Project Nr.: 823129

Co-operation level: Common Obligation

European Road Safety Inspection (EuRSI)

Start date of project: 01.10.2009
End date of project: 31.08.2011
Duration: 23 Months

Final Report

This report is prepared by the Contractor of the research project and presented to the Programme Executive Board.

ENR SRO1 Programme Executive Board:

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Date January 2012

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1 Introduction

The motivation for this project lies in the desire for Europe to reduce the number of fatalities & casualties arising from vehicle collisions across all States. Part of this initiative is the European Directive 2008/96/EC dealing with road infrastructure safety management which was issued on 19th November 2008. This EU Directive is compulsory for roads which are part of the trans-European road network (TEN). One of the reasons for issuing this Directive was to ensure a high level of safety on the TEN-Network, which is of fundamental importance for the integration and cohesion of the European Union. Road infrastructure is one of the policy areas for improving road safety and should contribute to the reduction of the number of collisions. At the heart of improving the safety of road infrastructure is the establishing of appropriate procedures. The EU Directive also states that the safety level of existing roads should be increased by investing financial resources in the road sections with the highest number of collisions and/or the highest collision reduction potential. Regular periodic road safety inspections (RSI) are an appropriate instrument for preventing possible dangers for all road users.

The EU Directive defines four types of instruments which should help to improve road safety including RSI. Within the Article “Safety Inspections” it is stated that the member states shall carry out safety inspections on existing roads in order to identify the road safety related features and to prevent collisions. These inspections should be performed periodically and by a competent entity. In the EU Directive safety inspection is defined as an “ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety.” EU member states are encouraged to draw up their own procedures which should demonstrate compliance with the Directive, and to make them public. The member states are also encouraged to apply this directive on other national roads, which are not part of the Trans-European Road Network.

The main aim of this project was to explore new approaches to collecting and processing road environment data in order to help identify and understand risk within the context of an RSI. Chief outputs from this project include a new approach to assessing risk using various static road factors, and the concept of a safe profile velocity, V_{SP}, (average safe driving profile under ideal, traffic-free conditions). Three software applications were developed and data from three separate road surveys were tested in this project. Initial results are promising and indicate a potential new approach to timely risk assessment in conjunction with RSIs. This final report details the work carried out by the EuRSI research team and is divided into six sections;

- Objectives
- Milestones & Deliverables
- Methodology
- Risk Analysis Results
- Project Outputs
- Future Research

2 Objectives

EuRSI initial objectives were set-out in the original proposal (also listed in 823129_DoW_EuRSI) and sought to address some of rural road related safety issues raised under Objective A and B of the *Safety at the heart of road design* call. The subsequent work-plan dealt with the Mobile Mapping System (MMS) technology for road network mapping and assessment of safety risk following an RSI. EuRSI proposed to address these short-comings through two main objectives;

Objectives
EuRSI sought to address some of the rural road related safety issues raised under Objective A and B of this call.

- Introduce latest mobile mapping based approaches to help automate route corridor data acquisition and processing. This included capturing intrinsic route corridor information including; road geometry, road-side features, hazard identification, existing safety intervention and pavement condition. Assessment of MMS technology for measuring and mapping road features.

- Investigate the role of both intrinsic and transient factors together with latest machine-learning techniques for assessing risk arising from road survey inspection. These included intrinsic route elements produced by the RSI as well as additional information including: vehicle collisions database. The aim was to investigate suitable safety risk assessment methodologies that could highlight rural road sections where immediate safety interventions might be required following an RSI.

The results of the project are presented in following sections and we emphasise the experimental nature of various aspects of this work. The project work-plan dealt with a lot of issues in relation to collecting, processing and modelling various road geometry & road side features in order to explore risk-assessment approaches. The main contributions of this project therefore dealt with a review of current MMS technology for route corrdior mapping as well as exploration of potential new approaches to assessment of risk along Eu road networks following an RSI.

3 Milestones & Deliverables

The milestones and deliverables are set-out in Tables 1 & 2 below. The original date together with actual date of delivery for each milestone and deliverable is listed below.

Nr.	Milestones	Due date	Actual Date
M1.1	Kick-off meeting – Review project scope & objectives	1st Oct 2009	1st Oct 2009
M2.2	Initial Feature Extraction	31st Nov 2009	31st Mar 2010
M3.1	Road Safety Inspection Schemes Review	31st Dec 2009	18th Mar 2011
M2.3a	Initial 3D Route Reconstruction	31st Dec 2009	16th Mar 2010
M3.2	Risk Assessment Review	31st Jan 2010	31st Aug 2011
M3.3	Rule based risk assessment module	30th Apr 2010	31st Aug 2011
M2.2	Refined Feature Extraction	31st May 2010	31st Aug 2011
M3.5	Road Safety Inspection Validation	31st May 2010	30th Nov 2011
M2.3b	Refined 3D Route Reconstruction	31st May 2010	31st Aug 2011
M4.2	4 X Country Route Test & Evaluation	31st Oct 2010	30th Nov 2010
M4.3	Evaluation Report	30th Nov 2010	30th Nov 2012
M5.3	Workshop	31st Jan 2011	13th Jan 2012

Table 1. Milestones of EuRSI project detailing ID, milestone, original date and actual date of accomplishment

Nr.	Deliverables	Due date	Actual Date
D3.1	Road Safety Inspection Schemes Review	31st Dec 2009	18th Mar 2011
D3.2	Risk Assessment Review	31st Jan 2010	31st Aug 2011
D3.3	Rule based risk assessment module	30th Apr 2010	30th Nov 2011
D2.2	Feature Extraction Toolkit	31st May 2010	31st Aug 2011
D3.5	Road Safety Inspection Validation	31st May 2010	30th Nov 2011
D2.3	3D Route Reconstruction Toolkit	30th Jun 2010	31st Aug 2011
D4.2	4 X Country Route Evaluation	31st Oct 2010	30th Nov 2010
D5.2	5 X Publications (Journal/Conferences)	31st Mar 2011	31st Aug 2011
D1.1	Final Report detailing Technology, Methodology, Evaluation, Workshop & Recommendations	31st Mar 2011	13th Jan 2012

Table 2. Deliverables of EuRSI project detailing ID, deliverable, original date and actual date of delivery

4 Methodology

The methodology was based around the original set of objectives of the EuRSI project and can be described under four main research tasks

- To collate information on contemporary approaches to RSI in Europe and further afield
- Explore new road mapping methodologies using mobile mapping technology
- Review various risk assessment methodologies and develop a novel approach to risk assessment within the context of RSI
- Produce software toolkit that would enable end-users carry out risk analysis

4.1 Contemporary approaches to RSI in Europe and further abroad

A report *Road Safety Inspection Review* (Deliverable 3.1) was carried out at the early stages of the project. The objective of this report was to give an overview of the different approaches and methodologies of Road Safety Inspection (RSI) in European countries. The research team carried out a review of existing approaches to RSI using information from reports, published online and through direct contact with road authorities and relevant organisations. Road safety inspection procedures were described with an emphasis on the steps for conducting RSI including the composition of checklists and the inspection report, the qualification of inspectors and the safety issues which have to be identified during the inspection. The eleven main recommendations are listed below in Table 3.

Recommendation	Detail
1	PIARC RSI guidelines definition be used
2	RSA standards could be used as a starting point
3	Two types of RSI (Periodic & Dedicated)
4	Collision data should be used in advance of dedicated RSI
5	Two person RSI teams
6	Four steps to RSI (Preparation, on-site inspection, report & remedial

	measures)
7	Ensure rota of teams & survey route are interchanged
8	Training for RSI Inspectors
9	Checklists are recommended
10	Road operators should determine the inspection schedule, implement the measures and monitor the results
11	5 year periodic review of Trans-European Road Network

Table 3. Key recommendations from Report *Road Safety Inspection Review* (Deliverable 3.1)

4.2 Explore new road mapping methodologies using mobile mapping technology

The mobile mapping system (MMS) used in this project was developed by NUIM and comprises an IXSEA LandINS GPS/INS, a 3D LiDAR sensor, and an imaging system and is shown in Figure 1.

Figure 1. Mobile mapping System developed by NUIM

At the heart of the system is the LandINS INS which is a high-grade, solid-state fibre optic gyroscope (FOG) technology with a drift rate of better than 0.05/hr, a more detailed description of its performance is detailed in Table 4.

True heading [deg]	0.01
Roll/Pitch [deg]	0.005
Position X and Y [m]	0.02
Position Z [m]	0.05
Measurement Rate	100Hz

Table 4 IXSEA LANDINS specifications.

A distance measurement instrument (DMI), fitted to the wheel of the vehicle, captures movement over the ground and is used in computing the final navigation solution during post-processing. The specifications for the Riegl VQ-250 LiDAR are shown in Table 5. The LiDAR system is mounted on the back of the van at a 45^{o} angle from both the horizontal and vertical axis of the vehicle. This produces scan lines which are not orthogonal to the road and produces richer 3D information. It captures up to 1 million points every 3.5 seconds using a 300kHz sensor. Typical data capture for VQ-250 LiDAR system is 20Gb per hour.

Measurement rate	300kHz
Minimum Range [m]	1.5
Accuracy [m]	0.01
Precision [m]	0.01
Intensity	16 bit
Field of View [deg]	360
Scan Speed	100Hz
Wavelength	1550*nm*

Table 5 Riegl VQ-250 specification.

Two of the six available progressive scan cameras (1280*1024) were used in the road tests. These were positioned inside the vehicle to the left and right of the front windscreen. A power sub-system onboard the vehicle is capable of supplying up to 3kW of power. Synchronisation and triggering of all sensors is centrally controlled over LAN using a high speed GPS timing device. Three 4U 19” servers provide data logging services and are fitted with removable disks to facilitate fast data processing. An operator is seated beside the driver during survey and controls all onboard systems using a central data acquisition console. System initialisation usually takes 20 minutes before the vehicle can begin surveying. This enables the navigation system to carry out coarse and fine alignment of inertial sensors.

At NUIM, algorithms for the extraction of the road edges, its surface and geometry from terrestrial LiDAR data were developed. The aim is to be able to automatically determine a number of key road geometry variables important to risk assessment and collision risk from an area surveyed with LiDAR. The first step is to extract the road edges from LiDAR, following this we need to process these edges where we will remove and correct for the edges which are incorrectly estimated. The final stage is to extract the road surface and determine the geometry of road sections at specific intervals. A survey in both directions is usually required if the road is a dual carriage way or motorway.

4.2.1 Road Edge Extractor

A two stage algorithm for extracting the road edge from LiDAR and navigation data was developed, the workflow of which is shown in Fig. 2.. The first stage of this algorithm creates a set of road cross sections. In the second stage these cross sections are processed into 2D lines. These lines are then analysed based on the slope, intensity, pulse width and proximity to the vehicle to determine the road edges.

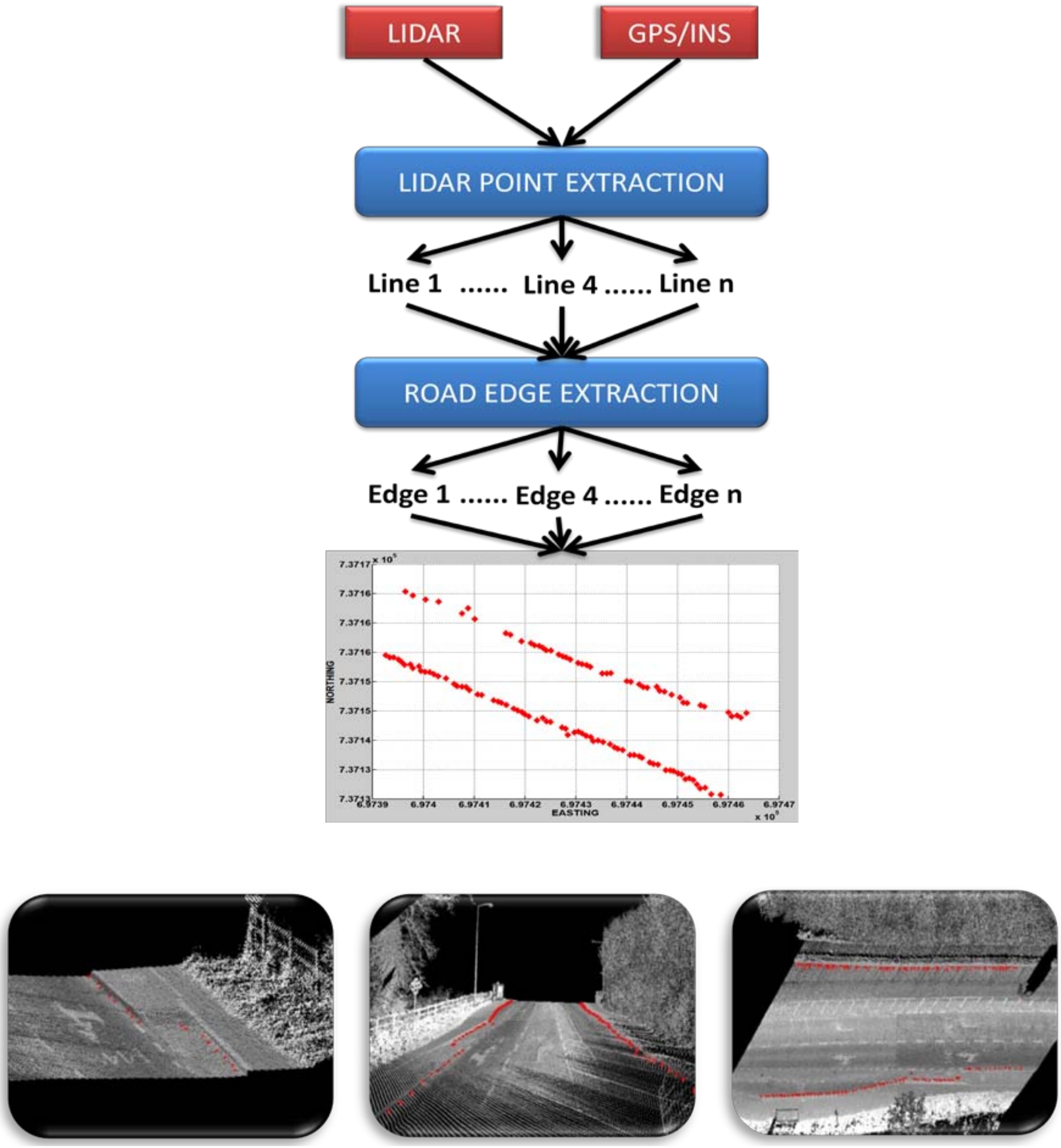


Figure 2. Road edge extraction example

A road edge processing algorithm was developed to remove false road edge points and to improve the accuracy of extracted road edges. There are a number of causes of these false road edge points. False positives most commonly occur in the right hand side road edge points for two reasons; The first reason is due to the fact that with single survey-run LiDAR data, the right hand edge has a lower point density than the left hand edge. This could be overcome by adding a second scanner to the system or by merging point clouds from surveys carried out in opposite directions. The second reason arises from occlusions or no returns. No returns are areas which have had pulses sent out by the scanner but no measurable return has been received by the scanner. These can be caused by standing water and are difficult to overcome. There are a number of types of occlusions ranging such as traffic in the opposite lane or vehicles overtaking. This leads to the road edge extractor finding sharp changes in elevation that lead to false positives. This is demonstrated in Fig. 3 with our processed solution in Fig. 4.

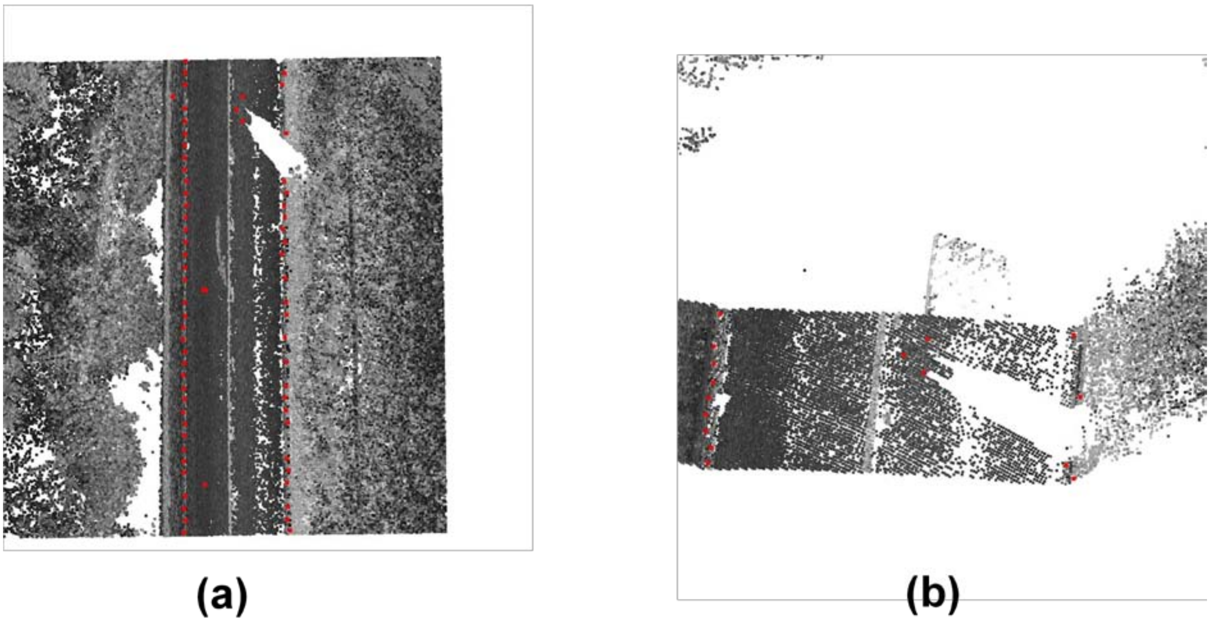


Figure 3. A 40m x 40m section of road with the extracted edges highlighted where a vehicle is occluding the right hand edge, (a) view from above (b) zoomed in view of problem area.

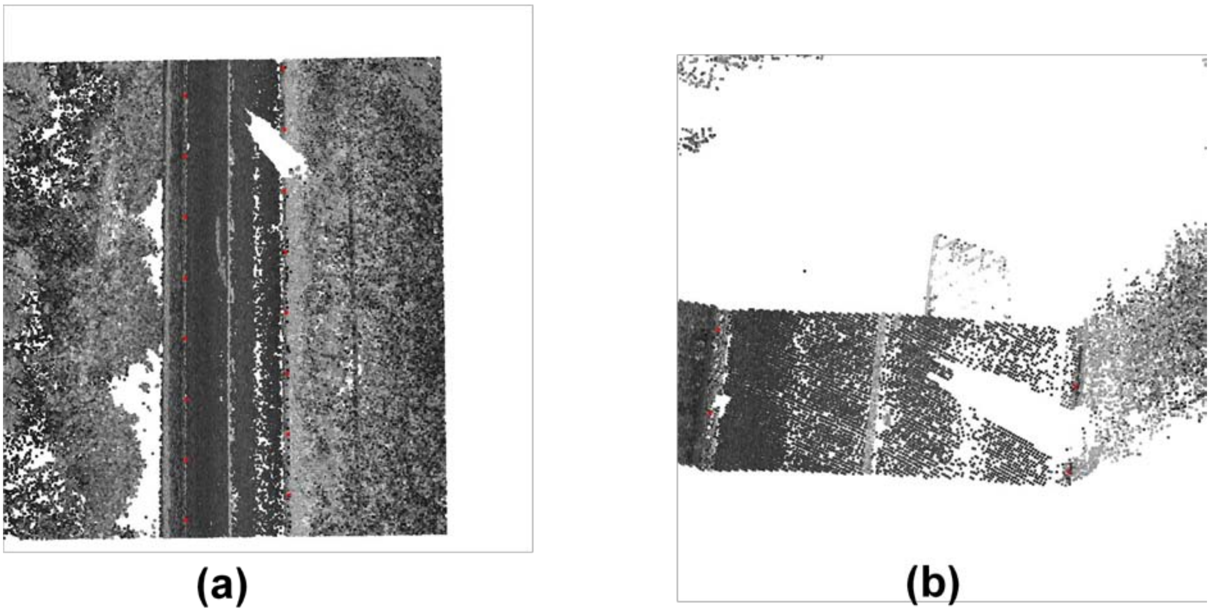


Figure 4. The section of road after road edge processing, (a) view from above (b) zoomed in view of problem area.

Over 100km of LiDAR road data from a variety of road environments were surveyed and processed in the three surveyed areas. All of this data is available using the "LiDAR Processing Application" developed for EuRSI. The application also provides access to the road edge extraction module allowing a user to load sections or LiDAR from the database and extract road edges, or to process large areas of the survey. Geocoded imagery from IBI Group's Routemapper system was used in order to verify the extracted and processed road edges. Various sections including; grass verges, kerb stones and walls were examined. The edges were selected from the imagery and plotted on the map as shown in Figures 5 - 7. In all these examples there was good correlation between processed road edges and selected edges from the imagery.

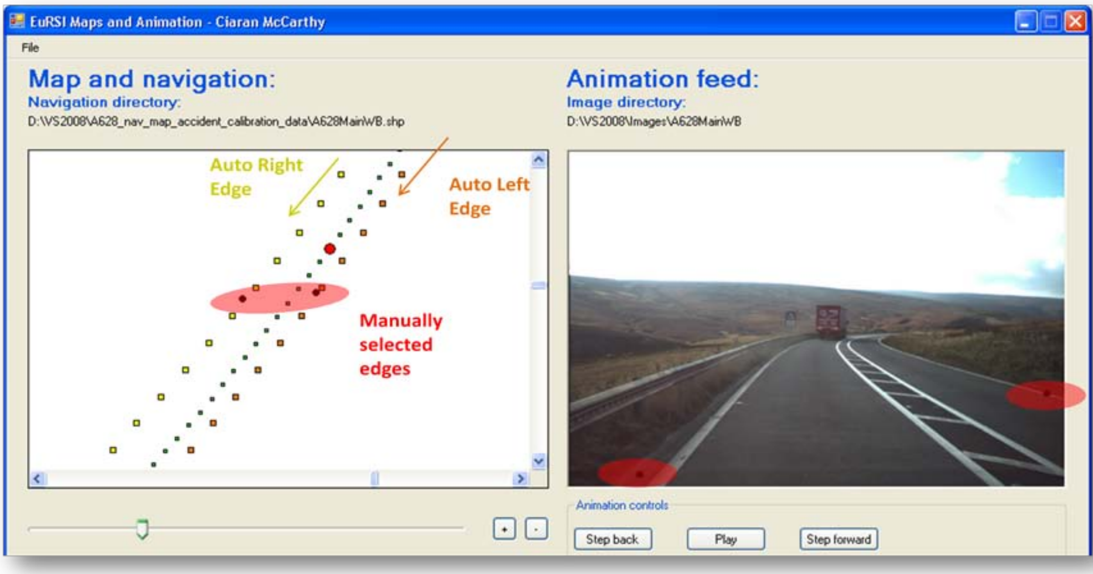


Figure 5 Grass Edges, highlighted in red are the manually selected road edges from the imagery in the right panel which are plotted in the map in the left panel, in yellow is the automatically extracted right edge and orange the automatically extracted right edge.

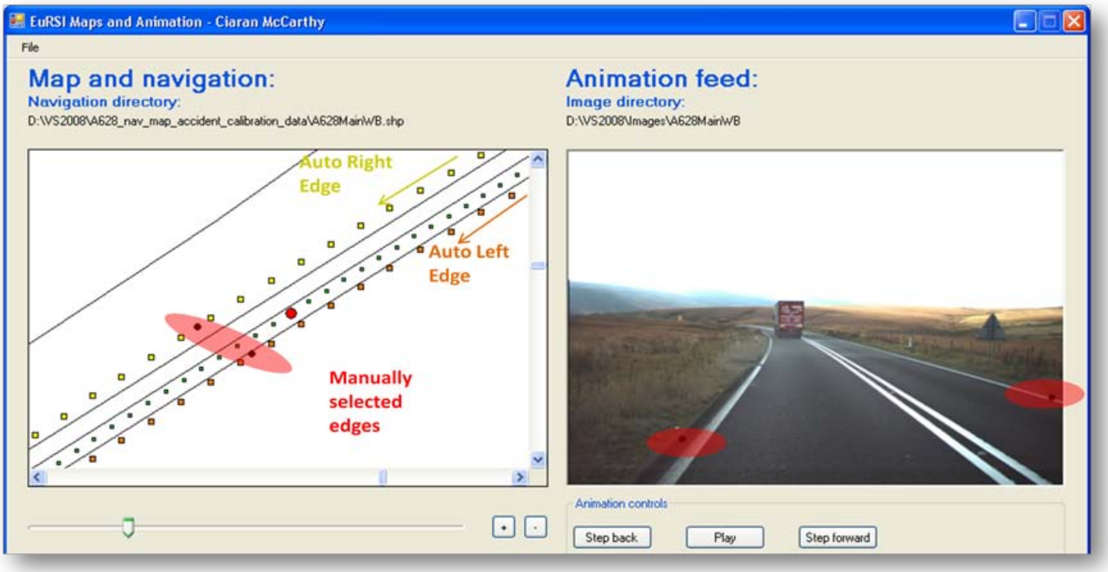


Figure 6 Kerb stone edges, highlighted in red are the manually selected road edges from the imagery in the right panel which are plotted in the map in the left panel, in yellow is the automatically extracted right edge and orange the automatically extracted right edge.

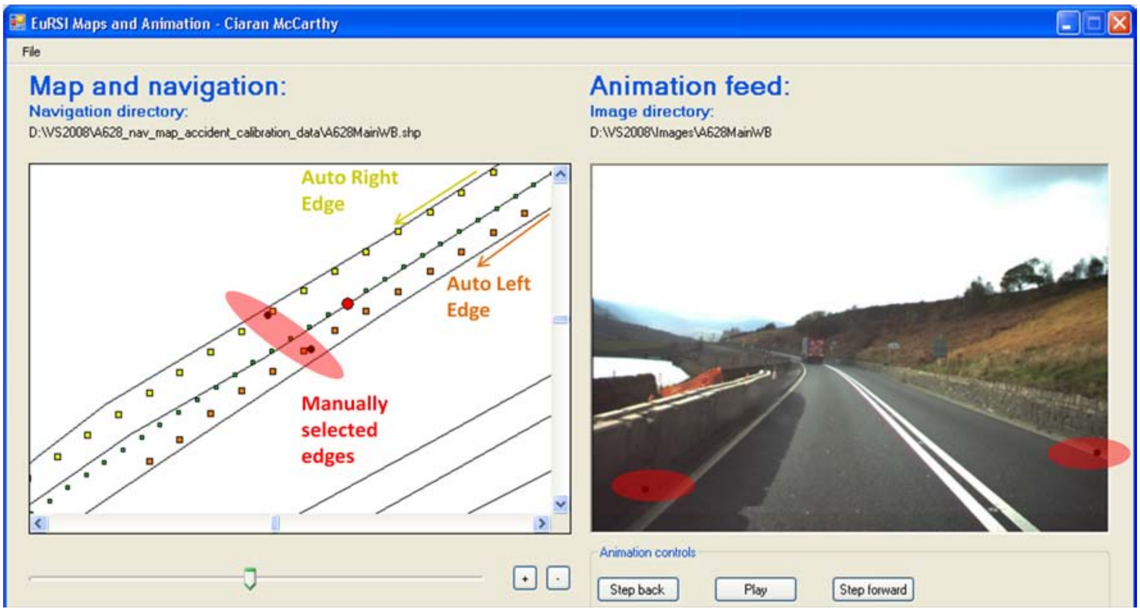


Figure 7 Wall edges, highlighted in red are the manually selected road edges from the imagery in the right panel which are plotted in the map in the left panel, in yellow is the automatically extracted right edge and orange the automatically extracted right edge.

It is clear from the results that the left road edge points are of a much higher accuracy, this is due to higher point density and general absence of occlusions. At some sections of road the right road edge had as few as 10 points per metre squared. The left edge rarely had less than 750 points per metre squared. The occlusions that were encountered included overtaking cars and traffic in other lanes. In some sections of the road there are special cases where the road edge extractor failed to collect enough valid road edge points. This, in turn, led to the road edge processor incorrectly selecting the road edge. In some cases this was unavoidable as there were traffic islands or kerbstones in between road lanes. Nearly all of these potential error sources can be removed by gathering more data either by carrying out a second survey travelling in the opposite direction or mounting a second laser scanner. Both approaches would increase the point density and the accuracy of the right road edge.

An automated cross-sectional geometry extractor was developed, Figure 8. This relies on successfully extraction and processing of road edges. The basic input are road-edges and the number of on-road sampling points, N, to be extracted. The road width distance is calculated along the road taking into account any height variations in the road.

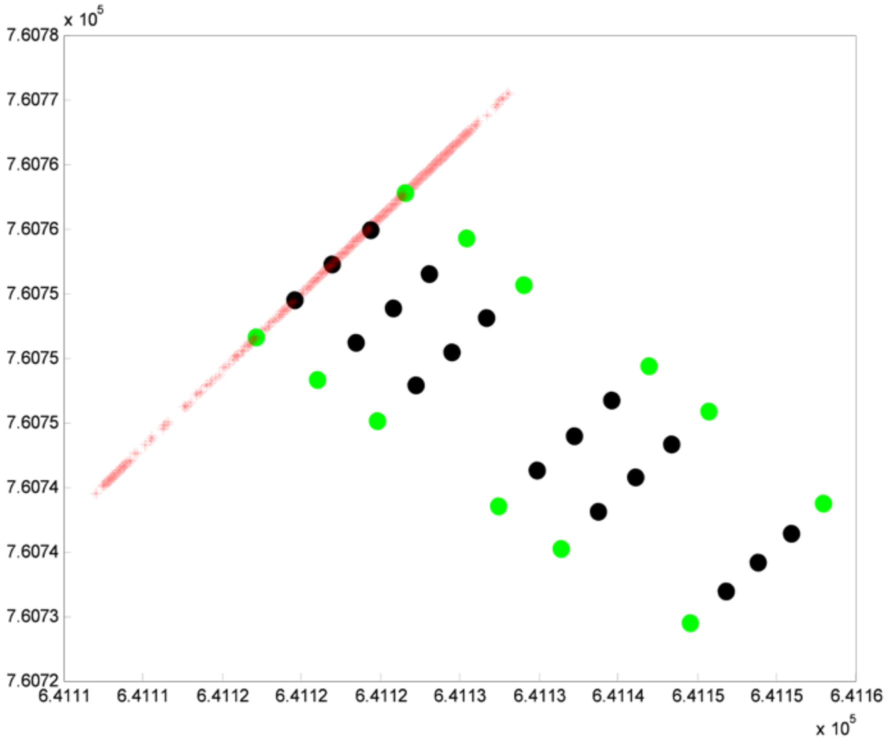
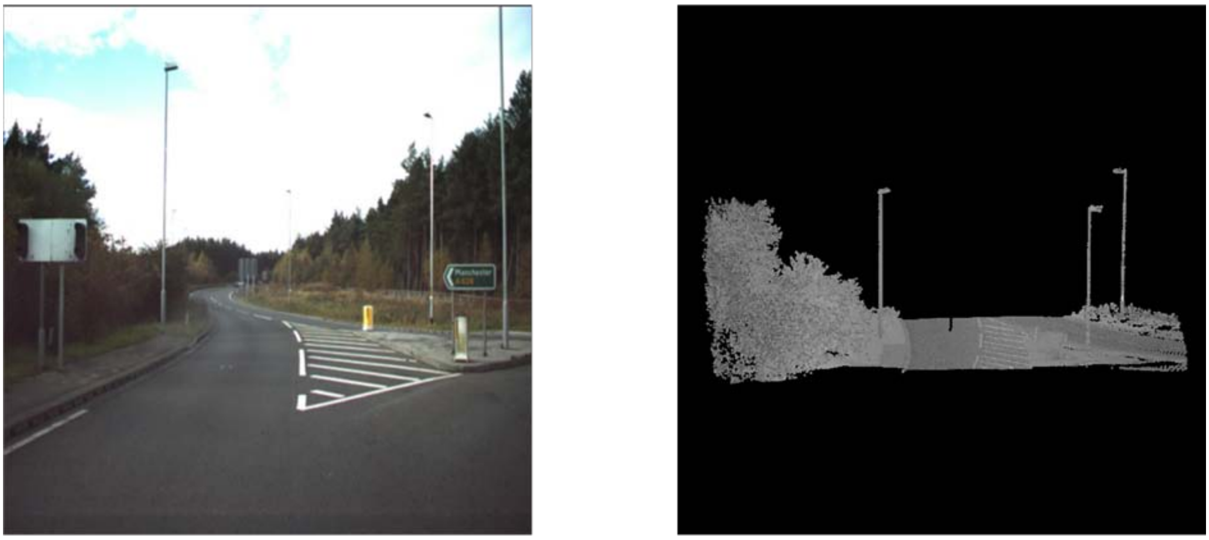


Figure 8 40ms of extracted geometry, a cross section of road LiDAR data in red, road edge points in green and the extracted on road points in black.

Full cross section description including cross-slope and super-elevation can be calculated from each sample orthogonal section.

4.2.2 Road Side Features

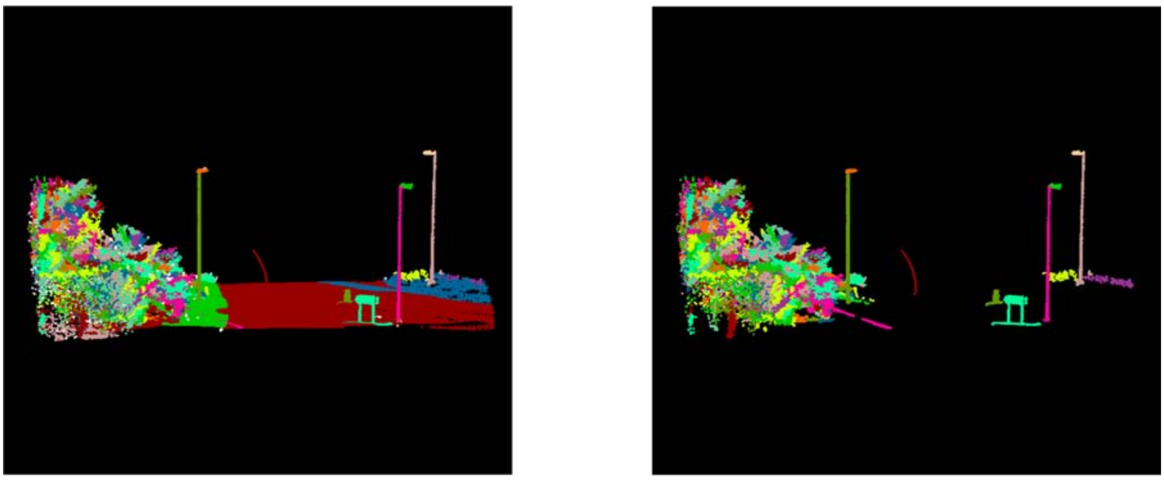
ITC have developed algorithms for the extraction and recognition of features from route corridors. The aim of this work is to classify and recognize important objects. By analysing a set of characteristics of segmented objects such as size, shape, orientation, objects such as pole-like features and linear features can be automatically identified. The next step was to classify these objects as poles, trees, buildings, walls and safety barriers. The ITC pole extraction algorithm was tested on the LiDAR data to demonstrate the applicability of their algorithms in the recognition of features.



(a) (b)

Figure 9. Cross section of LiDAR from A628, (a) imagery of scene and (b) LiDAR data.

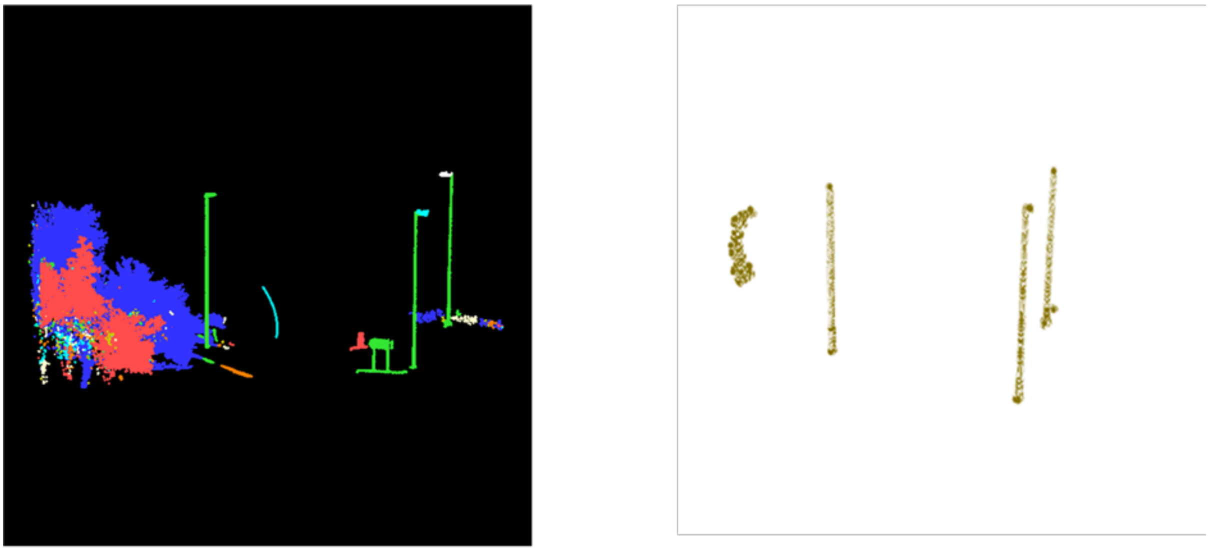
Each road section is processed in three steps, first a rough classification algorithm is applied followed by a pole-like recognition algorithm and finally a pole classification algorithm. In the first step a section of LiDAR data, see Fig. 9, is selected for input. A region growing algorithm is then applied which groups the point cloud data into regions based on relative distances between points as shown in Fig. 10 (a). The ground region is then identified partially through the knowledge that the ground region is directly below the navigation track. This region is then removed leaving only the non-ground points, see Fig. 10 (b). The remaining regions are then clustered into connected components leaving a set of objects, Fig. 11 (a).



(a) (b)

Figure 10. Result after the application of (a) the region growing algorithm and (b) after the removal of the ground regions.

In the second step, each of these objects is assessed for its similarity to a pole-like object and categorised as pole or non-pole. Pole-like objects include signposts, light poles, man-made poles and also tree trunks. Heavily vegetated areas result in more challenging processing where large bushed or forested areas occlude or make it difficult to detect tree trunks. The algorithm developed by ITC uses a novel percentile based processing solution to identify pole-like objects. In this algorithm each clustered object is divided into height percentiles, as shown in Fig 12. A percentile volume is selected for analysis, which is generally not the bottom-most percentile. This percentile is then subdivided into horizontal slices where the extent of each slice is measured. A pole-like object is accepted if this horizontal extent of the slices does not vary rapidly or frequently along the percentile. The advantage of using a percentile approach is to avoid using the base of pole-like objects where shrubbery can occlude the pole or using the top of the pole-like object where tree crowns or light fixtures could lead to not recognising the pole-like object. The accepted pole-like objects for this section are shown in Fig. 11 (b).



(a) (b)

Figure 11. Result of clustering the regions into (a) objects and (b) after recognition of pole-like objects.

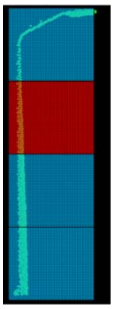
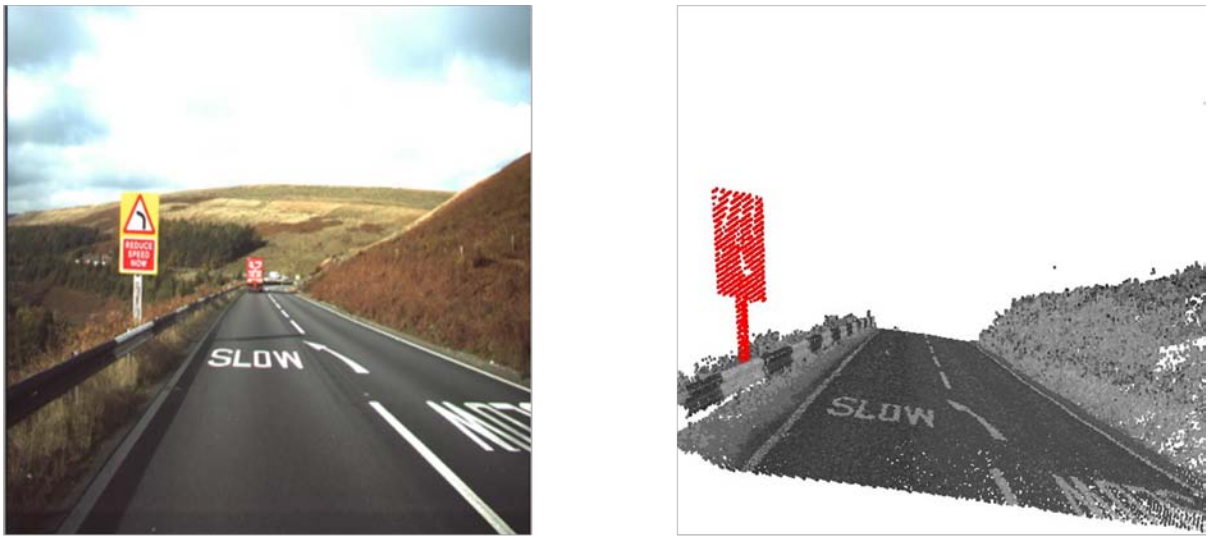


Figure 12: Pole-like object broken into four percentiles with the third being selected for evaluation.

An additional step has recently been developed by ITC where pole-like objects are classified into roadside objects. Firstly, all the points belonging to the identified straight part of the pole are removed. The remaining points are then matched against a set of shapes, and assigned as traffic signs if they match specific criteria. If the remaining points did not match a shape then the pole will be classified as a “other pole”. If after the removal of the straight part of the pole leaves no points this will classify the objects as a “bare pole” such as road bollards. Trees can also be classified using this process.

Over 70% of the traffic signs which have a single pole as their base have been detected over the 40km of road. Two examples of detected poles are shown in Figures 13 and 14. One type of road sign that was particularly difficult to detect is a traffic sign with two poles at its base. In Fig 14 (b) there is a sign with two poles at its base but these poles are close in proximity. However, if the pole bases are separated then the horizontal extent that is examined in the second step of the pole extraction algorithm is much larger than the defined threshold for a pole-like object and it is rejected, as shown in Fig. 15 (b). Detection rate for telegraph poles and traffic lights was greater than 60%, Fig. 13 (b) and 16 (b).



(a) (b)

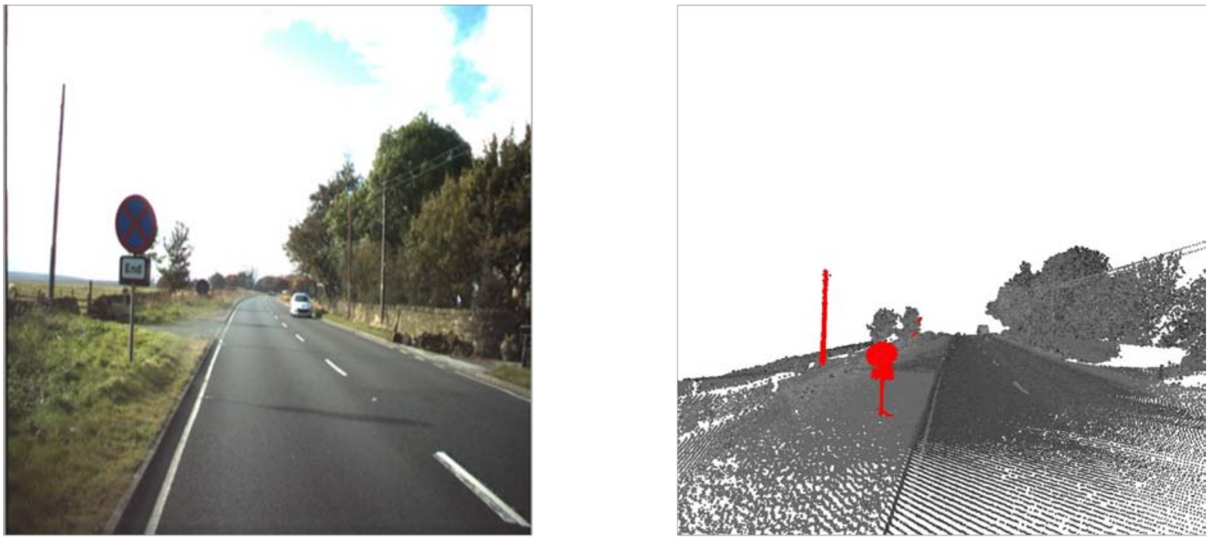
Figure 13. Example of extraction of a road sign, (a) imagery of scene and (b) LiDAR with highlighted extracted pole.

(a) (b)

Figure 14. Example of multiple signposts detected including a double based pole, (a) imagery of scene and (b) LiDAR with highlighted extracted poles.

(a) (b)

Figure 15. Example of signs with two bases which are not detected, (a) imagery of scene and (b) LiDAR.



(a) (b)

Figure 16. Example of telegraph pole detection and also foliage occluding the detection of other telegraph poles, (a) imagery of scene and (b) LiDAR with highlighted extracted poles.

For the 40kms of processed LiDAR, there was a low detection rate for trees. There have been two reasons for this, the first is due to the high concentration of trees in a small area as shown in Fig. 17. Secondly combined with the dense foliage at the time of collection, this resulted in poor performance during the coarse classification stage of the pole extraction algorithm in detecting pole-like structures. An example of the output of the algorithm in an area with a high concentration of trees is shown in Fig. 18 (b).

Figure 17. Imagery examples of the high density of trees in areas of the A628.

(a) (b)

Figure 18. The detection of individual tree trunks is hampered due to the concentration of tees in an area and dense foliage, (a) imagery of scene and (b) LiDAR with highlighted extracted poles.

4.2.3 Summary

Road Geometry

A fully automated road edge extractor (one of the first published) using LiDAR data was developed. This algorithm was tested extensively on 100kms of road data from three separate road survey.. In this data, the types of road edges vary from well defined curbs and walls to undefined edges where grass verges define the edge of the road. In all these cases the road edge extractor is implemented without any manual intervention and has successfully extracted the road edge. Data tested was from a survey in one direction, using a single scanning system. This has resulted in a much lower point density in the right hand edge, with accompanying lower accuracy. Some errors were produced on the left hand edge but these are uncommon. Novel spatial algorithms were developed to correct errors on both left and right road edge margins. A cross-sectional feature extraction tool was also developed.

Road side features

A fully automated pole-like object extractor was developed by ITC and applied to the data from the EuRSI project. It has been successful in detecting over 70% of single base road signs and over 60% of telegraph poles and street lights near the road. Due to the concentration of trees in small areas and the dense foliage in the test data, the detection rate for trees was quite low. The algorithm is still under development and has recently been extended to categorise recognised pole-like objects into bare poles, trees, traffic signs and other poles. It has also been extended to detect linear features such as building walls, fences and crash barriers.

- LiDAR good for recording various road geometry features including alignment & cross-section
- Challenges remain in automated feature extraction of road-side features such as vertical pole and horizontal fence like objects from LiDAR

4.3 Review various risk assessment methodologies and develop a novel approach to risk assessment within the context of RSI

A report regarding Risk Assessment Review (Deliverable 3.2) was compiled as part of the EuRSI work-plan. The initial starting point of this report was the overall objective; **"***to formulate a road safety risk assessment methodology to highlight locations and sections along rural road network that require safety interventions based on information acquired during RSI and any other relevant information***"**. The report describes best practice and a contemporary review of published research, methodologies, projects and initiatives that enabled the research team formulate a novel risk assessment framework within the context of RSI along rural road networks. The report was structured into four main sections

- Review of road safety factors and risk assessment methodologies
- Understanding the factors and data sources that are relevant to assessing risk within the context of Road Safety Inspection
- Devising a framework for assessing risk within the context of road safety inspection along rural roads
- Conclusions & Recommendations

Road user risk prevails from the start of any journey right through to the final destination. Static road risk factors can be continuous such as pavement surface condition or discrete such as road-side point hazards. Risk is a relative term since it depends on the interaction of a number of static and dynamic variables. The relationships between risk factors are complex and it is difficult to compute their potential or actual contribution to any collision event. In the first instance, a systematic approach is required to highlight and explain potential risk along rural roads in an operational environment. The report acknowledges that the task of identifying and measuring risk is non-trivial, involving a complex series of interactions centred around driver, vehicle and road environment. Road Safety Inspection is concerned, initially, with monitoring the existing physical road environment and within the context of EuRSI, is further limited to examining certain static risk factors such as road geometry, surface condition and hazards along rural road networks.

The main findings of this task can be summarised in the conclusions:

- Risk Assessment in the context of RSI needs to be defined. One proposed definition;
    - A risk assessment methodology associated with an RSI should be able to highlight and explain the main sources of risk along any rural road network in a timely, concise, robust fashion based on safety engineering principles. Risk assessment should (initially) confine itself to assessing the risk associated with the static physical road factors including geometry, road-side features and surface condition. Data sources should include those acquired and

derived from mobile mapping systems and accident databases. Particular attention should be paid to the role of vehicular velocity in assessing risk.

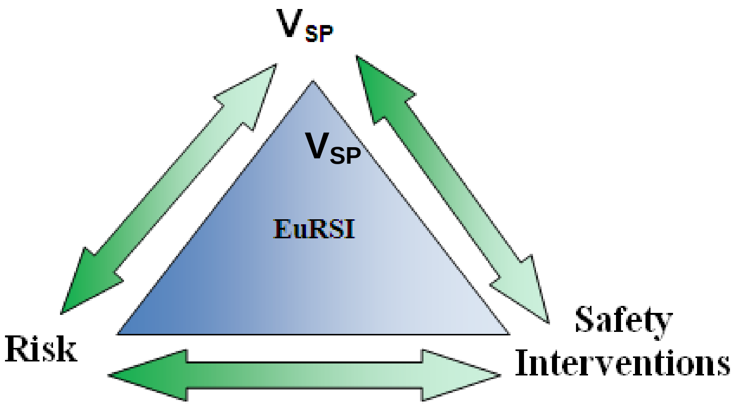
- Accident database
    - o Accident databases contain very useful historic data that has a role in risk assessment in RSI but contains a number of shortcomings when used to model risk. It is reasonable to assume that in some cases that it may be impossible to record the actual factors that caused the accident in any meaningful way. Additional shortcomings include poorly structured databases, incomplete or missing data resulting in difficulty in interpreting the actual factors in any accident. In the context of an RSI, accident databases can be used to highlight locations that are an obviously high-risk, identified by the number and severity of accidents. Accident data should take into account any road network upgrades i.e. accident data from the year 2001 may no longer be relevant to a section of road that was upgraded in 2002. Accident data can also be used to help prioritise remedial actions by the Network Safety Manager.

- Statistical Modelling
    - o Statistical modelling can be broadly grouped into global and more localised, collision specific accident prediction or safety risk modelling. Research in this area is quite active and some recent notable outputs includes complex modelling by Cafiso et al. (2010) and Turner et al. (2011). Comprehensive safety risk systems used in operational environments includes FHWA Interactive Highway Safety Design Model Crash Prediction Module and AARB's Road Safety Risk Manager. These systems, in particular the FHWA IHSDM CPM are reasonably complex and quite detailed. The advantages of statistical modelling within safety risk assessment are countered by the complexity and often site or scenario specific nature of the results produced by these algorithms. The scope of this project does not allow for additional time to investigate these methodologies any further. Further work is required in this area to assess whether the general approach and associated methodologies developed by contemporary research projects and national systems could have any significant impact to European RSI. The initial approach to risk assessment within the context of RSI here in Europe should concentrate on designing a system where risk can be detected in a timely and robust fashion and then explained in a meaningful way to the road safety engineer.

- Safe profile velocity V_{SP}
    - o A new factor, safe profile velocity V_{SP}, is proposed. This data is recorded using onboard GPS under typical (daylight, fair weather, free-flow) conditions, ideally, at the same time as the mobile mapping system data-acquisition. The driver is instructed to drive so as to ensure a safe, comfortable profile over the entire survey section. V_{SP} can be used as a proxy for perceived risk of the associated static road factors, as measured by the mobile mapping system. V_{SP} should be repeatable.

- RSI Risk Assessment Framework
    - o A novel framework is proposed for risk assessment in the context of RSI incorporating data from accident database, V_{SP}, and road factors. Three integrated levels of processing ensure that safety risk can be detected and explained using an evidence based safety engineering system. Existing safety interventions can be incorporated to determine whether any risk posed is adequately managed and ameliorated.

Perhaps, the most important output of the risk assessment study, within the context of Road Safety Inspection across Europe, is the attempt to make the connection between detectable road risk factors, road safety intervention and safe driving behaviour as observed from V_{SP}. Risk factors, as they pertain to RSI, can be discrete or continuous, static or transient, singular or multiple but the overall interaction is dynamic in nature. Relating a dynamic driving profile to both risk posed to road users and safety interventions implemented by network operators allows the road safety engineer to consider all aspects of the dynamic risk model within the scope of RSI namely: risk whether perceived or not (likelihood, severity, exposure), mitigation (safety features in place or required) together with the everyday, typical, average driver response represented by V_{SP}.



These three quantities have a reciprocal relationship where one is influenced by or, in turn, determines the other. Varying one will usually produce a change in the other two. This dynamic model varies geographically but the relationship between the three quantities still holds. This enables locations that require closer attention along the network to be detected as well as providing a better insight into the overall inter-relationship of Risk, Safety Interventions and driver behaviour at that location. Risk assessment in the context of RSI needs to be considered within this dynamic relationship model.

4.4 Produce software toolkit that would enable end-users carry out risk analysis

The results of the Risk Assessment Review (D3.2), detailed in section 4.3 were used to guide the design, construction of three software applications;

- LiDAR Processing — processing LiDAR and generating road edge geometry
- Road Feature Classifier — extraction of road-side features
- Risk Analysis — compute & visualise risk index score & V_{SP} data

The first two software toolkits deal with the lower level road geometry and road side feature extraction whilst the third, Risk Analysis, deals with identifying and explaining risk within the context of an RSI. Risk is always present along road networks; it changes constantly both spatially and temporally. This software module attempts to demonstrate a novel approach to risk analysis by computing a sample set of static road risk factors and comparing these with a dynamic measure of perceived risk in the form of a safe profile velocity V_{SP} . A novel feature of this application is making the connection between the risk posed by static road factors together with the perceived risk of an average driver as measured by a safe profile velocity V_{SP}. V_{SP} should represent the average safe profile of all drivers along that route under good weather, illumination, low driver-workload, traffic-free conditions. Any transient events should be removed from this profile e.g. having to stop suddenly because of an animal running out onto the road. This velocity can then be linked to driver's perceived, prioritised picture of risk of the road environment at any point along the journey.

Existing safety interventions should also help the driver *read the road* especially at locations where more caution is required, and so, make the necessary adjustments to how they drive in order to arrive safely at their destination. Not all risks (causative, outcome, exposure) are visible to the driver e.g. poor road surface condition, rock-outcrop behind some road side vegetation or a localized increase in traffic. This means that the driver might slow down when approaching a bend on the road but not necessarily change their speed when they pass regularly spaced utility poles at the side of the road. This software enables users make the link between static road factors, actual driver behaviour & historic accidents, and so, enables road authorities gain a better understanding of the real risk posed by various static factors along rural roads within the context of an Road Safety inspection (RSI).

The software suite can process datasets that are typically acquired from surveys used to measure and record the various road geometry, network topology, road-side feature, pavement condition and collisions. The software can accept data from mobile mapping systems (geocoded imagery and/or LiDAR) as well as existing road survey data as long as user ensures data format is compliant. Up to twelve risk factors are analysed in this version and end-user can vary the parameters for highlighting and grading risk within the context of an RSI. These twelve factors are chosen for demonstration since there are, of course, many more risk factors that could be included and any future versions should accommodate any number of risk factor inputs. Figure 19 details the flow of data from LiDAR Processing and Road Feature Classifier modules and indeed any additional road survey data sources to final processing using the Risk Analysis application.

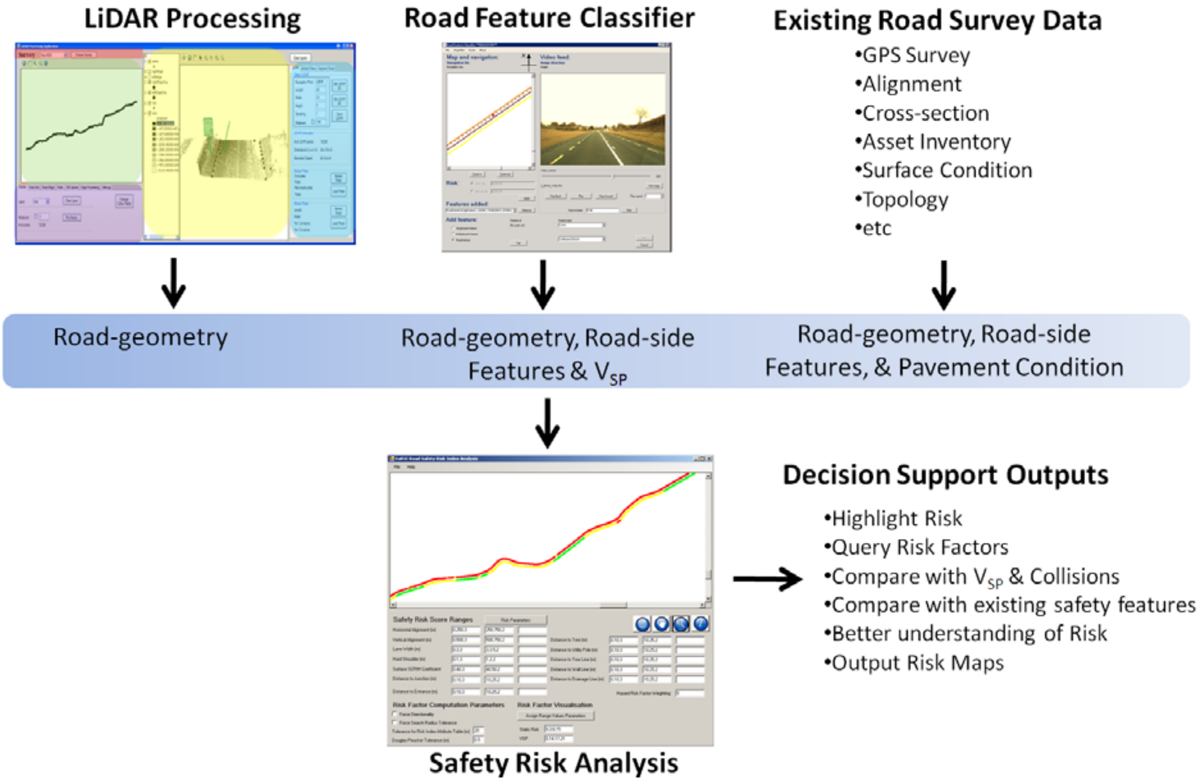


Figure 19. Overview of data from source through to risk analysis

Outputs from the risk analysis application include GIS ESRI shape files that enable risk to be highlighted and explained as it relates to the static road environment. However, this risk index can also be compared with the dynamic safe profile velocity (V_{SP}), representing average safe driving profile, as well as historic collisions. Future improvements could also include the ability to modify the risk index score using V_{SP} and data from existing safety interventions to produce a more realistic map of where immediate improvements are required.

4.4.1 LiDAR Processing

This software, Figure 20, enables LiDAR data to be loaded into a database, extracted, processed and visualised. The user can process LiDAR to extract road edges as well as certain road side features. Performance and data quality vary depending on the LiDAR data quality and scene complexity.

Input	**Geocoded LiDAR data**
Output	**Road edges (alignment), cross sectional profile and position and class of road side feature type.**

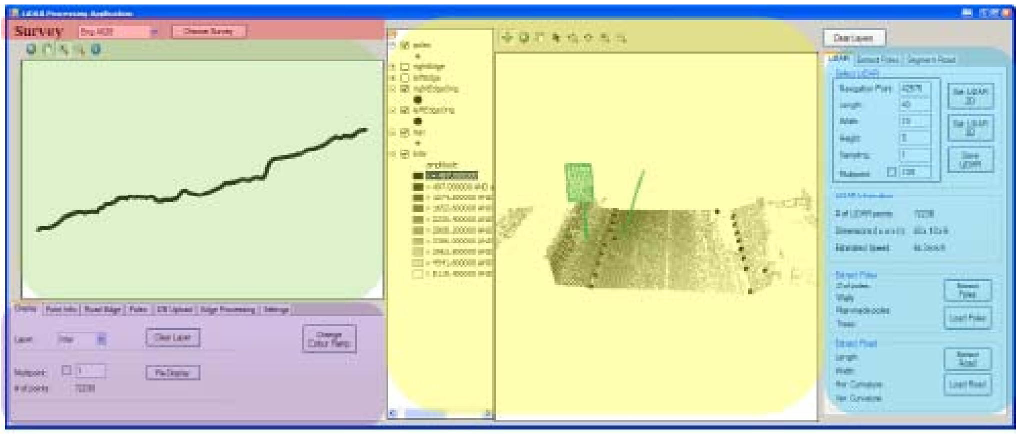


Figure 20. Screen-shot of LiDAR Processing toolset

4.4.2 Road Feature Classifier

This software module, Figure 21, enables both road geometry and road side features to be extracted and output as ESRI shape files. The user can navigate forwards or backwards through the data-streams using the map or multimedia player controls. In-frame measurements can be carried out and results such as position and feature class type exported to a shape file.

Input	**Geocoded Imagery (Image & GPS)**
Output	**Road geometry and road side features**

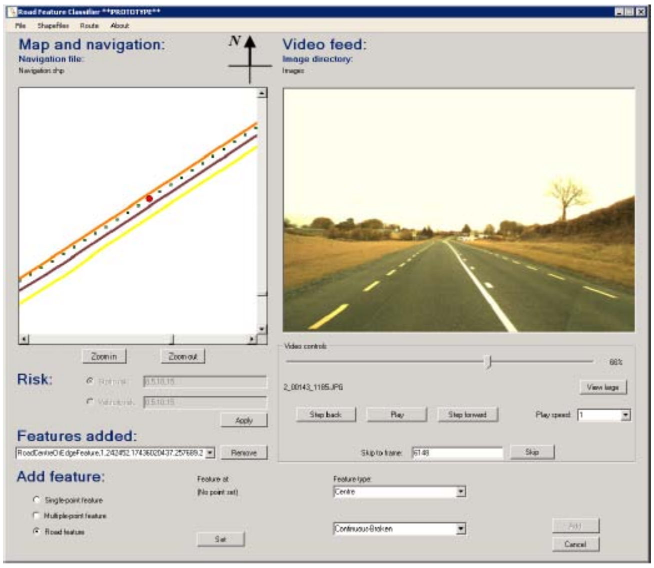


Figure 21. Screen-shot of Road Feature Classifier toolset

4.4.3 Risk Analysis

The purpose of this software, Figure 22, is to take the outputs from LiDAR Processing and Road Feature Classifier and build a risk matrix, Appendix 8.1, based around static road geometry and road side features. An index score can be computed for any sample point along the road network under inspection. A safe profile velocity (V_{SP}) dataset can also be created and this together with collision data can be compared with the Risk Index Score. This application enables the user to identify areas of risk and understand the factors. These risk maps can be used to carry out a preliminary assessment of risk following an RSI.

Input	**Outputs from LiDAR Processing and Road Feature Classifier**
Output	**Risk indices indicated by Risk Index score, Collision data and V_{SP}**

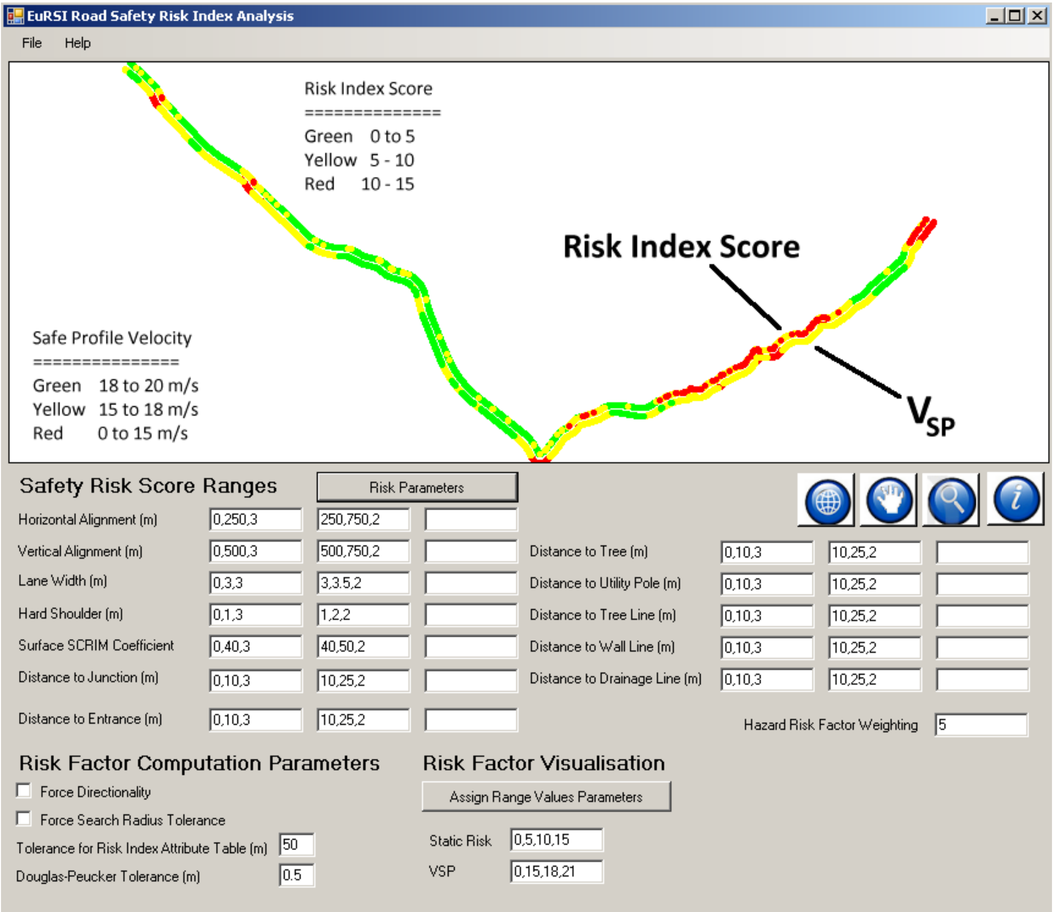


Figure 22. Screen-shot of Risk Analysis toolset displaying final outputs: Risk Index Score & V_{SP} using the Irish sample dataset. In this example for computing the Risk Score, the Red symbols indicate a high number of risk factors, Yellow = medium and Green = Low. For V_{SP}. Red = low velocity (< 15m/s) therefore high perceived risk by the driver, Yellow = medium and Red = high velocity so, therefore low perceived risk by the driver.

5 Risk Analysis Results

Three test-sites were chosen in UK and Ireland, Figure 23. These were surveyed using the mobile mapping system (MMS) at various dates between Nov 2010 and April 2011. Additional datasets relating to road surface condition, collisions and topographical detail was collated for each site.

Figure 23. Test-sites in UK and Ireland where MMS data was acquired

The datasets collected by the MMS were pre-processed as described in report *Automatic Feature Extraction from LiDAR* using the *LiDAR Processing* and *Road Feature Classifier* systems described in Section 4.4.2. The LiDAR Processing system enabled the road edge to be extracted whilst the Road Feature Extractor allowed road side features to be digitised. The data source and output from various software systems and databases are detailed in Table6.

Data Source/ Data Output	**Road Geometry**	**Road Side Features**	**Ancillary data**
LiDAR Processing	Road Edge, Road centre-line, Width		
Road Feature Classifier		Hazards (Poles, Trees, Walls, Drainage), Junctions, Entrances, Hard-Shoulder	
Collision database			Hot Spots
MMS Survey Navigation File			Distance & Time
Road Surface Condition			SCRIM
Risk Analysis	Alignment (Horizontal & Vertical)		V_{SP}

Table 6. Details of data sources and outputs for various software modules and databases

The data processing work flow can be divided into four stages;

Data Processing Work flow

- LiDAR processing
  - Compute road edge and nominal road centre line using LiDAR data
- Road Feature Classifier

  - Extract road side features, junctions, entrances and hard-shoulders using Road Feature Classifier
- Data Collation
  - Collate additional datasets such as collisions and road surface condition from external sources
- Risk Analysis
  - Construct Alignment (Horizontal and Vertical), V_{SP} using Risk Analysis data processing routines
  - Construct Risk Matrix using Risk Analysis
  - Compute Risk Index score
  - Visualise and query Risk Index Score, VSP & Collision data

One of the conclusions, from deliverable D3.2 Risk Assessment Review, focused on the need to highlight and explain risk within the context of an RSI in a meaningful and timely fashion. The goal here should not be an absolute quantifiable risk score which is very difficult to produce in any case but rather an index of risk that can be easily computed, visualised and queried by the user. This is why during Risk Analysis a road risk index score was computed using simple rules which can be changed by the end user. In this application, the model is very simple and is based on sever intrinsic road risk factors (H_{ROC} ,V_{ROC}, W, HS, RS, J & E) and five road side hazards (T, TL, DL, WL, UP) which are weighted by factor HW. The Index score is computed as follows:

Road Risk Index Score$_{XY}$ = (H_{ROC} + V_{ROC} + W + HS + RS + J + E) + (T + TL + DL + WL + UP) / HW

XY	:	Sample Point X-coordinate, Y-coordinate
H_{ROC}	:	Horizontal Radius of Curvature
V_{ROC}	:	Vertical Radius of Curvature
W	:	Width
HS	:	Hard-Shoulder
RS	:	Road Surface (SCRIM)
J	:	Junction
E	:	Entrance
T	:	Large Tree
TL	:	Tree Line
DL	:	Drainage Line
WL	:	Wall Line
UP	:	Utility Pole
HW	:	Hazard Weighting

Please refer to Appendix 8.2 for more detail on Road Risk Index score computation as well as the user software guide provided with Risk Analysis software. All three datasets were processed using the same parameters and the same range values were applied to the Risk Index Score & V_{SP}. Collisions were plotted if two or more events occurred in close proximity. The same colour look-up table was applied to the Risk Index Score & V_{SP} for each respective road test based on user selectable range values, Table 7.

Risk Indicator	Colour	Risk Rating	Lower bound	Upper bound
Risk Index Score Computed from 12 Static Risk Factors	Green	Low	0	5
	Yellow	Medium	5	10
	Red	High	10	25
Safe Profile Velocity V_{SP} meters/second	Green	Low	18	25
	Yellow	Medium	16	18
	Red	High	0	16

Table 7. The range values used to classify all three test datasets

There is reasonable correlation between perceived risk, indicated by V_{SP} and Risk Index score in the Irish dataset, Figure 24. The accident data also seems to highlight similar sections of road that have apparent higher risk indicated by the index score and V_{SP}.

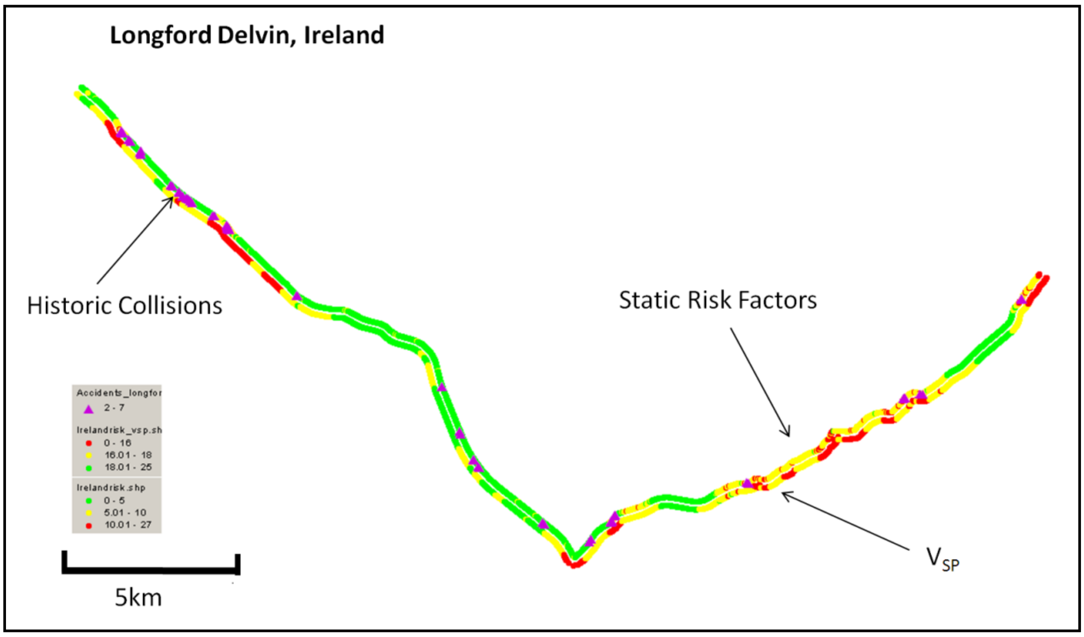


Figure 24 Results of Irish Test data depicting Risk Index Score from Static Risk Factors (upper trace) with V_{SP} (lower trace) and collisions (purple triangles).

Figure 25, details the section between Mullingar and Delvin, highlighting reasonable correlation between Risk Index score and V_{SP}.

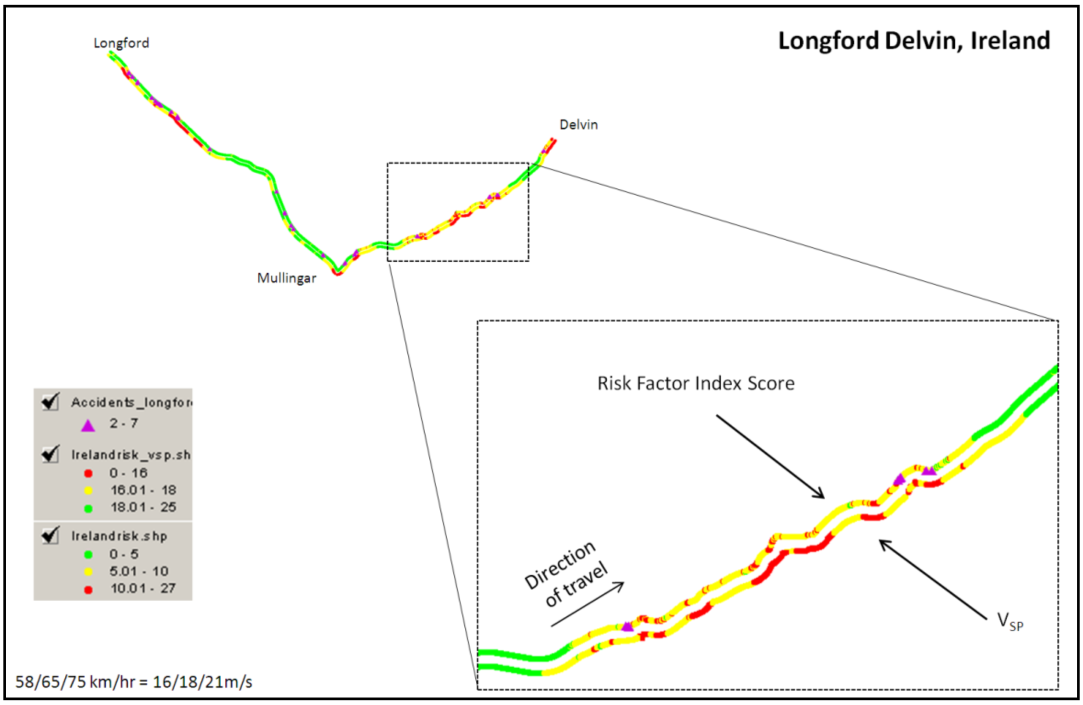
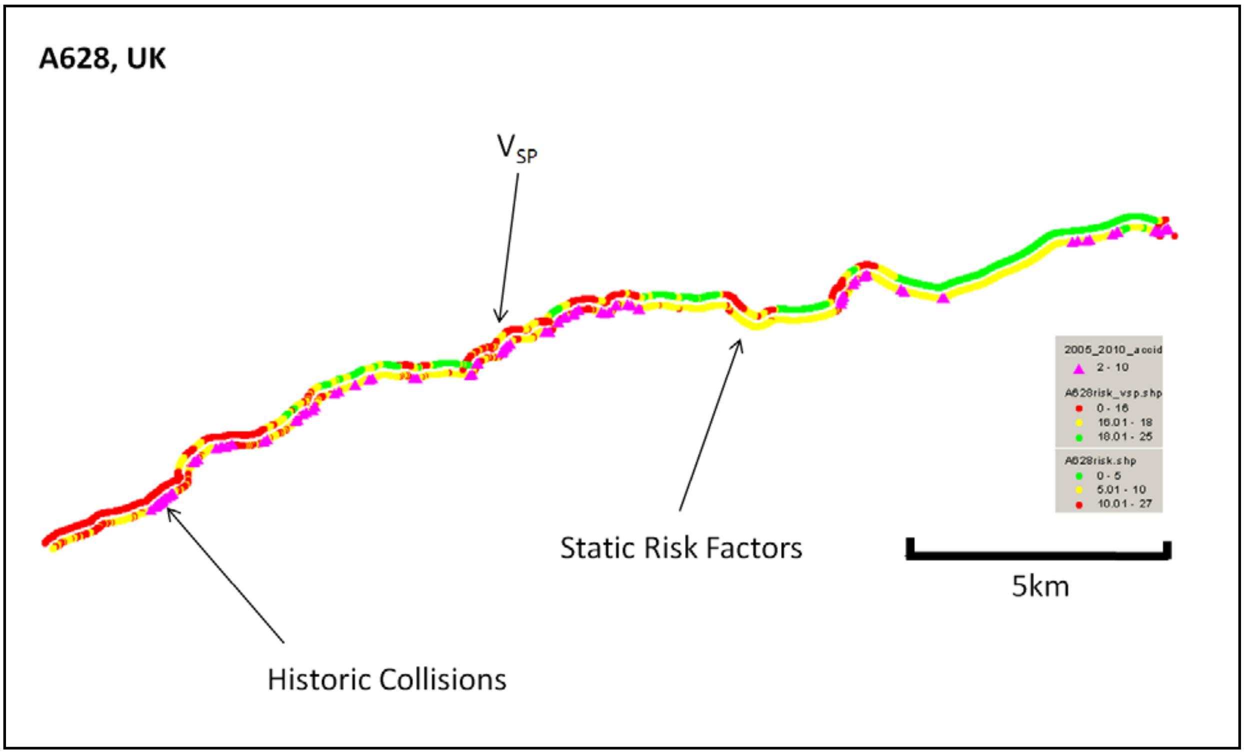
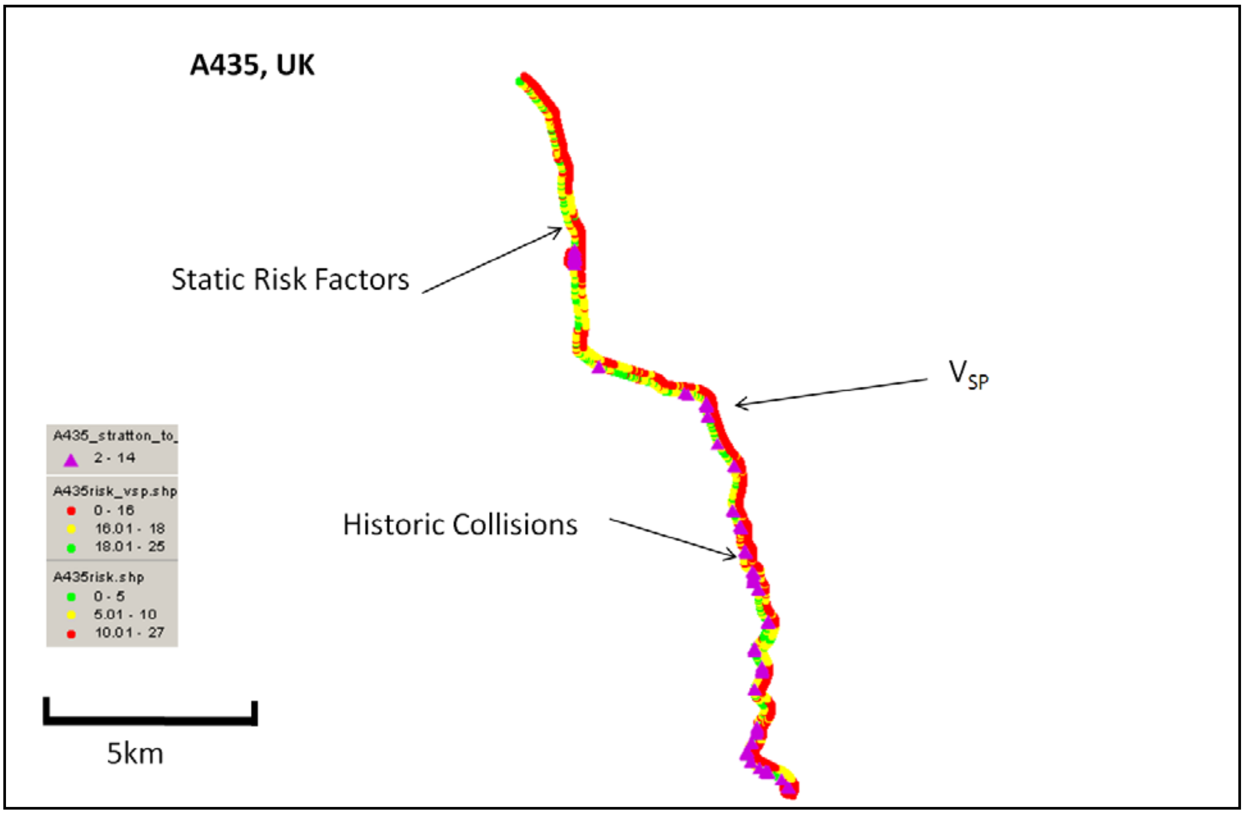


Figure 25. More detail on Mullingar to Delvin section.

The correlation between the same three indicators in the UK datasets is not as strong. This is due to the relatively busy traffic on both A628, Figure 26, and A435, Figure 27, that resulted in survey vehicle slowing down and speeding up. **Note, the V_{SP} concept was developed after survey and data acquisition**. Nevertheless there are sections of A628 where correlation is reasonable.

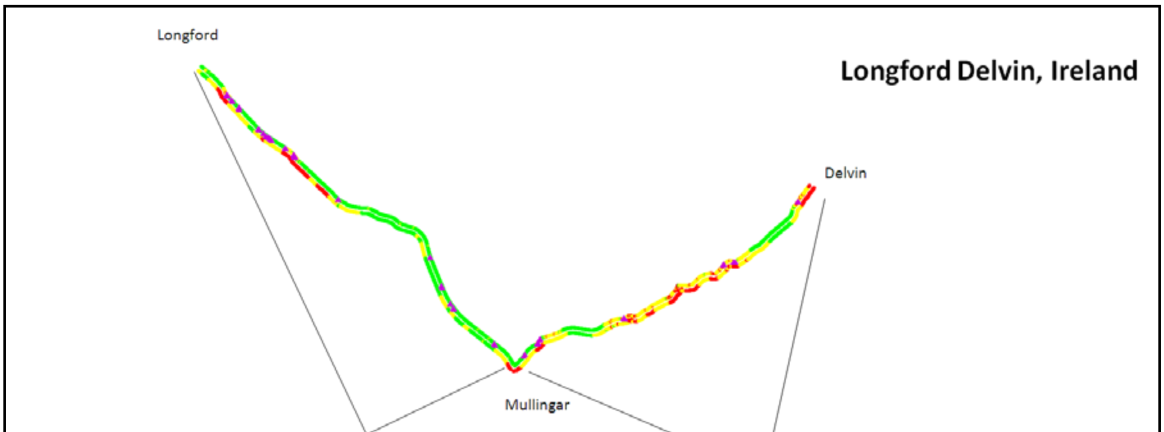


Frame 26. Results of A628, UK data depicting Risk Index Score from Static Risk Factors (upper trace) with V_{SP} (lower trace) and collisions (purple triangles)



Frame 26 Results of A435, UK data depicting Risk Index Score from Static Risk Factors (upper trace) with V_{SP} (lower trace) and collisions (purple triangles)

The Risk Index Score, V_{SP} and collisions were aggregated and averaged over two road sections for Ireland test data (Longford to Mullingar and Mullingar to Delvin), Figure 27. It is interesting to note the differences in road safety performance indicated by these variables. Although the Mullingar to Delvin seems to indicate higher risk due to index compared with Longford to Mullingar, the number of collisions are greater for the latter. This may be explained by lower AADT on Mullingar to Delvin compared to Longford to Mullingar. Also the relatively dangerous section for Mullingar to Delvin, Figure 25, is continuous and characterised by bad bends, narrow lanes and many crests and sags. Accordingly drivers reduce their speed (also indicated by lower speed in V_{SP}) for this section resulting in a lower occurance of collisions.

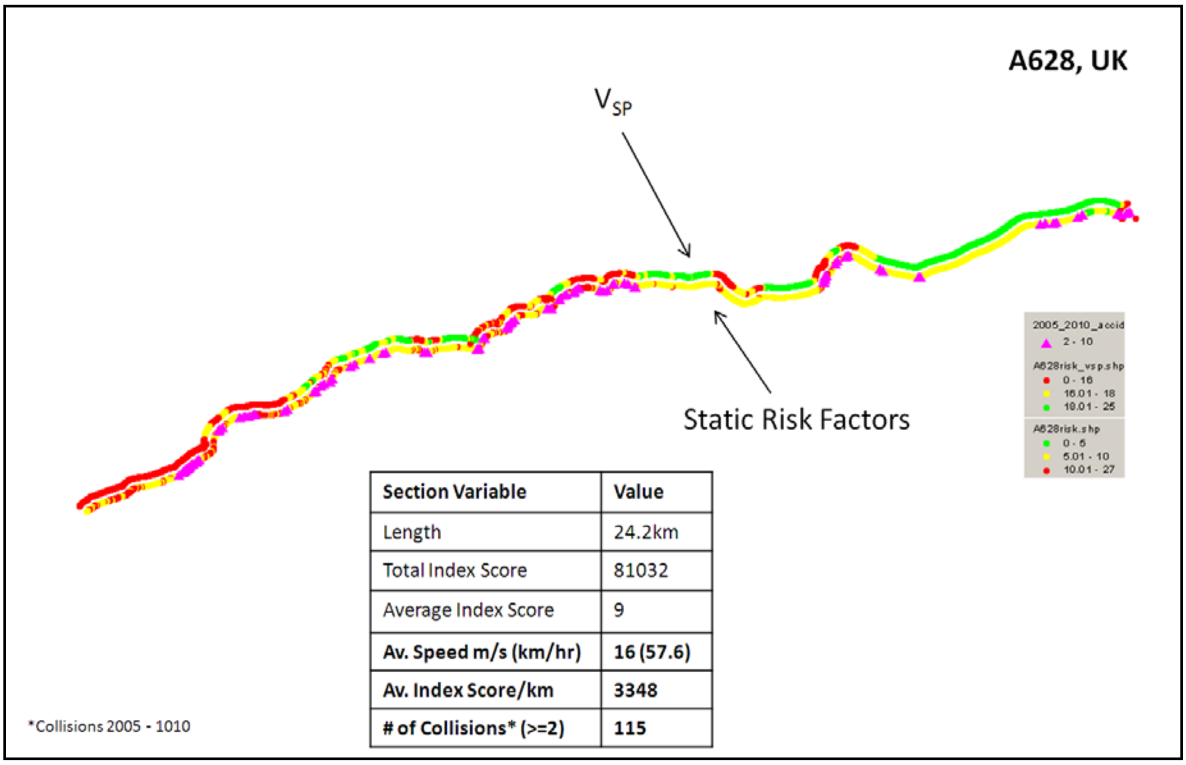


Section Variable	Value
Length	22.1km
Total Index Score	8123
Average Index Score	1.6
Av. Speed m/s (km/hr)	**17.3(62.3)**
Av. Index Score/km	**367.6**
# of Collisions (>=2)	**46**

Section Variable	Value
Length	18.1km
Total Index Score	24164
Average Index Score	5.5
Av. Speed m/s (km/hr)	**16.4 (59)**
Av. Index Score/km	**1335.0**
# of Collisions (>=2)	**18**

Frame 27. Comparison of section length, Risk Index Score, average Risk Index Score and collisions for the Irish Longford to Delvin route.

The Risk Index Score, V_{SP} and collisions were aggregated and averaged over two road sections for A628 in UK, Figure 28. Here the risk index factor is very high when compared with Irish road, Figure 27, probably due to the urbanised zone at the far West of the road sections resulting in a lot of junctions, entrances. Also, the number of collisions are a lot higher again probably due to the much higher AADT.



Section Variable	**Value**
Length	24.2km
Total Index Score	81032
Average Index Score	9
Av. Speed m/s (km/hr)	**16 (57.6)**
Av. Index Score/km	**3348**
# of Collisions* (>=2)	**115**

Frame 28. Comparison of section length, Risk Index Score, average Risk Index Score and collisions for the A628 route.

It is clear that there are a number of short-comings in the current approach and improvements include;

- Comprehensive rule base for choosing risk scoring parameters that are based on road safety engineering principles and supported by research.
- Devising a more comprehensive formula for quantifying the Risk Index Score.
- Risk should not be treated as single point but rather linear or indeed areal in extent. This rule base should also take into account & highlight regions of change rather than absolute location of risk e.g. transition from a straight to a bend.
- A more robust approach for aggregating risk factors (if more than one exists) at any one location so, that the overall risk index score represents the presence of cumulative risk more accurately
- Ensuring acquisition of an accurate V_{SP} (good weather, illumination and traffic-free conditions)
- Extending the number of risk factors to include cross-section factors as well as additional road side hazards
- V_{SP} should be acquired in both directions

6 Project Outputs

EuRSI project produced a number of outputs, listed in Table 8. These include technical reports dealing with reviews of contemporary RSI Schemes & Risk Assessment; three software toolkits for processing road corridor data and computing risk index score; results from LiDAR processing and risk analysis, a web-site as well as more than seven publications.

Output	Description
Technical Reports	• D3.1 RSI Schemes Review • D3.2 Risk Assessment Review
Software	• LiDAR Processing • Road Feature Classifier • Risk Analysis
Testing & Validation	• Automatic Feature Extraction from LiDAR • Final Report including results carried out at three road test-sites (Ireland & UK)
Web-site	www.eursi.net – to be updated after workshop
Publications	• Timothy McCarthy and Conor McElhinney (2010). European Road Safety Inspection Research Project. Proceedings, AET, Glasgow, UK, Sept 2010. • Conor P. Mc Elhinney, Pankaj Kumar, Conor Cahalane, Timothy McCarthy (2010) Initial results from European Road Safety Inspection (EURSI) mobile mapping project, 440-445. In ISPRS Commission V Technical Symposium. • Paul Lewis, Conor P. Mc Elhinney, Bianca Schön, Timothy McCarthy (2010) Mobile Mapping System LiDAR Data Framework, 135-138. In 5th International Conference on 3D GeoInformation. • Pankaj Kumar, Conor P. Mc Elhinney, Timothy McCarthy (2011) Utilizing terrestrial mobile laser scanning data attributes for road edge extraction with the GVF snake model. In MMT'11, The 7th International Symposium on Mobile Mapping Technology. • Conor P. Mc Elhinney, Paul Lewis, Timothy McCarthy (2011) Mobile terrestrial LiDAR data-sets in a Spatial Database Framework. In accepted to MMT'11, The 7th International Symposium on Mobile Mapping Technology. • Conor Cahalane, Conor P. Mc Elhinney, Timothy Mccarthy (2011) Calculating the effect of dual-axis scanner rotations and surface orientation on scan profiles. In accepted to MMT'11, The 7th International Symposium on Mobile Mapping Technology. • Timothy McCarthy, Lars Pforte and Conor McElhinney (In prep). A framework for risk assessment along rural roads. Accident Analysis & Prevention

Table 8. Details of outputs from EuRSI project

7 Future Research

A number of areas have been highlighted for future research. These include

- **Risk Index Score** A more rigorous assignment of risk factor parameters and weightings based on road engineering & safety reports

- **Risk Factors** Increase the number of risk factors from present 12

- **Transient Factors** Incorporation of transient risk factors such as weather, illumination & traffic

- **Risk Analysis** Develop as an online web service which would encourage sharing of data, knowledge and also adoption of standards and unified approaches

- **Sampling.** Risk Index score maps should highlight change in risk rather than absolute risk locations and a suitable sampling strategy is required. This should be linear/areal in extent and take into account Risk, V_{SP} and existing Safety interventions.

- **Safe Profile Velocity V_{SP}**
    - This technique should be improved to ensure adherence to average driving profile under good conditions. This methodology should be checked for quality including accuracy, & repeatability. Acceleration should also be examined in more detail to decide best approach to including this variable in producing an enhanced figure
    - **V_{SP}** could also be used to ***normalise*** the search tolerance distances used to identify location of risk factors

- **Safety Interventions** These should be also measured, scored and integrated with risk, VSP and Collisions in order to develop a more comprehensive approach to prioritising remedial measures

- **Visualisation** More comprehensive integration of risk factor data inputs, Risk Index Score, V_{SP}, Collisions, geocoded imagery (MMS), topographical maps & existing safety interventions. This would present a more comprehensive picture of the road environment.

- **Online pan-European Road Safety Risk Analysis Platform**.

    - Migrate risk analysis and associated data handling tools to an online Web portal enabling road authorities across Eu-27 to share data and expertise, use latest toolsets and encourage a common approach through adoption of standards

    - ITS. Explore new safety advisory services (in-car or wireless) using these datasets and incorporating real-time weather and traffic information and so, contribute to adoption of new EU ITS Directive.

8 Appendix

8.1 Computing Risk Factors

Risk factors are computed in the EuRSI Risk Analysis software. Twelve separate files are used to compute 12 separate risk factor variables. **Note** although V_{SP} is processed using the Risk Analysis software, in order to link it directly with the sampling interval, it is not actually used in calculating the overall static safety index score since it is used as a comparative risk indicator. The algorithm for computing risk can vary depending on each file. Road risk factor files are all point features except for the hard shoulder which has been recorded as a line feature shape file. Features can be continuous i.e. always present such as alignment, width, road surface (SCRIM) or can be discrete such as trees, junctions, and walls. So, for example in Figure 8.1.1, the hard-shoulder is either present and has a width value or absent. The value of this hard shoulder attribute is tested and stored for each sample point within the risk factor matrix table.

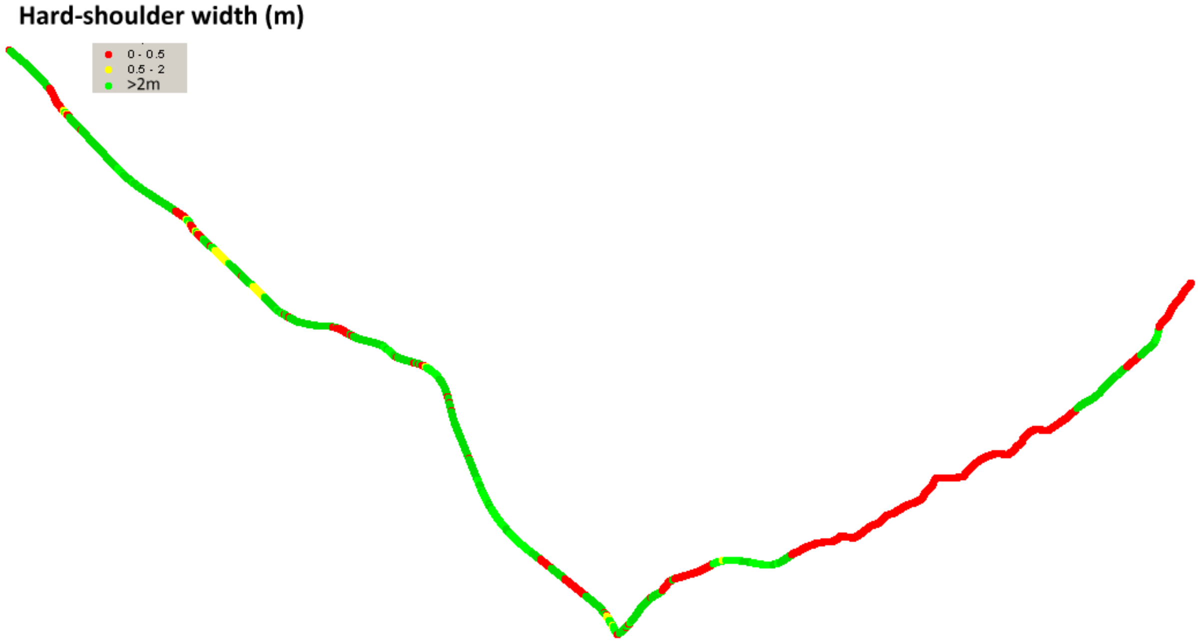


Figure 8.1.1 Plot of hard-shoulder width for Irish Road test. Red denotes 0m to 0.5m, yellow 0.5m – 2m and green >2m.

The search algorithm depends on feature type and for example, can be closest point ***find the width of road closest to that sample point and report the width,*** or directional ***find any pole features at or in front of that sample point within a tolerance or range (chosen by user) of 50m (approximate stopping distance at 80km/hr).***.

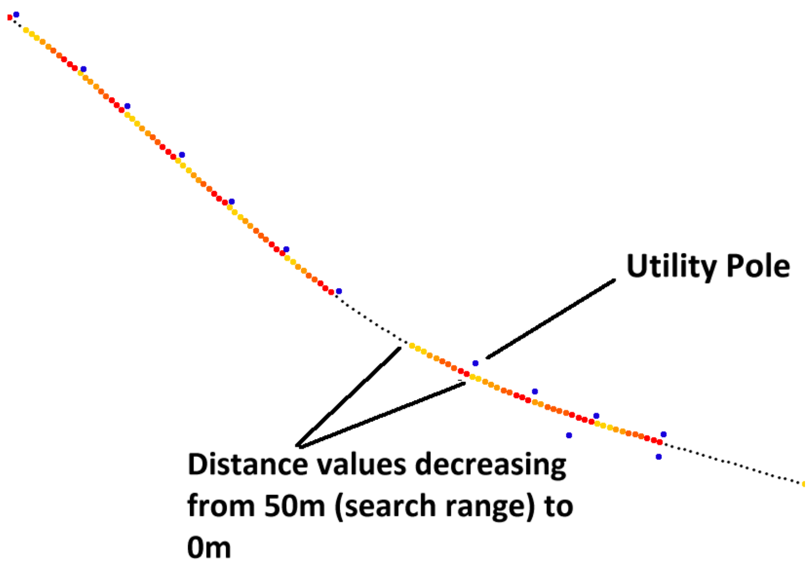


Figure 8.1.2 Plot of distance of sample point yellow to red (50m to 0m) to Utility Poles. The algorithm searches forward and +/- 90-degrees to direction of travel (NW to SE) within (in this example) a 50m range, locates a **Pole** feature and measures the distance and stores this value in the risk matrix table (Road_Safety_Index).

The attribute together with associated risk factor value is stored in the risk matrix table. A summary of road risk features, tolerance values, search methodology, feature category and risk value stored are listed in Table 8.1.1 below.

Road Risk Factor Feature	Sample Tolerance value (m)	Search Type	Feature Category	Value Stored in Risk Factor Table
Horizontal Radius	1000	Directional	Continuous	Radius
Vertical Radius	1000	Directional	Continuous	Radius
Width	5	Closest point	Continuous	Width
Hard Shoulder	5	Orthogonal	Discrete	Distance to edge of Hard Shoulder
Entrance	50	Directional	Discrete	Distance to feature (within tolerance value)
Junction	50	Directional	Discrete	Distance to feature (within tolerance value)
SCRIM	10	Closest point	Continuous	SCRIM value at nearest point
Pole	50	Directional	Discrete	Distance to feature (within tolerance value)
Individual Trees	50	Directional	Discrete	Distance to feature (within tolerance value)
Tree Line	50	Directional	Discrete	Distance to feature (within tolerance value)
Wall Line	50	Directional	Discrete	Distance to feature (within tolerance value)
Drainage Line	50	Directional	Discrete	Distance to feature (within tolerance value)

Table 8.1.1 listing a summary of 12 road risk factor feature, tolerance values, search methodology, feature category & risk value stored

The SQL Server database table (Road_Safety_Index) below details the Risk Factor stored for of the project areas. There are 17 main attributes in the risk matrix table:

ID	Record-ID
HROC	Horizontal Radius of Curvature
VROC	Vertical Radius of Curvature

WIDTH	Lane Width
SURFACE	Surface Condition eg SCRIM
VSPV	Safe Profile Velocity V_{SP} - velocity
VSPA	Safe Profile Velocity V_{SP} - acceleration
SCORE	Static Risk factor score (12 factors)
XCOORD	X coordinate of sample point
YCOORD	Y coordinate of sample point
TREE_LINE	Distance to line of trees
LARGE_TREE	Distance to single large tree
ENTRANCE	Distance to entrance
JUNCTION	Distance to junction
UTILITY_POLE	Distance to utility pole
HARD_SHOULDER	Distance to hard shoulder edge
WALL_LINE	Distance to wall feature
DRAINAGE_LINE	Distance to drainage feature

Table 8.1.2 Risk Matrix Table Attribute field names and description

A sample table detailing attribute names and values are listed below in Figure 8.1.1

I..	HROC	VROC	WIDTH	SURFACE	ACCIDE...	VSPV	VSPA	SCO...	XCOORD	YCOORD	TREE_LINE	LARGE_TREE	ENTRA...	JUNCTION	UTILITY_POLE	HARD_SHO...	WALL_LINE	DRAINAGE
1	9999	172.52	4.6	62	9999	17.022...	-0.06620...	6	230576.29	268768...	9999	9999	9999	9999	9999	9999	9999	9999
2	25007.2	172.52	4.6	62	9999	17.018...	-0.00398...	6	230579.62	268766...	9999	9999	9999	9999	9999	9999	9999	9999
3	25007.2	172.52	4.6	62	9999	17.018...	-0.00398...	6	230582.95	268763...	9999	9999	9999	9999	9999	9999	9999	9999
4	25007.2	172.52	4.6	62	9999	17.018...	-0.00398...	6	230586.26	268760...	9999	9999	9999	9999	9999	9999	9999	9999
5	25007.2	172.52	4.6	61	9999	17.018...	-0.00398...	3	230589.57	268757.9	9999	9999	9999	9999	9999	4.332100963...	9999	9999
6	25007.2	172.52	4.6	61	9999	17.048...	0.02984...	3	230592.88	268755...	9999	9999	9999	9999	9999	4.333378846...	9999	9999
7	25007.2	172.52	4.6	62	9999	17.048...	0.02984...	3	230596.19	268752...	9999	9999	9999	9999	9999	4.334656711...	9999	9999
8	25007.2	172.52	4.6	62	9999	17.048...	0.02984...	3	230599.5	268749...	9999	9999	9999	9999	9999	4.351400310...	9999	9999
9	25007.2	172.52	4.6	62	9999	17.048...	0.02984...	3	230602.81	268746...	9999	9999	9999	9999	9999	4.375865181...	9999	9999
10	25007.2	172.52	4.6	63	9999	17.104...	0.05613...	3	230606.11	268744...	9999	9999	9999	9999	9999	4.398929711...	9999	9999
11	25007.2	172.52	4.6	63	9999	17.104...	0.05613...	3	230609.42	268741...	9999	9999	9999	9999	9999	4.423364851...	9999	9999
12	25007.2	172.52	4.6	66	9999	17.104...	0.05613...	3	230612.75	268738...	9999	9999	9999	9999	9999	4.427285555...	9999	9999
13	25007.2	172.52	4.6	66	9999	17.104...	0.05613...	3	230616.08	268735...	9999	9999	9999	9999	9999	4.439006355...	9999	9999
14	25007.2	172.52	4.6	66	9999	17.175...	0.07124...	3	230619.41	268733...	9999	9999	9999	9999	9999	4.442981817...	9999	9999
15	25007.2	172.52	4.7	66	9999	17.175...	0.07124...	3	230622.74	268730.4	9999	9999	9999	9999	9999	4.454702715...	9999	9999
16	25007.2	172.52	4.7	66	9999	17.175...	0.07124...	3	230626.09	268727...	9999	9999	9999	9999	9999	4.453672046...	9999	9999
17	25007.2	172.52	4.7	64	9999	17.264...	0.08889...	3	230629.44	268724...	9999	9999	9999	9999	9999	4.460379016...	9999	9999
18	25007.2	172.52	4.7	64	9999	17.264...	0.08889...	3	230632.79	268722.1	9999	9999	9999	9999	9999	4.467081008...	9999	9999
19	25007.2	172.52	4.7	63	9999	17.264...	0.08889...	3	230636.14	268719...	9999	9999	9999	9999	9999	4.473782975...	9999	9999
20	25007.2	172.52	4.7	63	9999	17.264...	0.08889...	3	230639.5	268716...	9999	9999	9999	9999	9999	4.431463758...	49.87958...	9999
21	25007.2	172.52	4.7	64	9999	17.349...	0.08494...	3	230642.86	268713...	9999	9999	9999	9999	9999	4.395634002...	45.65163...	9999
22	25007.2	172.52	4.7	64	9999	17.349...	0.08494...	3	230646.22	268710...	9999	9999	9999	9999	9999	4.359875144...	41.45258...	9999
23	25007.2	172.52	4.7	64	9999	17.349...	0.08494...	3	230649.58	268708...	9999	9999	9999	9999	9999	4.324116287...	37.29222...	9999
24	25007.2	172.52	4.7	64	9999	17.349...	0.08494...	3	230652.95	268705...	9999	9999	9999	9999	9999	4.297125236...	33.16275...	9999
25	25007.2	172.52	4.7	64	9999	17.435...	0.08584...	3	230656.32	268702...	9999	9999	9999	9999	9999	4.262609092...	29.11795...	9999
26	25007.2	172.52	4.7	66	9999	17.435...	0.08584...	3	230659.69	268699...	9999	9999	9999	9999	9999	4.235629119...	25.17676...	9999
27	25007.2	172.52	4.7	66	9999	17.435...	0.08584...	3.4	230663.07	268696...	9999	9999	9999	9999	48.69748592...	4.202292485...	21.40720...	9999
28	25007.2	172.52	4.7	65	9999	17.435...	0.08584...	3.4	230666.45	268694...	9999	9999	9999	9999	44.40284736...	4.184110355...	17.90529...	9999
29	25007.2	172.52	4.7	65	1	17.522...	0.08751...	3.4	230669.83	268691...	9999	9999	9999	9999	40.13286898...	4.166013971...	14.89287...	9999
30	25007.2	172.52	4.7	66	1	17.522...	0.08751...	3.4	230673.21	268688...	9999	9999	9999	9999	35.89635206...	4.147917438...	12.72250...	9999

Figure 8.1.3 Screen dump of Safety Risk Matrix table (SQLServer name = Road_Safety_Index)

8.2 Computing Risk Index Score

The parameters for computing the risk score for each risk factor can be entered by the user. Click **Risk Parameter** button (toggle on/off) on main form, Figure 8.2.1. Each factor can have up to three range values applied in three boxes along side each risk factor. In the example below, Horizontal Alignment has three boxes with only the first two sets of range values entered;. So, for the first range in the first box, if the value of the radius of curvature lies between 0m to 250m, then a value of 3 (i.e. a high risk rating) is assigned. For the second range in the second box, if the value of the radius of curvature lies between 250m to 750m, then a value of 2 is assigned. The user must enter the lower range value, upper range value and actual risk score as a comma delimited string e.g. **0,250,3**. Note that road risk factors computed for hazards: Trees, Tree Line, Wall Line, Drainage Line & Utility Pole are all summed together and divided by the **Hazard Risk Factor Weighting** which in the example below is 5 i.e. the total number of hazards in this particular example. This weighting value is used to signify the possible lower contribution of hazards when computing the overall risk index score and should be applied at the discretion of the user. In reality, there are, of course, more hazards than just these five and any one factor can have a different contribution to risk depending on location and proximity to other risk factors. These five hazard factors together with a nominal weighting of 5 are used as a representative sample.

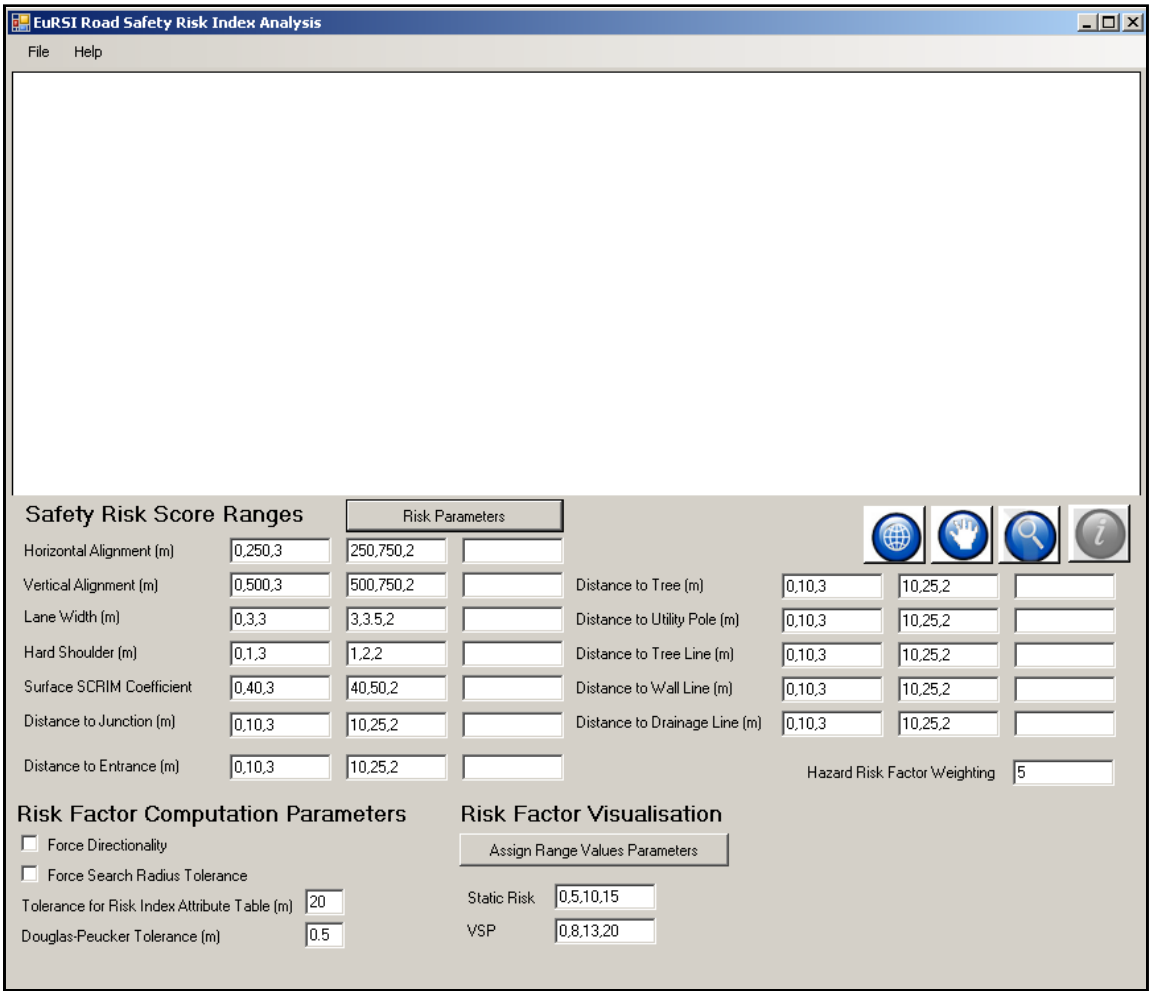


Figure 8.2.1. EuRSI software application displaying Risk Paremeters for Risk Score Analysis.

One of the conclusions, from deliverable D3.2 Risk Assessment Review, focused on the need to highlight and explain risk within the context of an RSI in a meaningful and timely fashion. The goal here should not be an absolute quantifiable risk score which is very difficult to produce in any case but rather an index of risk that can be easily computed, visualised and queried by the user. This is why a road risk index score was computed using simple rules which can be changed by the end user. In this application, the model is very simple and is based on sever intrinsic road risk factors (H_{ROC} ,V_{ROC}, W, HS, RS, J & E) and five road side hazards (T, TL, DL, WL, UP) which are weighted by factor HW. The Index score is computed as follows:

Road Risk Index Score$_{XY}$ = (H_{ROC} + V_{ROC} + W + HS + RS + J + E) + (T + TL + DL + WL + UP) / HW

H_{ROC}	:	Horizontal Radius of Curvature
V_{ROC}	:	Vertical Radius of Curvature
W	:	Width
HS	:	Hard-Shoulder
RS	:	Road Surface (SCRIM)
J	:	Junction

E	:	Entrance
T	:	Large Tree
TL	:	Tree Line
DL	:	Drainage Line
WL	:	Wall Line
UP	:	Utility Pole
HW	:	Hazard Weighting

The user can compute this risk index score by clicking File, Compute Risk Index Score