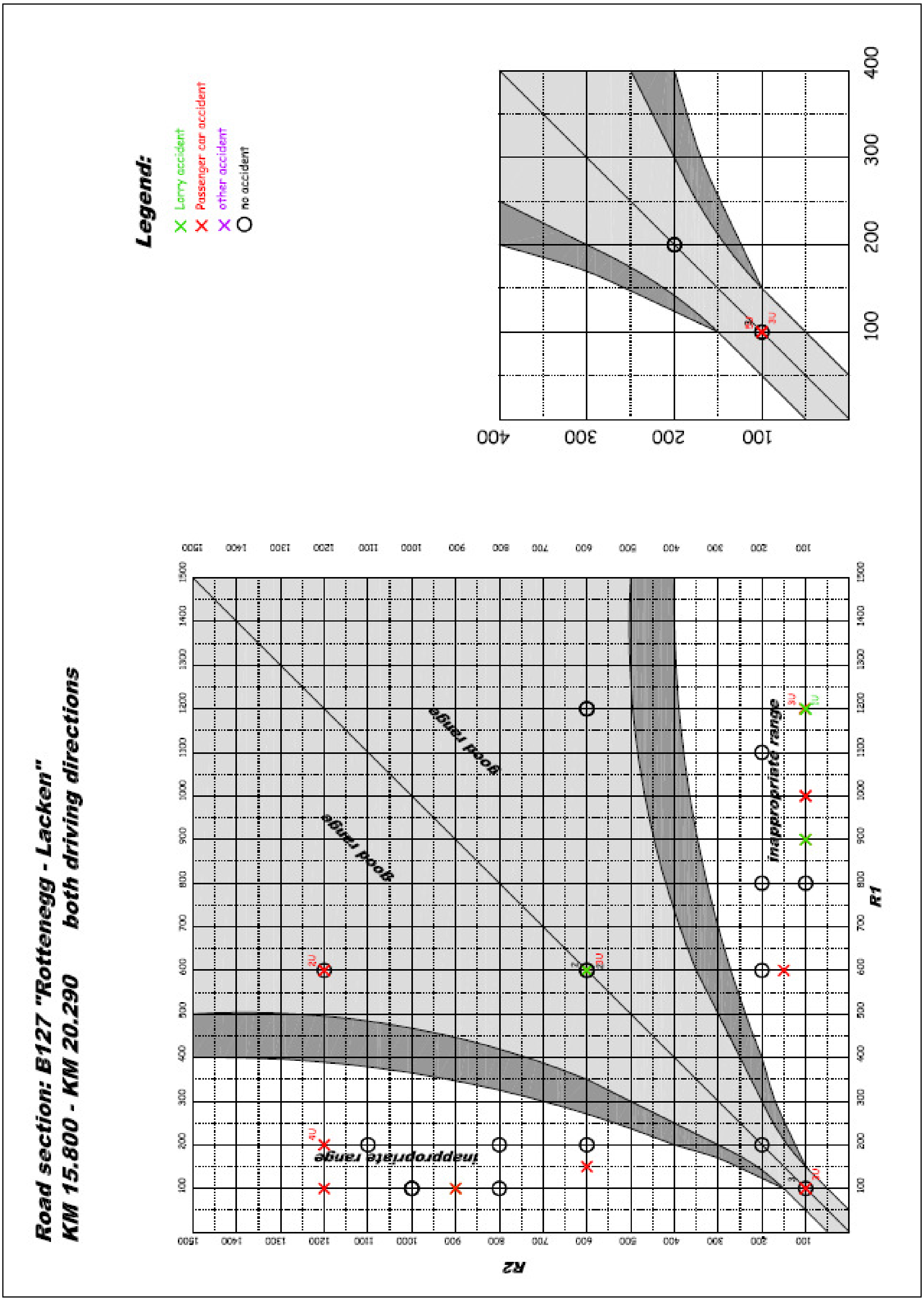

Figure 105: Radii tulip of road section B127 – all other accidents.

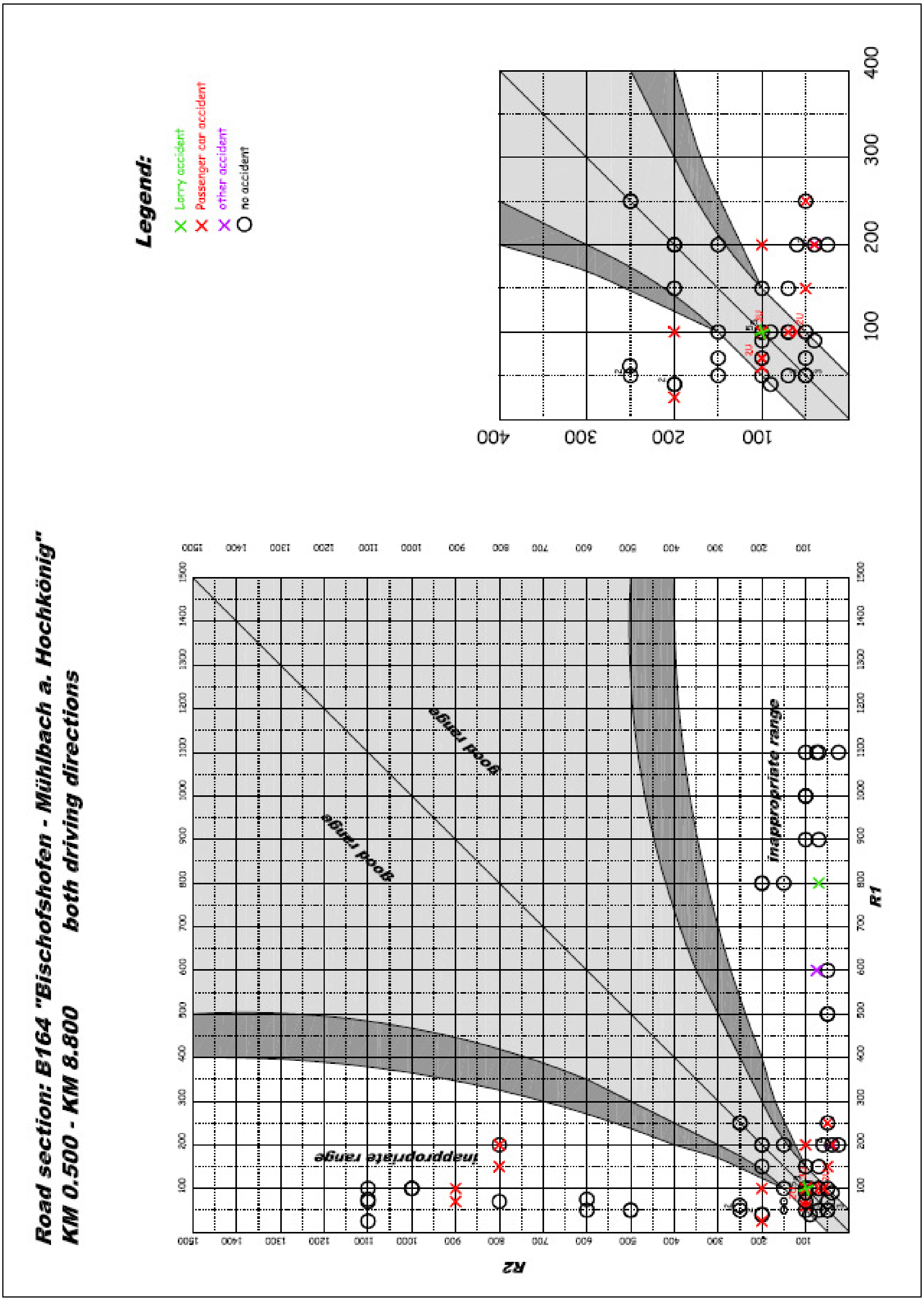

Figure 106: Radii tulip of road section B164 – all other accidents.