ERA NET Road

Safety at the heart of Road Design

Final Workshop

EuRSI

13th January 2012

Stockholm, Sweden

Tim McCarthy

National University of Ireland Maynooth

Partners

National University of Ireland Maynooth (Coordinator)

ITC, University of Twente, The Netherlands

Nast Consulting GmbH, Austria

IBI Group, UK

Pavement Management Services, ireland

Project Objectives

- Investigate latest mobile mapping based approaches to help automate route corridor data acquisition and processing
- Explore the role of both intrinsic and transient factors together with latest computational techniques for assessing risk within the context of a road survey inspection
- Encourage wider EU stakeholder participation and engagement in adopting a common approach through review of existing RSIs, Risk assessment methodologies and road testing

Milestones

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

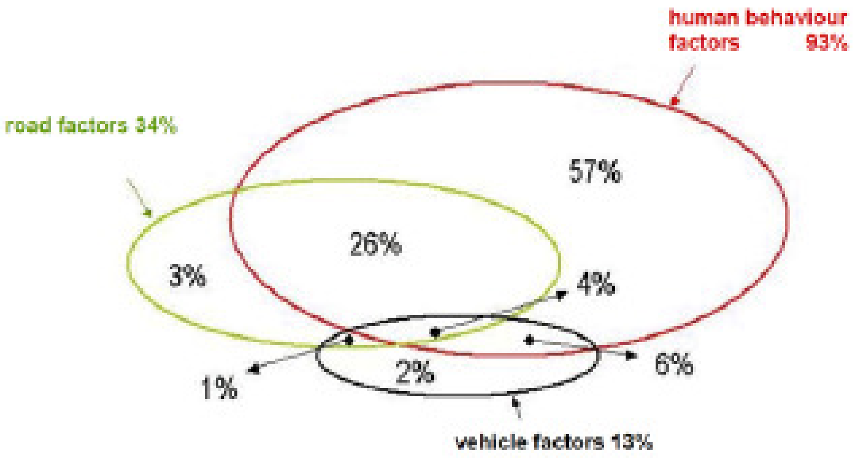
Deliverables

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

Road Safety Risk

Nature of Risk along road networks - can be described using various criteria/categories

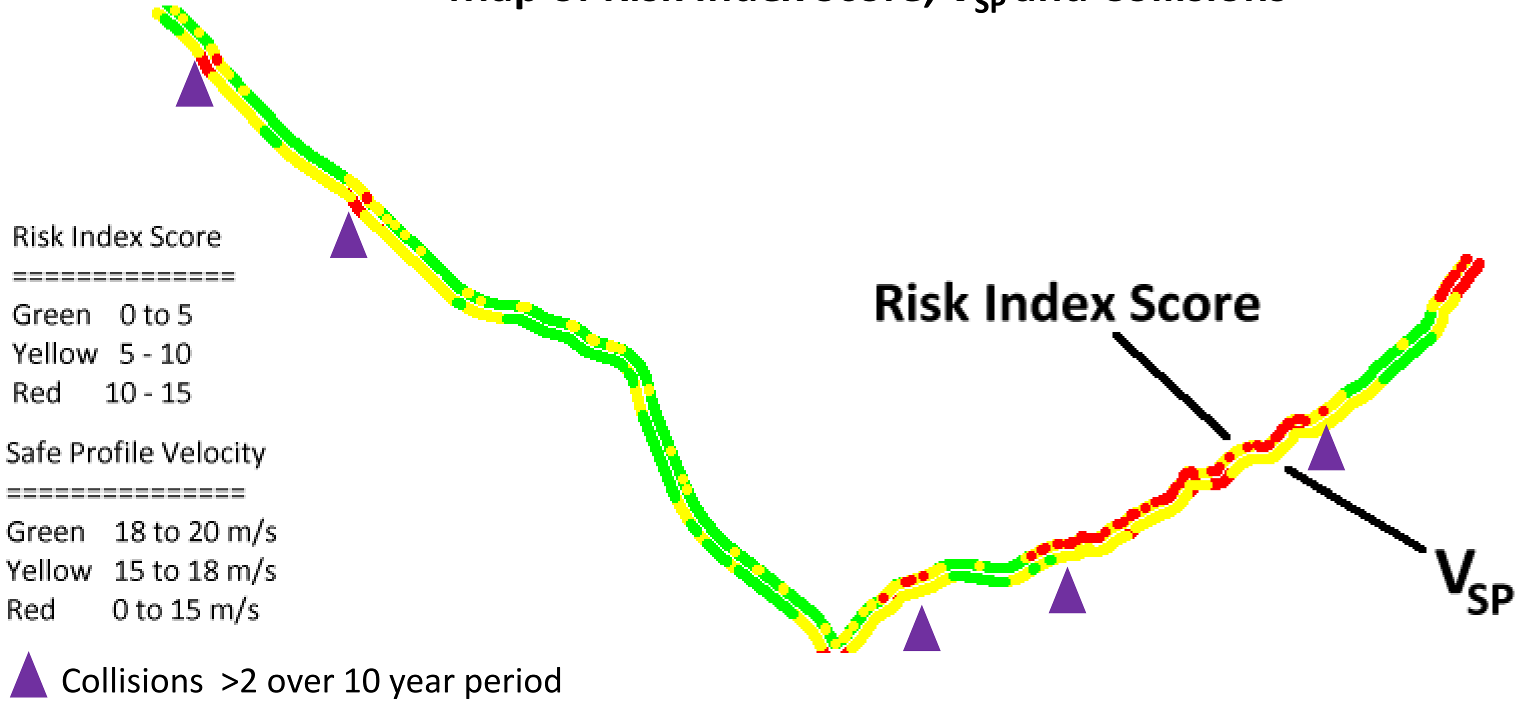
- Causative, Severity, Exposure
- Road environment, vehicle & driver behaviour
- Spatial & temporal
- Static & dynamic
- Historic & predictive
- Continuous & discrete
- Permanent & transient
- Single & multiple
- Explained & un-explained
- Point, linear, areal, directional



PAIRC 2007

EuRSI Output : A novel computational approach for highlighting and explaining risk within the context of RSI

Map of Risk Index Score, V_{SP} and Collisions



Project Overview

1. Understand **contemporary approaches to RSI** in Europe and further abroad
2. Research new road mapping **methodologies using mobile mapping technology**
3. Review various **risk assessment methodologies & new approaches** to assessing risk within the **context of RSI**
4. Produce **software toolkit** that would enable end-users carry out **risk analysis**
5. Test the approach using road data and report initial findings

1. Road Safety Inspection Review - Recommendation

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

2. Mobile Mapping technology for road network surveying

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

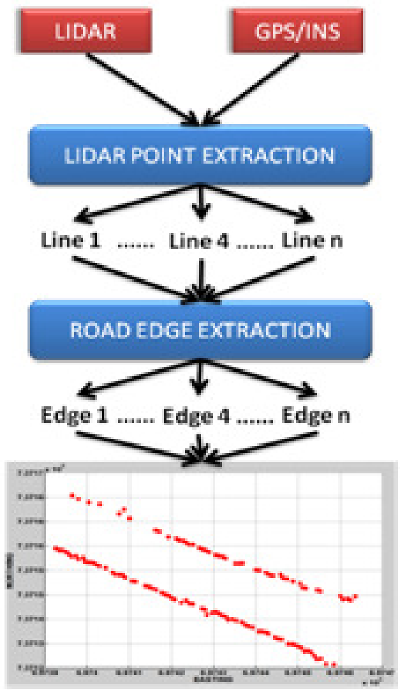
IXSEA LANDINS specifications.

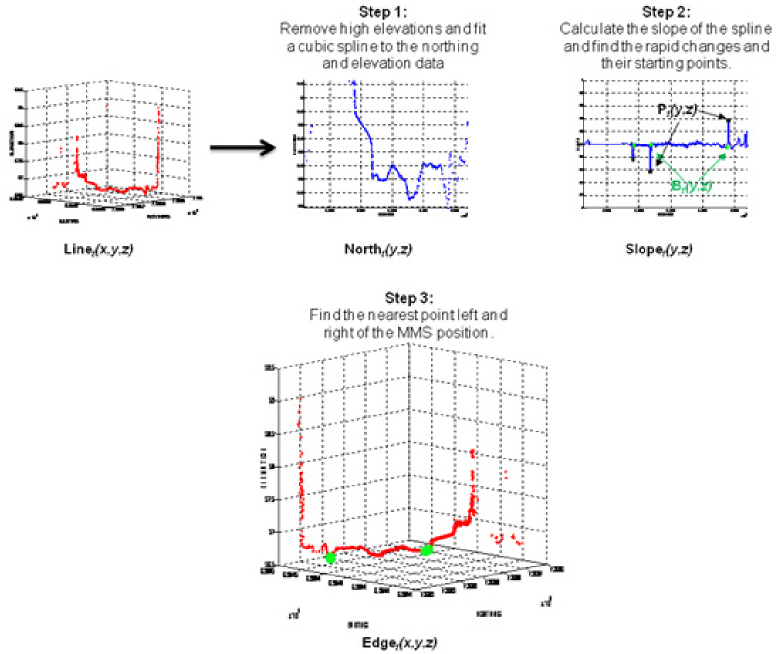
Measurement rate	300kHz
Minimum Range [m]	1.5
Accuracy [m]	0.01
Precision [m]	0.01
Intensity	16 bit
Field of View [deg]	360
Scan Speed	100Hz
Wavelength	1550*nm*

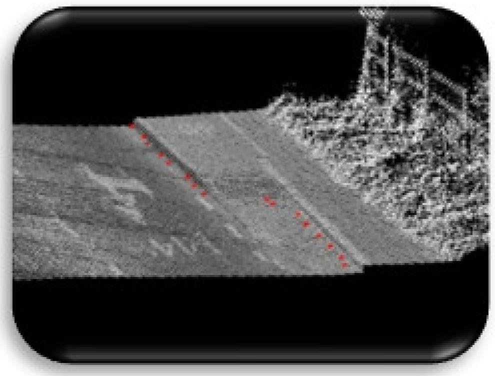
Riegl VQ-250 specification.

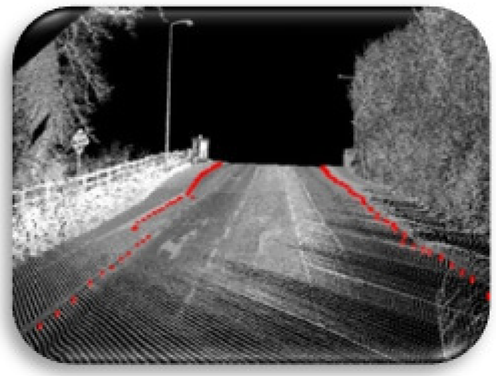
Acquires >20GB/hr

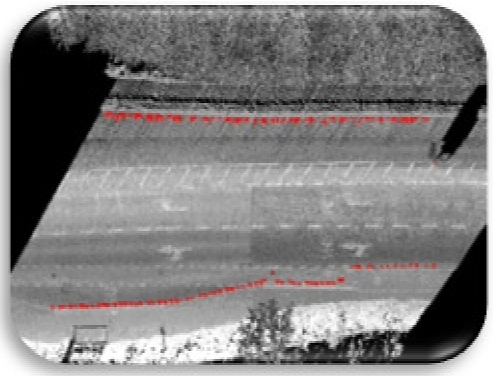
2. LiDAR – Road Edge Feature Extraction







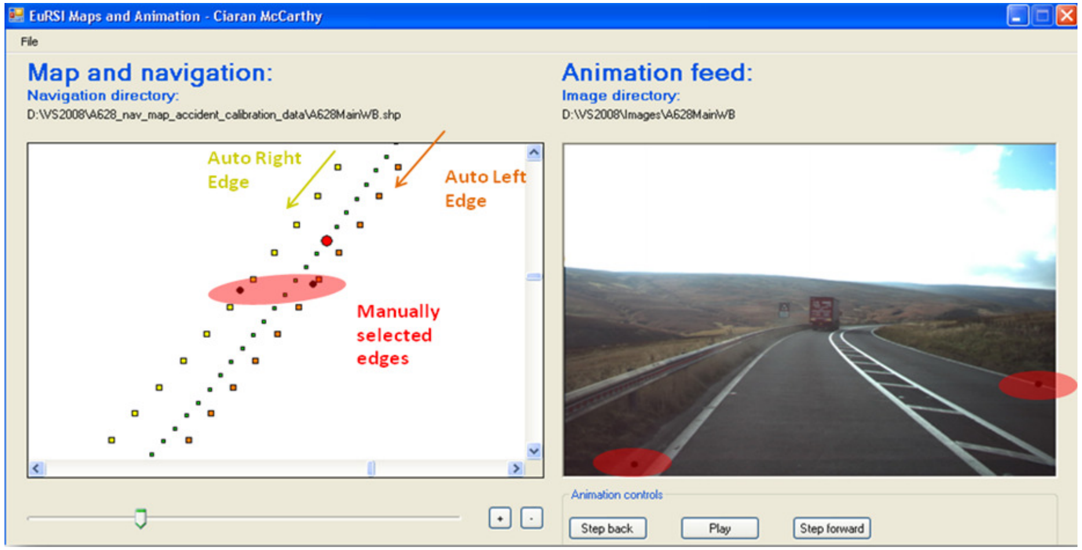




EuRSI European Road Safety Inspection

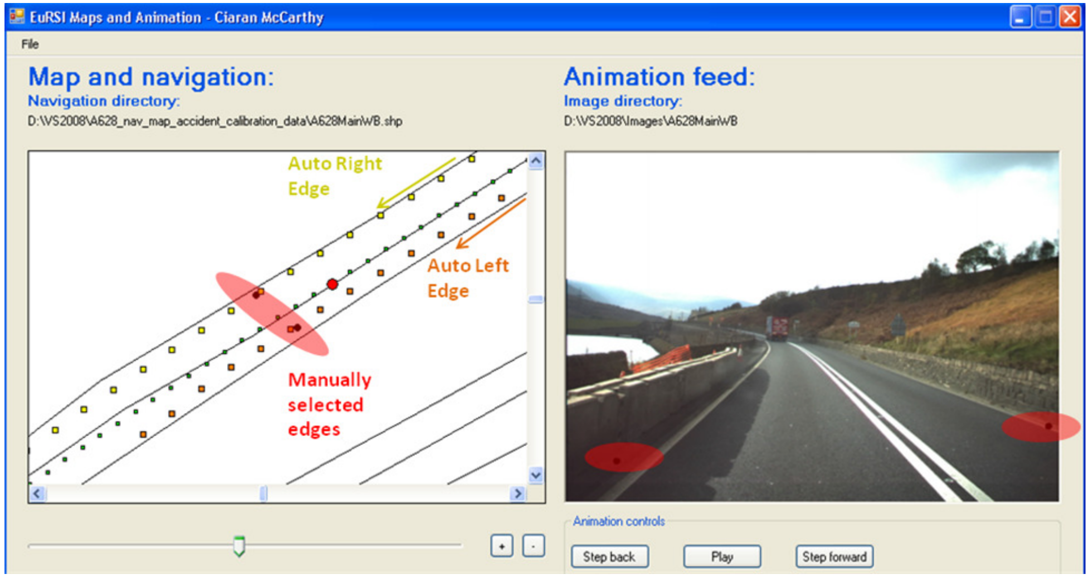
road ERA net

2. LiDAR – Road Edge Feature Extraction

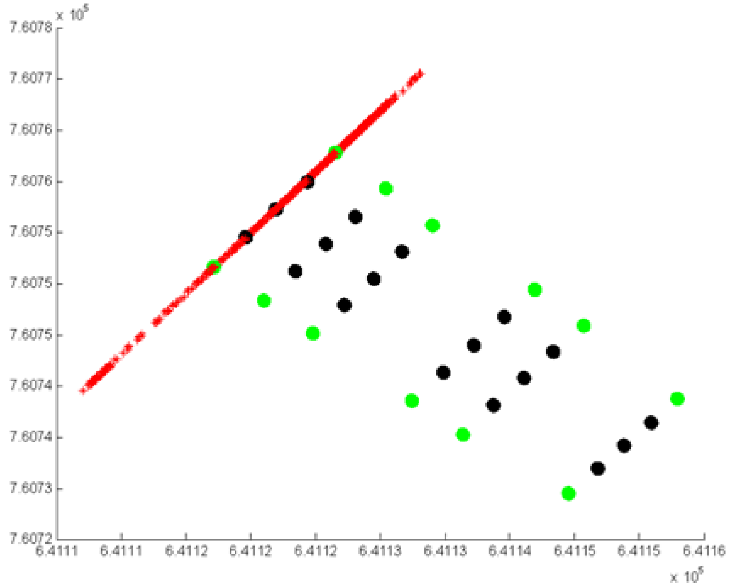


Grass Edges, highlighted in red are the manually selected road edges from the imagery in the right panel which are plotted in the map in the left panel, in yellow is the automatically extracted right edge and orange the automatically extracted right edge

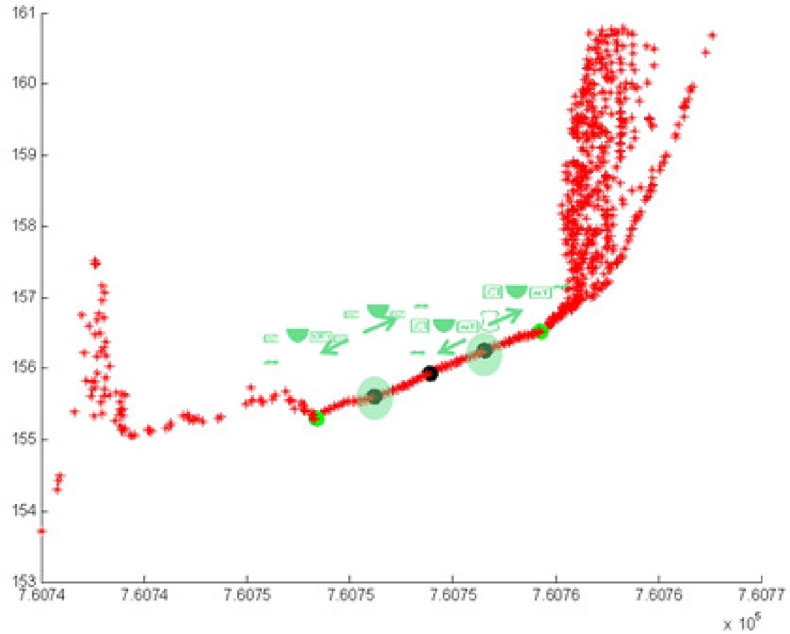
Wall edges, highlighted in red are the manually selected road edges from the imagery in the right panel which are plotted in the map in the left panel, in yellow is the automatically extracted right edge and orange the automatically extracted right edge



2. LiDAR – Road Edge Feature Extraction – Cross-section



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



Horizontal road slope for a road cross section of the N4 in Ireland

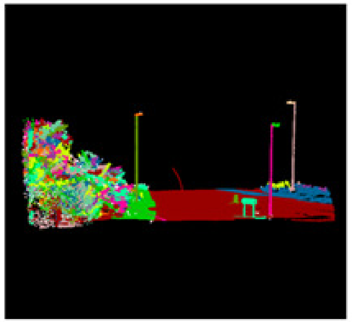
2. LiDAR – Road Side Features (Pole Objects)

(a)

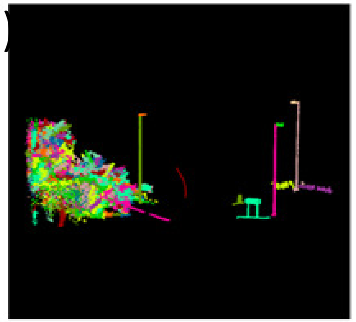
(b)

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

(c)

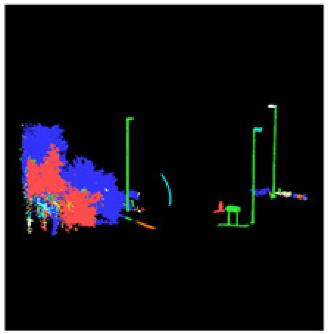


(d)



Result after the application of (c) the **region growing algorithm** and (d) after the removal of the ground regions

(e)



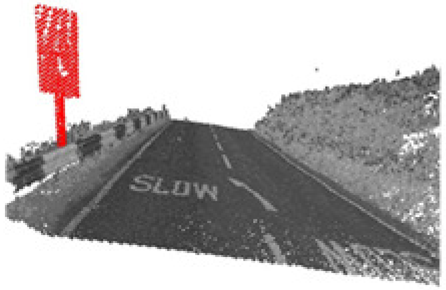
(f)

Result of **clustering the regions into (e) objects** and (f) after recognition of pole-like objects

2. LiDAR – Road Side Features (Pole Objects)

(a)

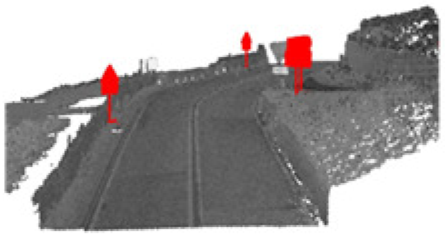
(b)



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

(c)

(d)

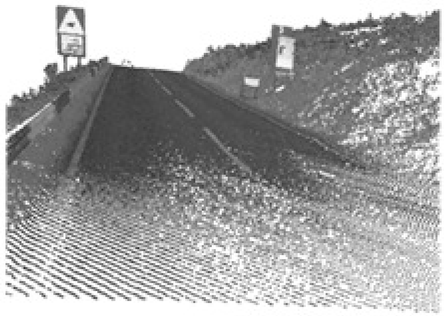


Example of multiple signposts detected including a double based pole, (c) imagery of scene and (d) LiDAR with highlighted extracted poles

2. LiDAR – Road Side Features (Pole Objects)

(a)

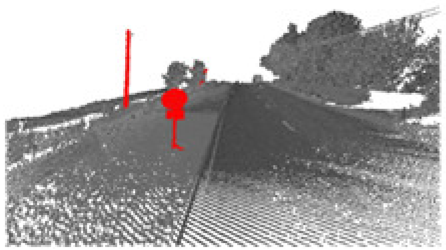
(b)



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

(c)

(d)

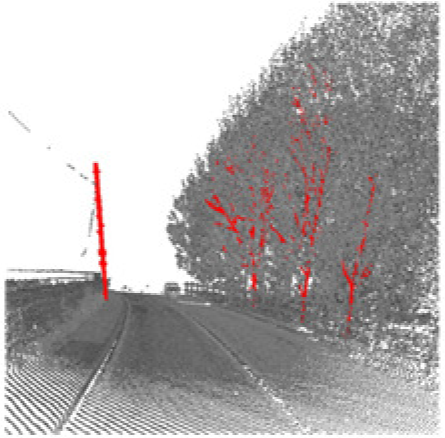


Example of telegraph pole detection and also **foliage occluding the detection of other telegraph poles**, (c) imagery of scene and (d) LiDAR with highlighted extracted poles.

2. LiDAR – Road Side Features (Pole Objects)

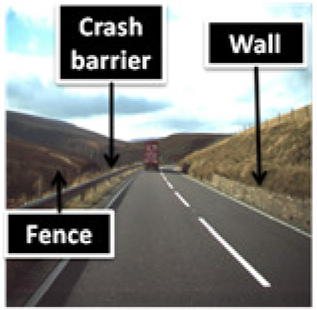
(a)

(b)

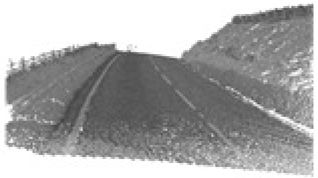


The detection of individual tree trunks is hampered due to the concentration of tees in an area and dense foliage, (a) imagery of scene and (b) LiDAR with highlighted extracted poles.

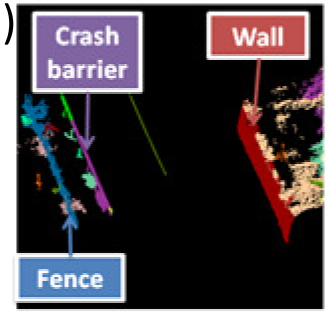
(c)



(d)



(e)



Example of a road section with multiple linear features, (c) imagery, (d) LiDAR and (e) output objects after rough classification

2. LiDAR – Results

Feature-type	Detection Rate	Comment
Single base road signs	70%	Problems when sited near vegetation & other objects
Utility Pole eg Power & Telephone Poles	60%	Problems when sited near vegetation & other objects
Trees	Low	Dense foliage
Linear Objects eg Walls and guardrails		Preliminary test ing, in-sufficient data
Road Edge	**85% - 100%**	**Left edge (closest to the vehicle) produced higher classification rates than further right edge of road**
Road Cross section	**100%**	**Dependent on successful delineation of road edge**

3. Risk Assessment Review - Statistical Modelling

- Statistical modelling can be broadly grouped into **global and more localised**, collision specific accident prediction or safety risk modelling.

- The advantages of statistical modeling within safety risk assessment are countered by the **complexity** and often **site or scenario specific nature** of the results produced by these algorithms.

- **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.

3. Risk Assessment Review - Accident database

- 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 location**, identified by the number and severity of accidents.
- Accident data can also be used to help **prioritise remedial actions** by the Network Safety Manager.

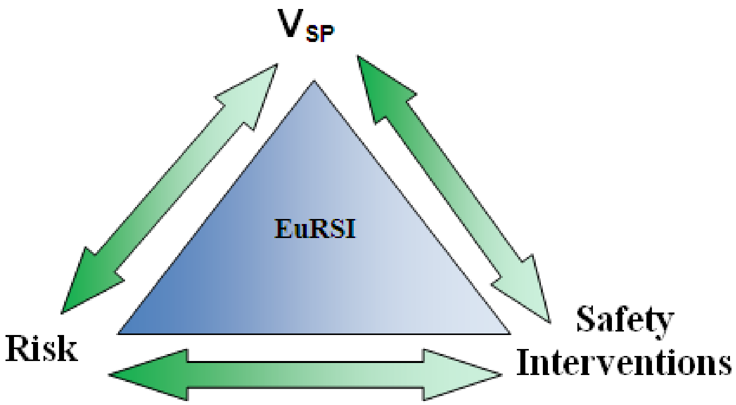
Findings from D3.2

3. RSI Risk Assessment Framework

Requirements:

- 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.
- 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 **safe profile velocity (V_{SP})** in assessing risk.

3. RSI Risk Assessment Framework – Safe Profile Velocity V_{SP}



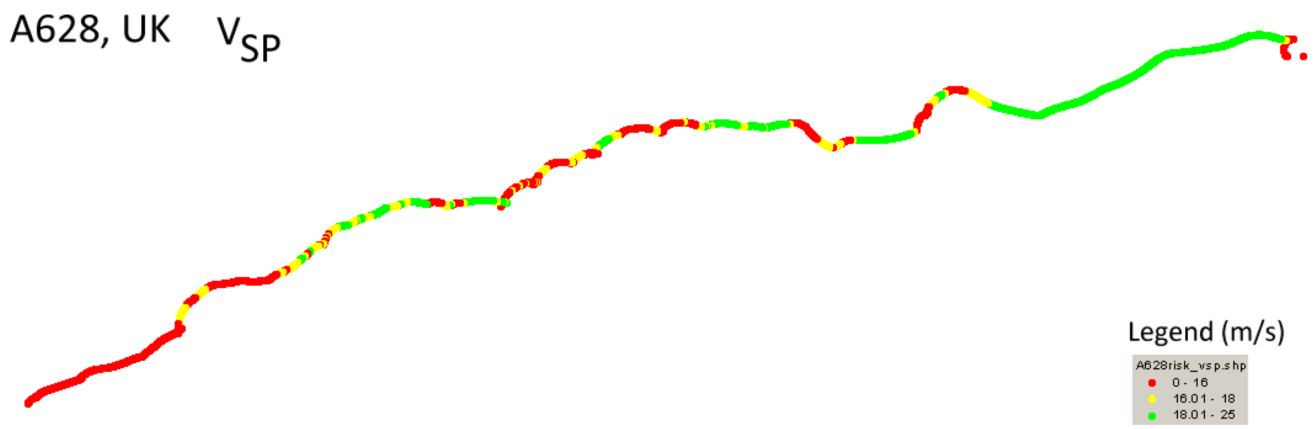
•Risk factors, as they pertain to RSI, can be discrete or continuous, static or transient*, singular or multiple but the overall interaction is dynamic in nature.

•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**, **Mitigation** (safety features in place or required) together with **V_{SP}**, (everyday, typical, average driver response)

***transient factors** include various categories from traffic to weather conditions, and require additional technologies to measure and record so, will not be treated here but need to be acknowledged within the overall context of risk assessment

3. RSI Risk Assessment Framework – Safe Profile Velocity V_{SP}



- This data is recorded using onboard GPS under typical (daylight, fair weather, free-flow) conditions, low driver work-load, 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.

- Transient events e.g. sudden braking at a junction can be removed using imagery from mobile mapping system as well as events logged by driver

- 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.

3. RSI Risk Assessment Framework

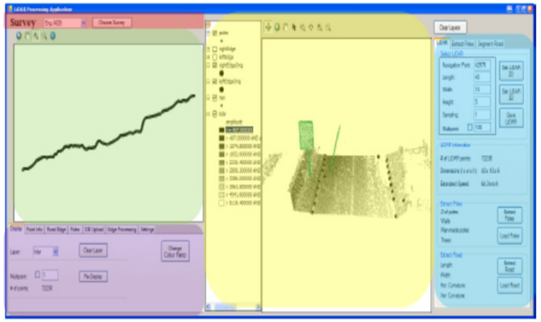
- A novel framework is proposed for risk assessment in the context of RSI incorporating data from **1) road factors, 2) V_{SP} and 3) accident database**.

- Three integrated levels (examining road factors, V_{SP}, and collisions) of processing enables **safety risk can be detected and explained** using an evidence based safety engineering system.

- Enhancements could include addition of existing **safety interventions can be incorporated** to determine whether any risk posed is adequately managed

4. EuRSI Software Toolset Overview

LiDAR Processing



Road Feature Classifier

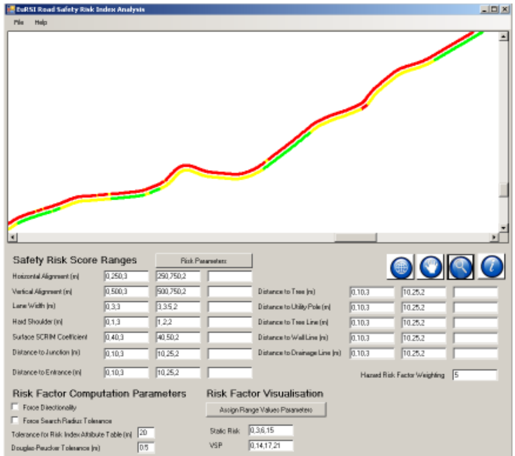
Existing Road Survey Data

- GPS Survey
- Alignment
- Cross-section
- Asset Inventory
- Surface Condition
- Topology
- etc

Road-geometry

Road-geometry, Road-side Features & V_{SP}

Road-geometry, Road-side Features, & Pavement Condition



Safety Risk Analysis

Decision Support Outputs

- Highlight Risk
- Query Risk Factors
- Compare with V_{SP} & Collisions
- Compare with existing safety features
- Better understanding of Risk
- Output Risk Maps

4. EuRSI Software Toolset Overview

Details of data sources and outputs for various software modules and databases

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}

4. EuRSI Software Toolset Overview

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

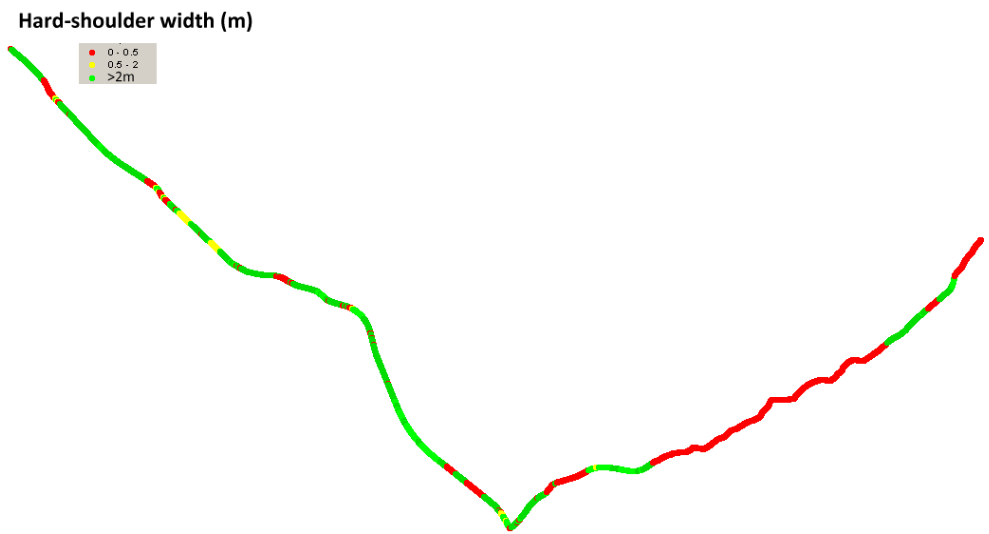
Data Collation

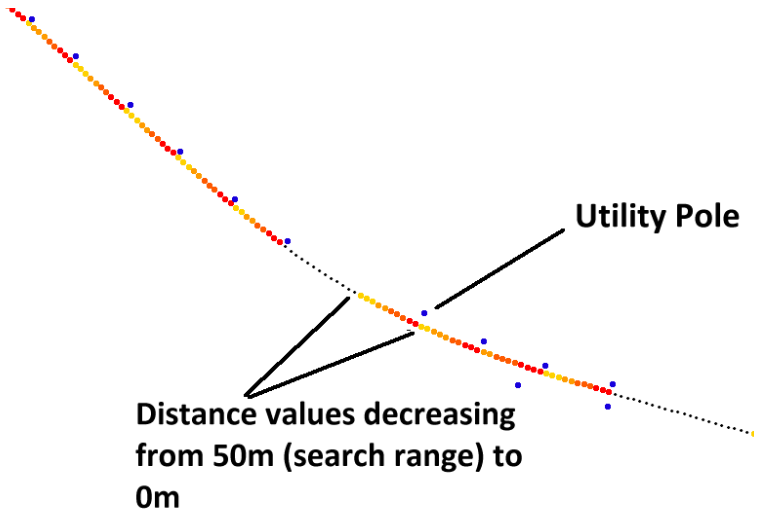
- Collate additional datasets such as collisions and road surface condition from external sources

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

4. EuRSI Software Toolset Overview – Pre-processing Risk Factors





4. EuRSI Software Toolset Overview – Pre-processing Risk Factors

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

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)

4. EuRSI Software Toolset Overview

Road Risk Index Score represents the number of risk factors, each having a nominal risk score, detected at any one sample location

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

XY		Sample point location
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

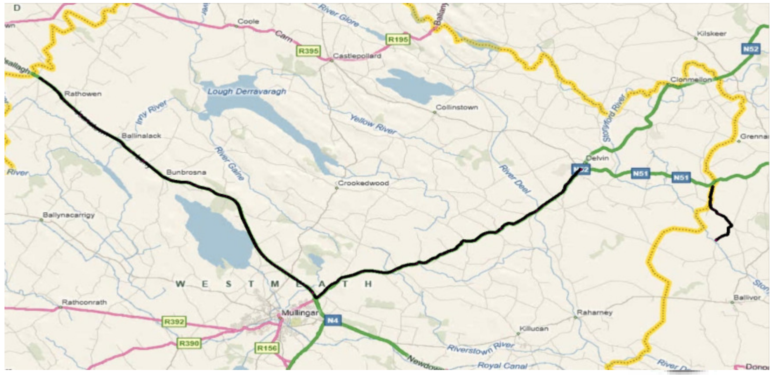
4. EuRSI Software Toolset Overview

Range Value calculation for visualisation

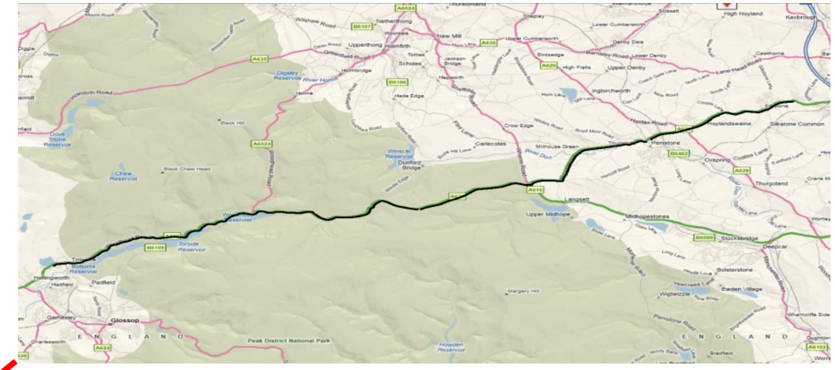
Risk Indicator	Colour	Risk Rating	Lower bound	Upper bound
Risk Index Score Computed from 12 Static Risk Factors	Green	Low	0	5
	Yellow	Medium	5	10
	Red	High	10	25
Safe Profile Velocity V_{SP} meters/second	Green	Low	18	25
	Yellow	Medium	16	18
	Red	High	0	16

5. Testing & Results

Three test-sites were chosen



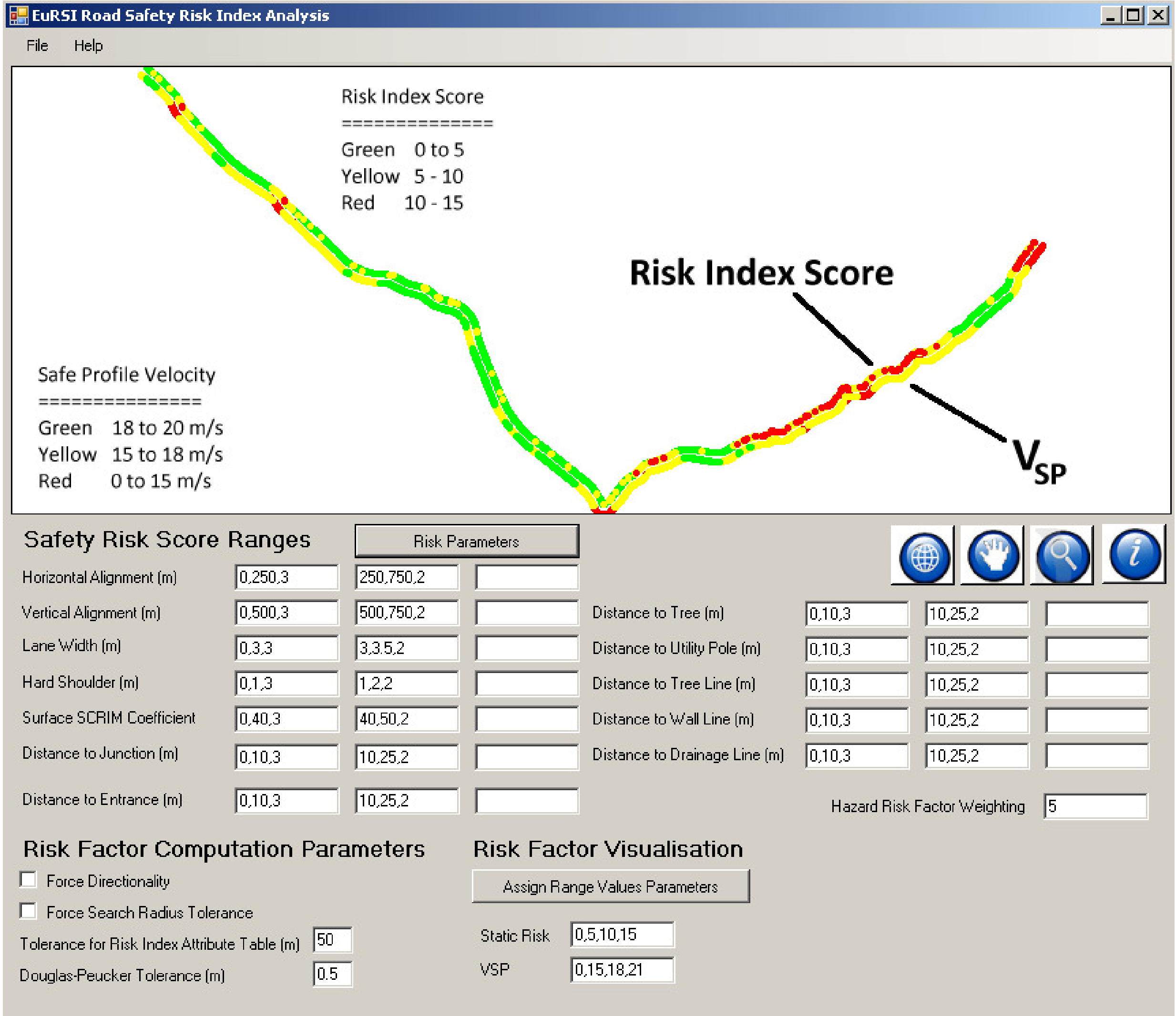
Longford-Delvin, Ireland



A628, North England

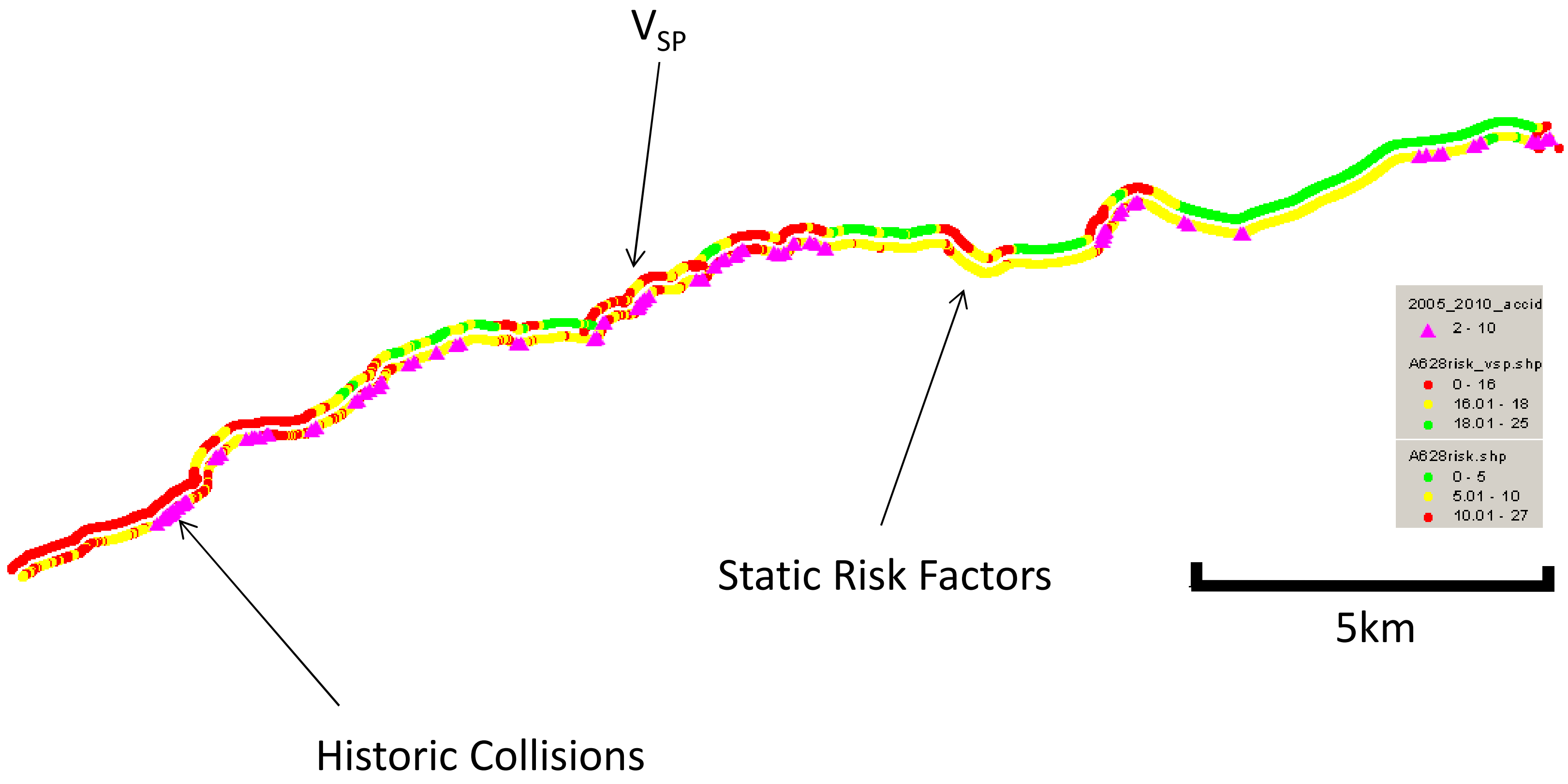
A435 Gloucestershire, England

5. Testing & Results



5. Testing & Results

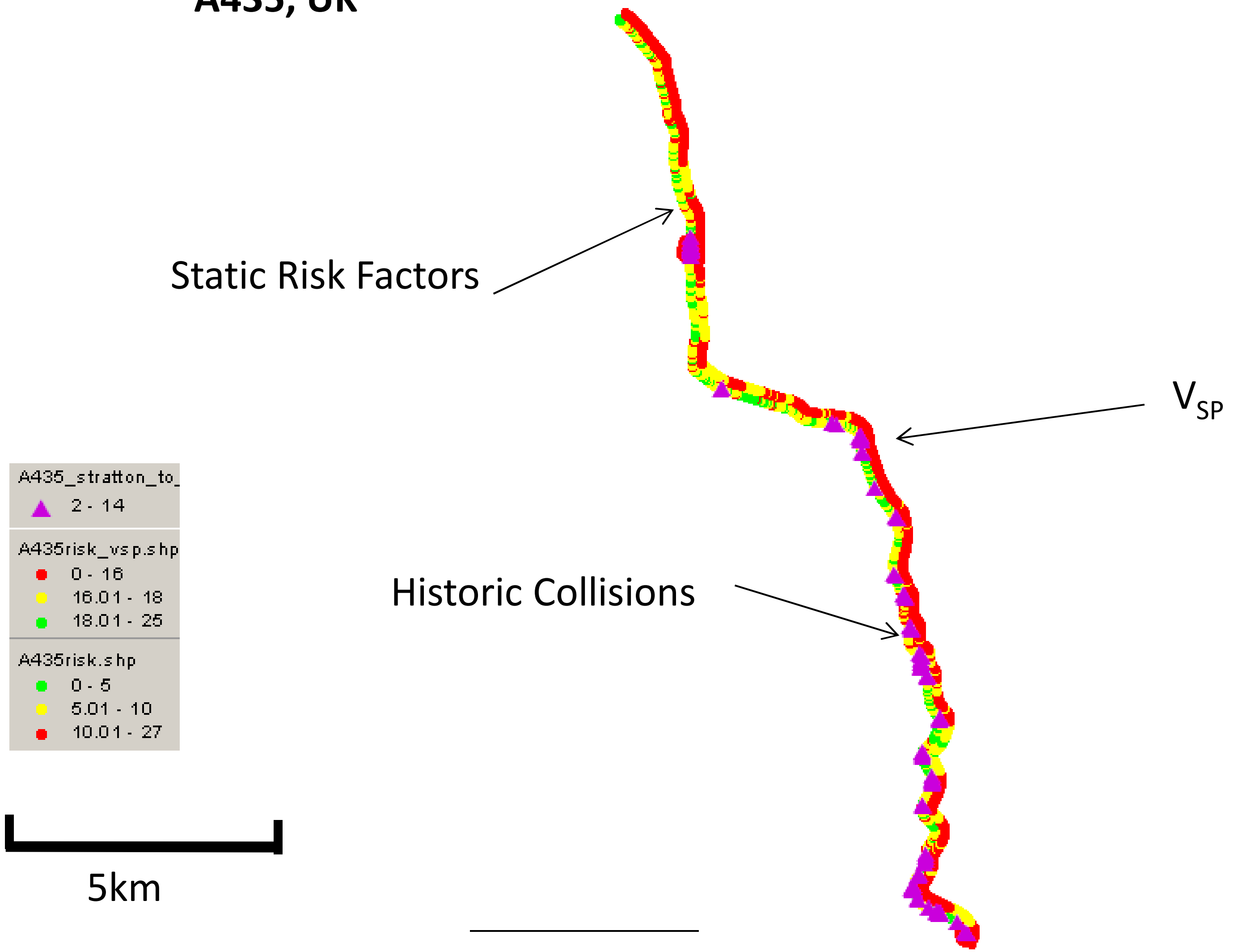
A628, UK



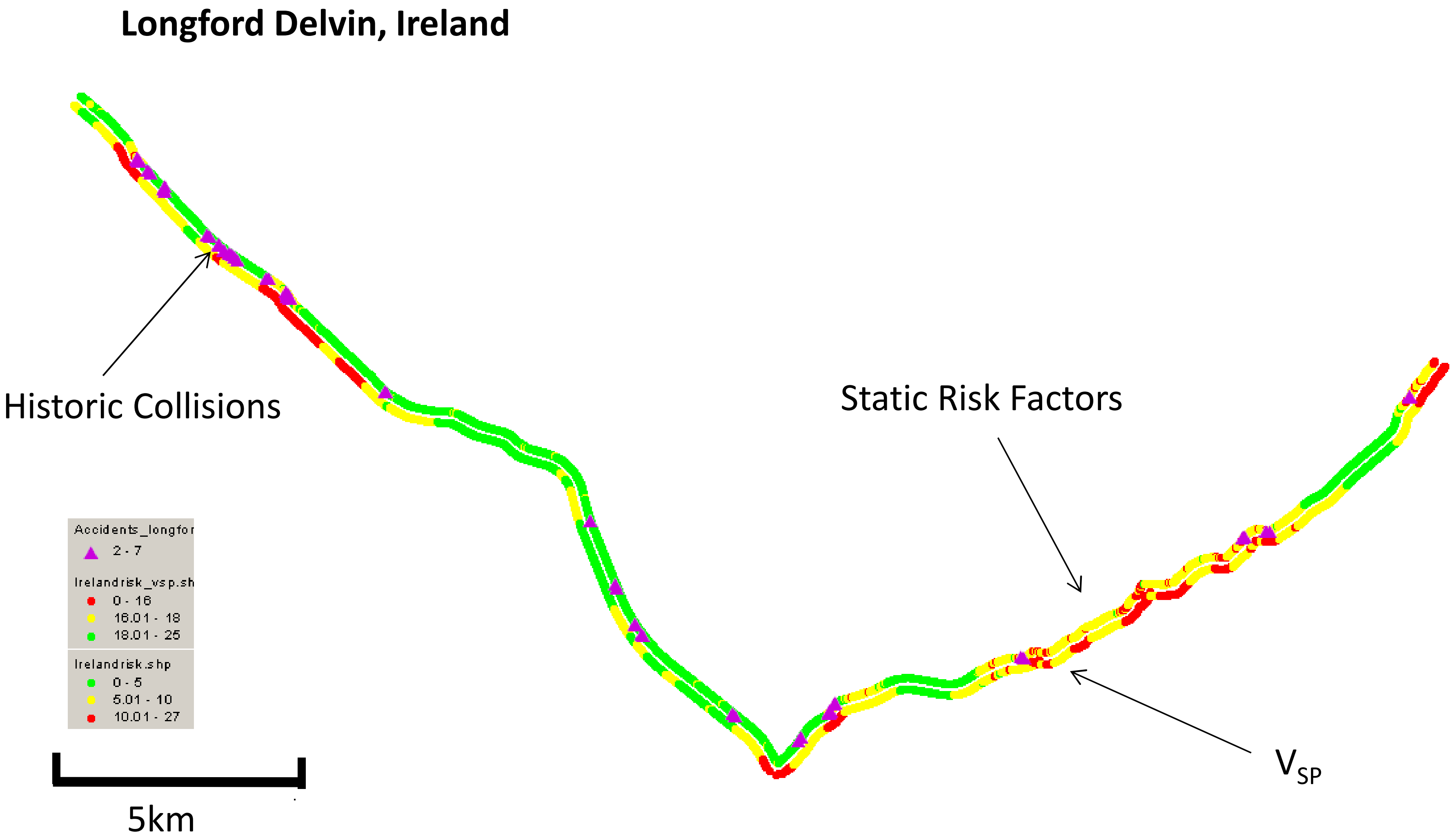
•Ensuring acquisition of an accurate VSP (good weather, illumination and traffic-free conditions)

5. Testing & Results

A435, UK

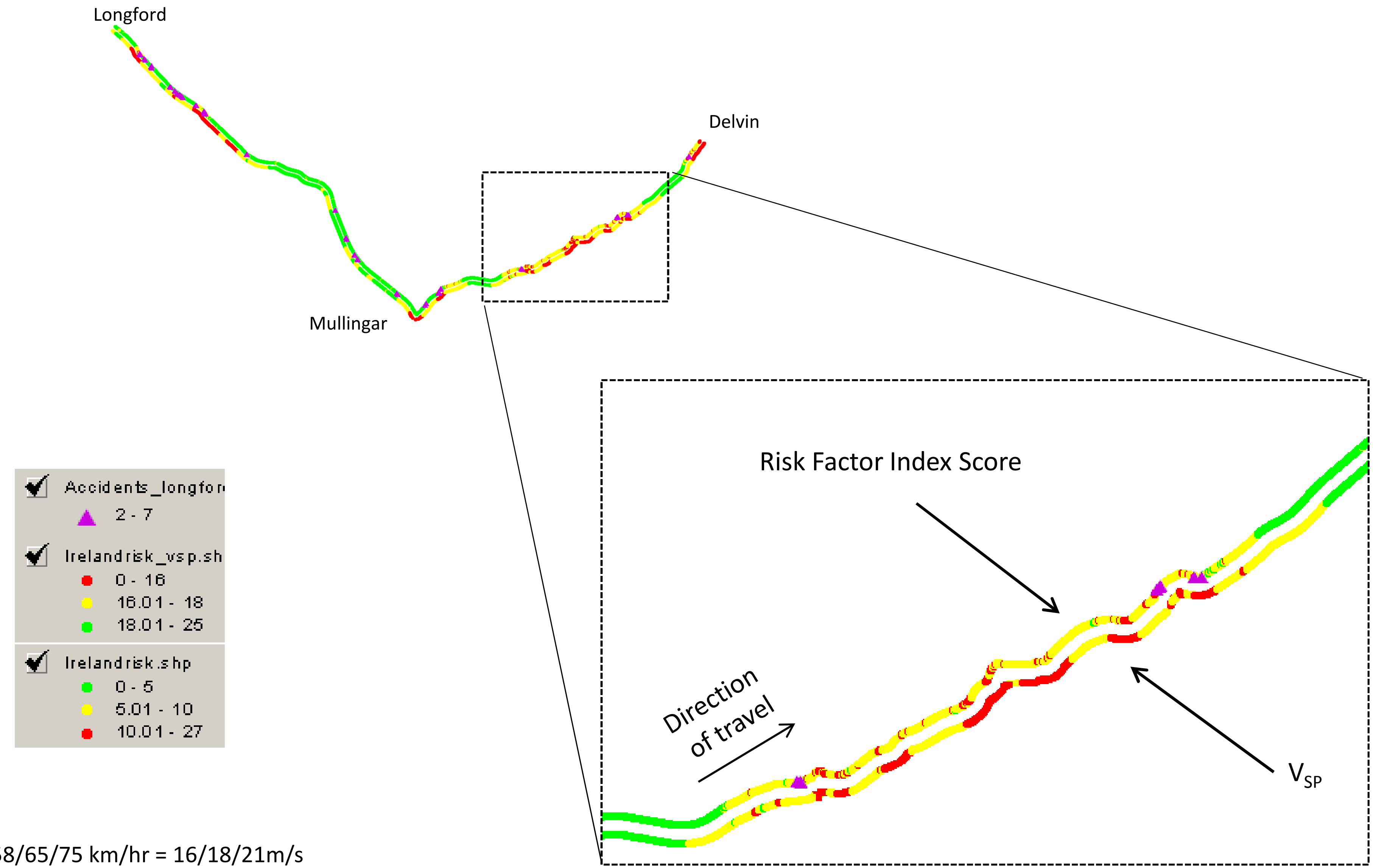


5. Testing & Results



5. Testing & Results

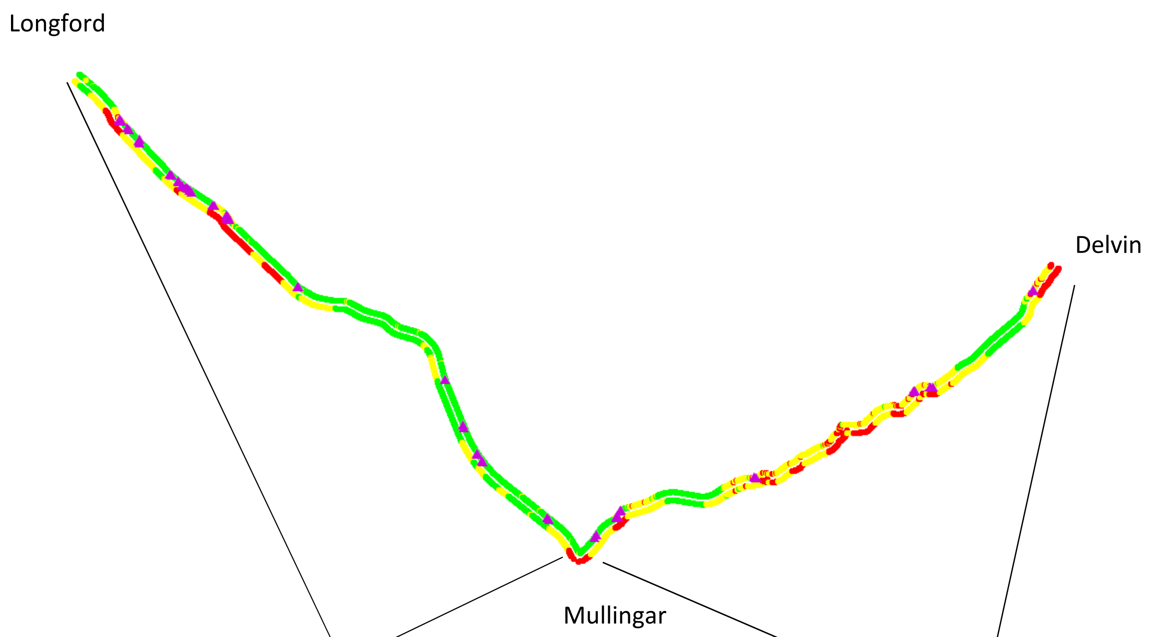
Longford Delvin, Ireland



58/65/75 km/hr = 16/18/21m/s

5. Testing & Results

Longford Delvin, Ireland

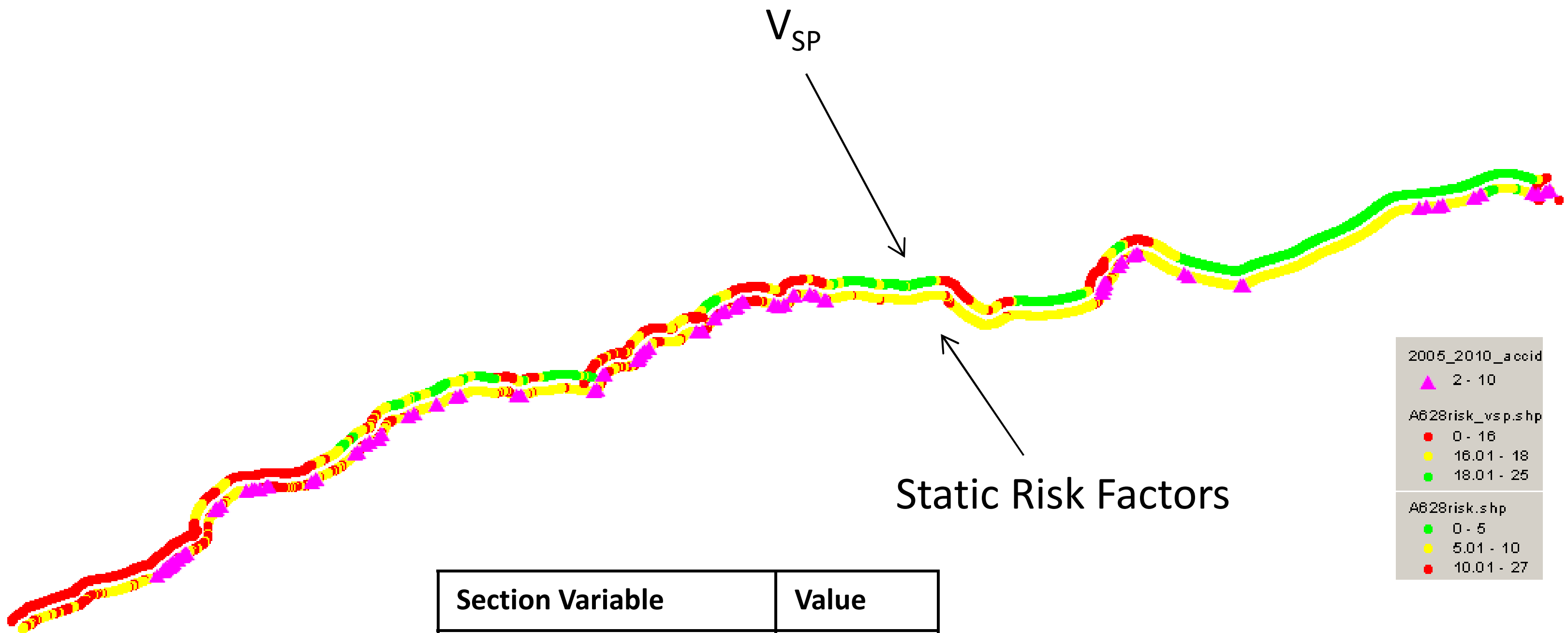


Section Variable	Value
Length	22.1km
Total Index Score	8123
Average Index Score	1.6
Av. Speed m/s (km/hr)	**17.3(62.3)**
Av. Index Score/km	**367.6**
# of Collisions (>=2)	**46**

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**

5. Testing & Results

A628, UK



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**

*Collisions 2005 - 1010

5. Testing & Results – Caveats

•Comprehensive rule base for choosing risk scoring parameters that are based on road safety engineering principles. This rule base should also take into account the notion of *change zones* rather than absolute location of risk eg transition from a straight to a bend.

•Risk generally occurs over a linear or areal extent and is not simply a single location

•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 (indicative) 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

Project Outputs

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

Further Research

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

Sampling. Should risk be computed over a linear/areal range rather than discrete point sources, highlighting change e.g. straight/curve transition

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

Further Research

Safe Profile Velocity V_{SP}

This technique should be improved to ensure adherence to average driving profile under good conditions and low driver work-load. This methodology should be checked for quality including accuracy, & repeatability. Acceleration should also be examined in more detail to decide best approach in including this variable to producing a more comprehensive figure

V_{SP} could also be used to ***normalise*** the search tolerance distances used to identify location of risk factors

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.

One suggestion

Online pan-European Road safety Risk Analysis Platform

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

•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.

End