Risk-Based Geometric Design for Road Improvements

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28th September 2018

TII National Roads Conference 2018

Context & The Challenge for Road Network Management

TII Strategic Goal

Secure the provision,
maintenance and operation of
<u>safe, efficient and sustainable networks</u>
of national roads, light rail and metro.

Road Network Management

Context & The Challenge for Road Network Management

1.	National Road Network Length	= 5,300 km	
2.	Motorway Network	= 900 km	
3.	High-Quality National Primary Roads	= 1,350 km	
4.	**Low-Quality National Primary Roads**	**= 400 km**	
5.	**National Secondary Road Network**	**= 2,650 km**	**Mostly legacy roads**
6.	**Legacy National Road Network**	**= 3,000 km approx.**	**57% of Total**

"Legacy Roads" are very variable and inconsistent in quality.

Upgrade of existing single carriageway roads would cost typically €5m/km.

A full upgrade programme of the legacy National Road Network would cost €15 billion !!

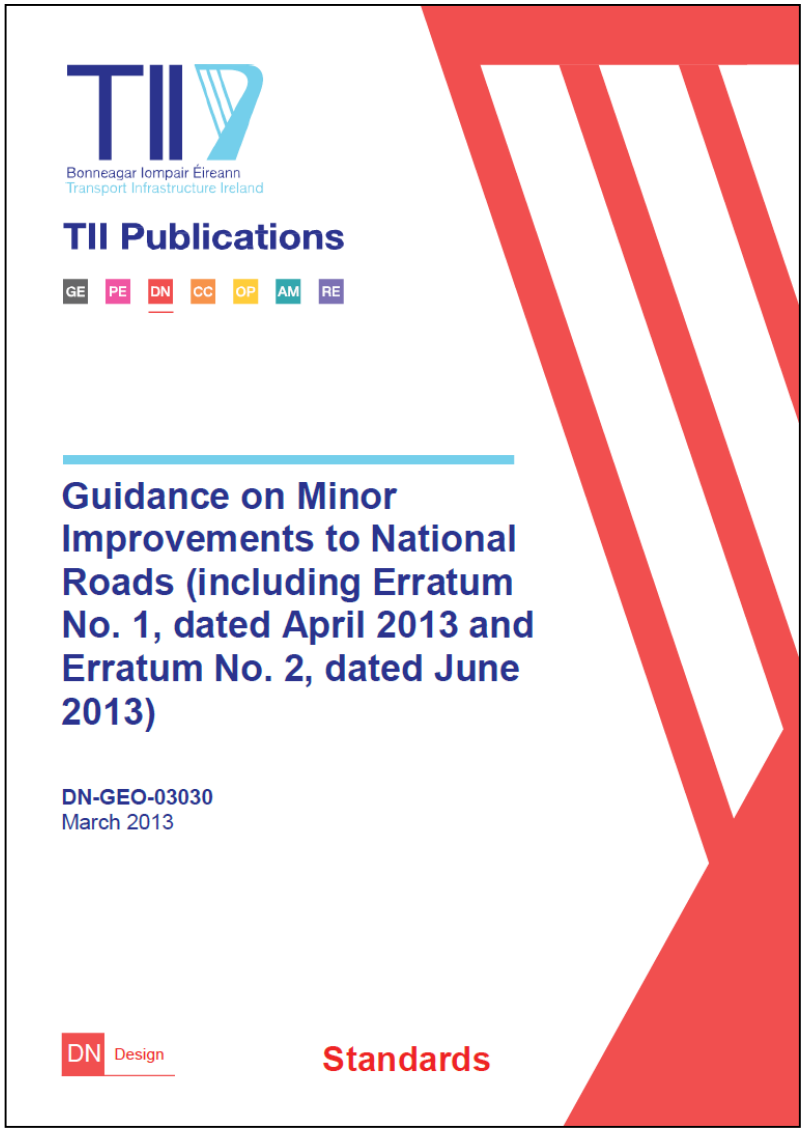
How can the asset be managed for improved performance in a sustainable and cost effective manner?

Road Design Standards

Transport Infrastructure Ireland
Publications

DN-GEO-03030 (Former TA 85)
Guidance on Minor Improvements to National Roads

DN-GEO-03031 (Former TD 9)
Rural Road Link Design



Road Design Standards

DN-GEO-03030 Guidance on Minor Improvements to National Roads

Objectives of Minor Improvements Schemes:

Example: Removal of a sub-standard bend. Which Bends?

"Achieve a localised improvement appropriate, and consistent with the characteristics of the adjacent sections of the route …."

Primary focus is to Manage the Asset:

Maximise Performance & Minimise Collision Risk

"Many roads in Ireland are legacy roads with sub-standard design features… upgrade some, but not all these existing deficiencies within environmental & budget constraints."

Road Design Standards

DN-GEO-03031 Rural Road Link Design

Relaxations for Horizontal Curvature

3 Steps for Type 2 Single

4 Steps for Type 3 Single.

On what Basis to select? Justification?

a) What is Consistent in terms of curvature?

b) How can Safety Benefits be characterised and evaluated?

c) Risk Transfer if a road is improved at too high a standard locally?

d) How much improvement is "enough" over cumulative schemes?

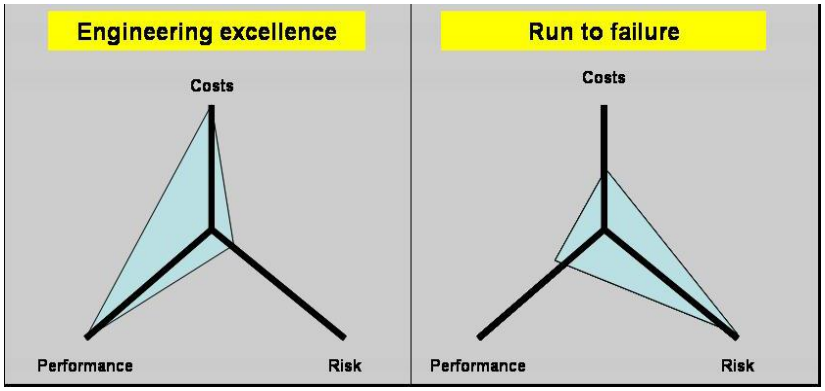
RibGeom

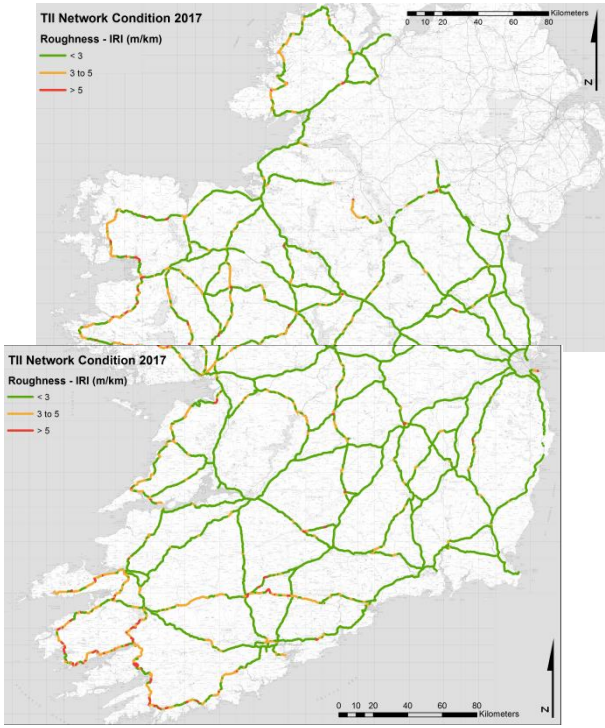
A New Approach to Appropriate Application of Road Design Standards

Risk-Based Geometric Design

A Risk Assessment tool:

1. Risk Based Asset Management – Optimised Performance / Cost / Risk
2. Identify the most critical locations for risk
3. Examine the causes of risk
4. Assess potential improvements
5. Risk Based Prioritisation
6. Inform network improvement strategies
7. Inform design standards





Risk-Based Geometric Design

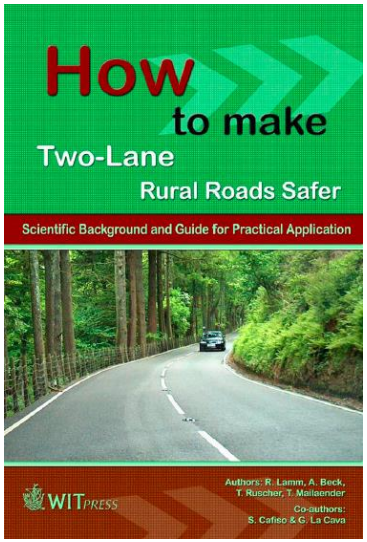
Design consistency
The conformance of a road's geometric and operational features with **driver expectancy**.

Driver's expectancy
Readiness to respond to situations, events, and information in predictable and successful ways

Geometric inconsistencies
Surprise the driver and reduce the safety of the road.

Geometric - Risk Analysis Model – International Best Practice

Germany
(Lamm, et al., 2007)

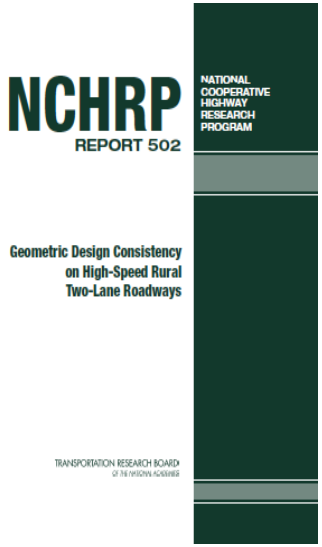


Speed

USA
American Society of Civil Engineers
(Gibreel, et al., 1999)

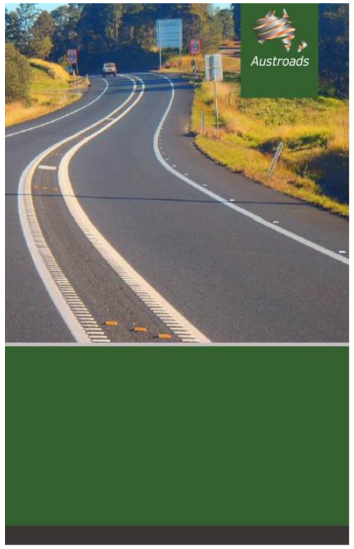
Stability

USA
National Cooperative Highway Research Program
(NCHRP, 2003)



Visibility

Australia
(Austroads Ltd., 2015)



Alignment

USA
Federal Highways
(Messer, et al., 1981)

Workload

Geometric - Risk Analysis Model

➢ Risk Analysis Model

A model has been created to define the **overall geometric risk of 7 elements**:

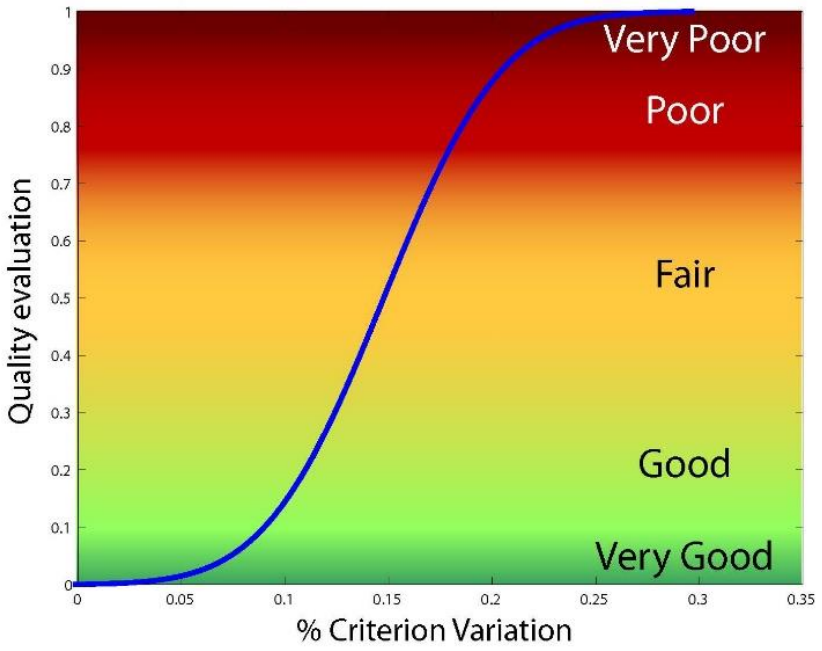
1. **Speed Variation: Design Speed**
2. **Speed Variation: Operating Speed**
3. **Alignment: Horizontal Curvature**
4. **Vehicle Stability: Side Friction**
5. **Alignment: Vertical Curvature**
6. **Sight Distance**
7. **Driver's Workload (How alert and Active must they be)**

$$M_i = w_1 \cdot Q_{C_{I\,i}} + w_2 \cdot Q_{C_{II\,i}} + w_3 \cdot Q_{C_{III\,i}} + w_4 \cdot Q_{SSD_i} + w_5 \cdot Q_{CRR_i} + w_6 \cdot Q_{VRR_i} + w_7 \cdot Q_{Wl}$$

Geometric - Risk Analysis Model

The main characteristics are:

- **Multicriteria analysis** (7 combined risk criteria)
- **Risk Rating:** 1 (Riskiest) – 0 (Safest)



Operating Speed Variation

= Consistency Score:

Very Good:	< 5 km/h
Good:	5-10 km/h
Fair:	10-20 km/h
Poor:	20-30 km/h
Very Poor:	> 30 km/h

Geometric - Risk Analysis Model

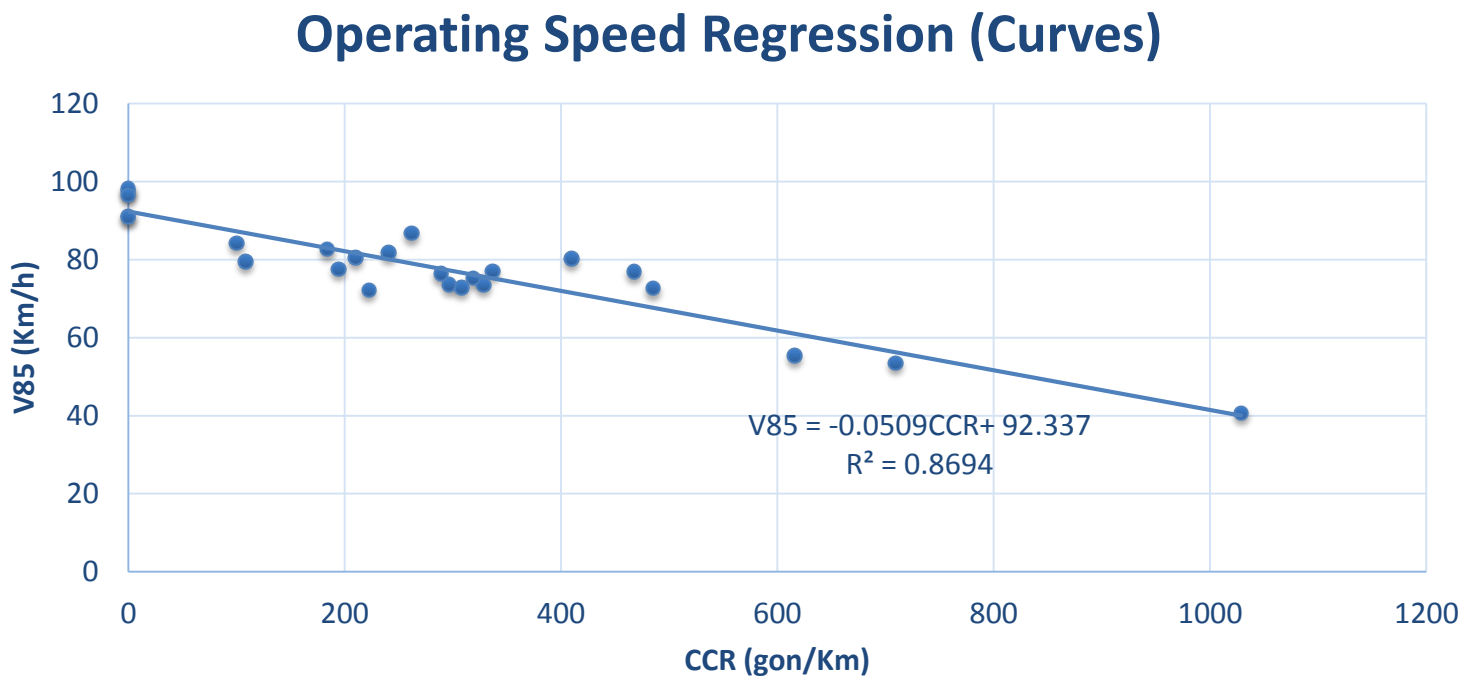
Risk rank locations. To prioritize improvements

Sorted Risk

Or	ID	Type	Ini Ch	End Ch	Risk
1	19	Bend	1556	1643	0.92
2	29	Bend	2495	2622	0.86
3	21	Bend	1662	1764	0.76
4	37	Bend	4052	4189	0.54
5	31	Bend	2673	2782	0.50
6	33	Bend	2871	3021	0.46
7	9	Bend	711	857	0.42
8	28	Tangent	2389	2495	0.36
9	35	Bend	3769	3860	0.36
10	20	Tangent	1643	1662	0.35
11	13	Bend	1039	1178	0.33
12	17	Bend	1325	1511	0.32
13	34	Tangent	3021	3769	0.32
14	12	Tangent	998	1039	0.31
15	36	Tangent	3860	4052	0.31

Operating Speed Model

Speed Model was defined to calculate the curve and tangent operating speeds of any road alignment

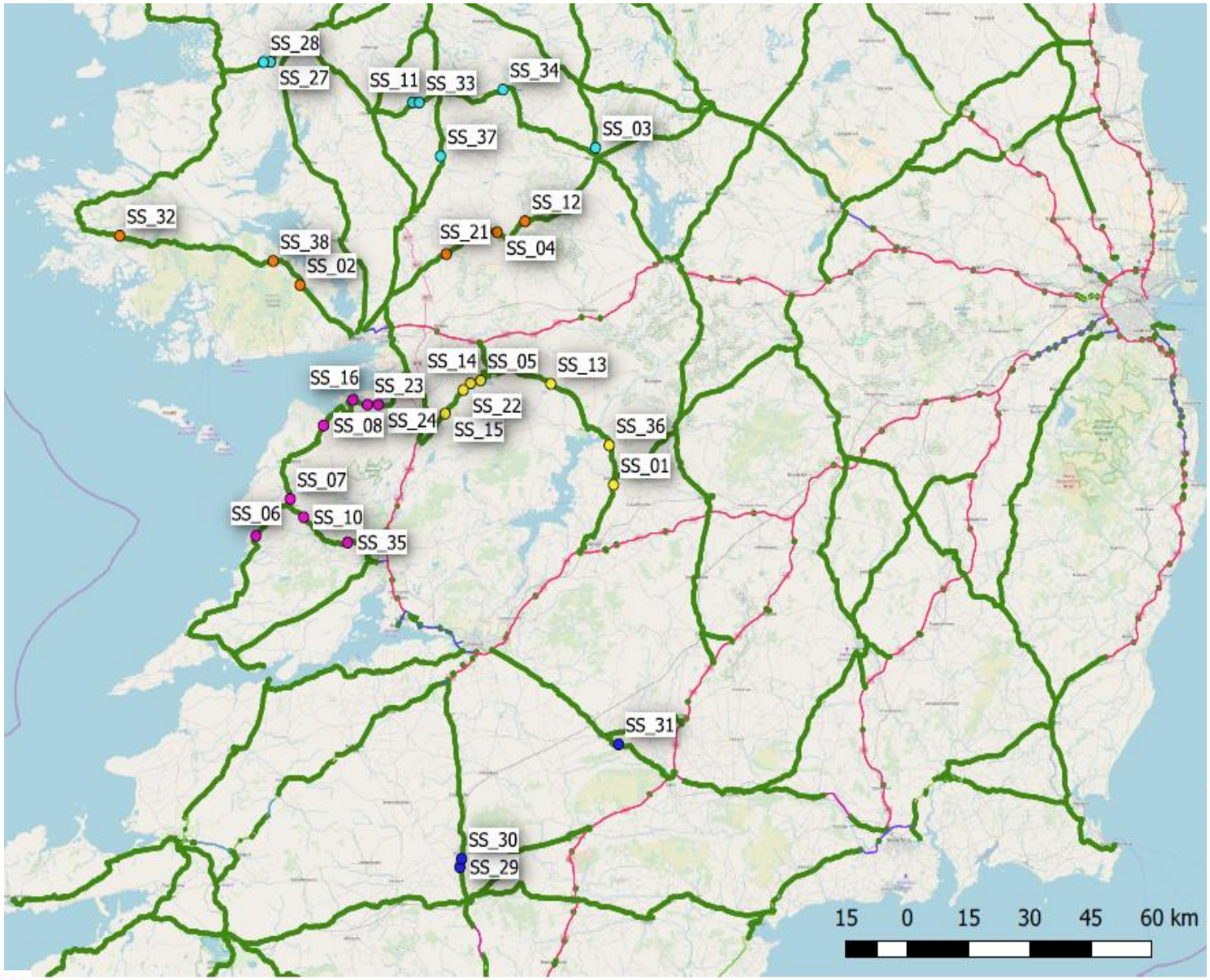


$$V_{85} = -0.0509 \cdot CCR + 92.337 \qquad R^2 = 0.8694 \text{ (Lineal Regression)}$$

$$V_{85} = 2 \cdot 10^{-6} \cdot CCR^2 - 0.0528 \cdot CCR + 92.577 \qquad R^2 = 0.8696 \text{ (Polynomial Regression)}$$

$$V_{85} = 94.824 \cdot e^{-8 \cdot 10^{-4} \cdot CCR} \qquad R^2 = 0.881 \text{ (Power Regression)}$$

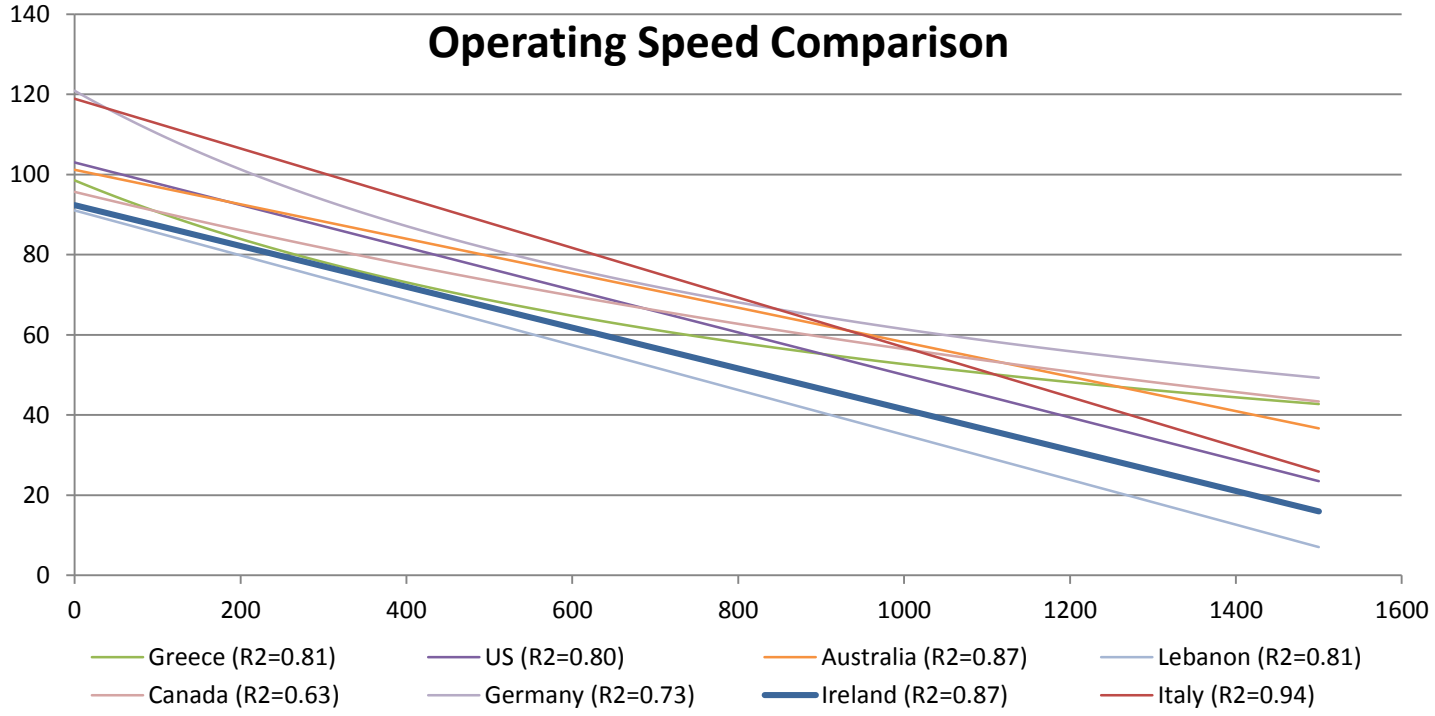
Pilot Sites for Real Operating Speed Data



Operating Speed Model

➢ **Operating Speed–** Speed regression

The approximation formula results in:



Accuracy level

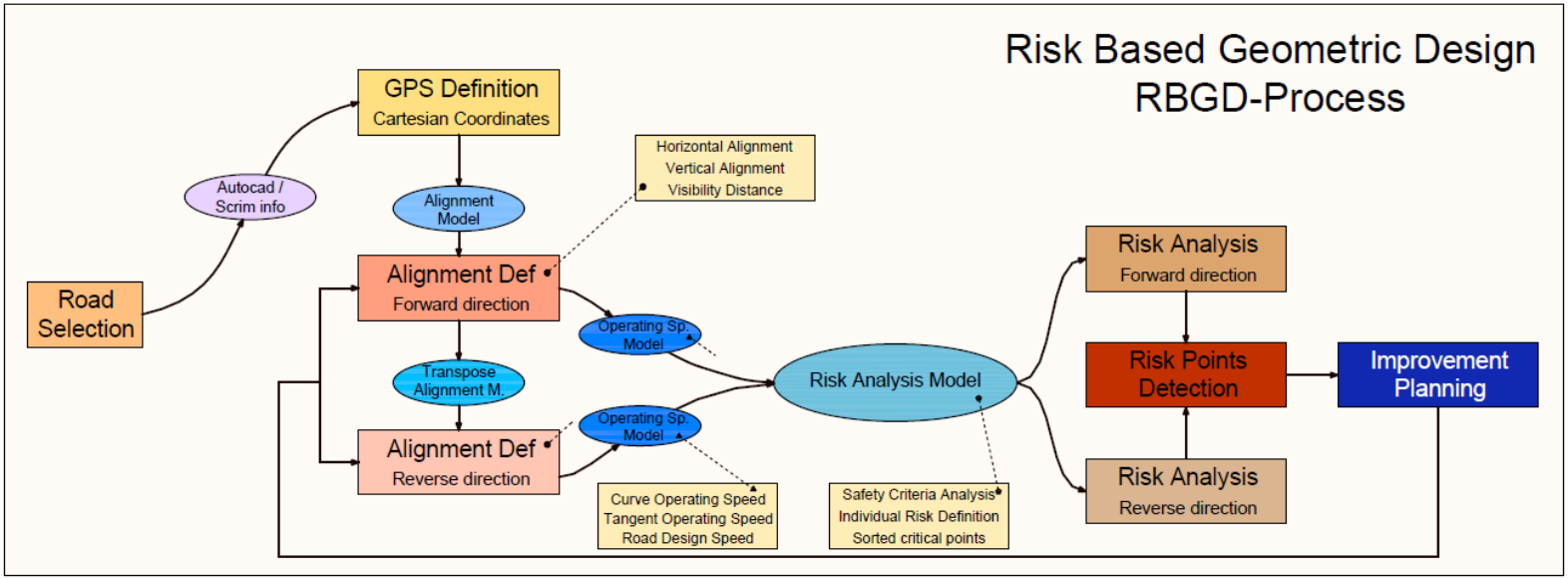
Order	R^2	Country
1	0.94	Italy
2	0.87	**Ireland**
3	0.87	Australia
4	0.81	Greece
5	0.81	Lebanon
6	0.8	US
7	0.73	Germany
8	0.63	Canada

Risk-Based Geometric Design

➢ Risk Analysis process

Consequently, the work process is the following:

1. Define road alignment and visibility
2. Determine Operating and Design speed
3. Analyze risk for both directions
4. Determine critical locations
5. Design improvement scheme
6. Re-analyze risk after actions



Case Study No.1

N14 at Tullyrap, Co. Donegal

N14 – Case Study Route

Manorcunningham

N14 at Tullyrap

Lifford

Extents of N14 Study Route

N14 – Case Study Route

N14 Route

- 17.5 km between Lifford and Manorcunningham, County Donegal.
- Road Width Varies between 6.0m and 7.0m.
- Typical Verge Width: 2m.

N14 at Tullyrap

- 1.65km in length.
- Very narrow verge width, down to zero at locations.
- Recorded Collision History: 7 collisions over 7 Years.

N14 – Derived Horizontal Alignment

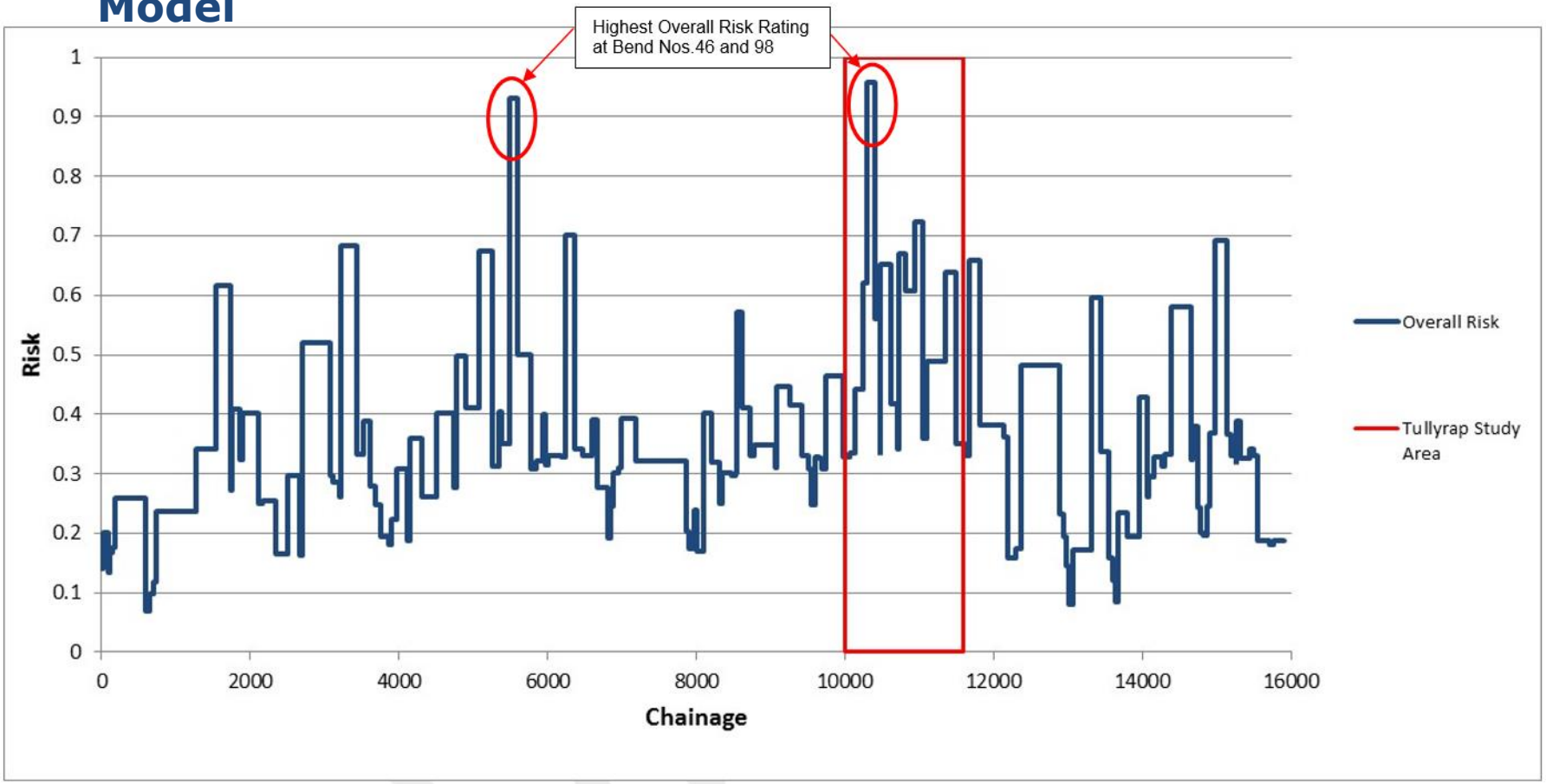
- **Existing N14 alignment derived from available routine SCRIM Survey GPS data**

Curve Radius	DN-GE0-03031 Standard for 100km/h Design Speed (Table 1.3)	Number of Curves
<127m	Beyond Standard (6 Steps Below Des Min)	2 (2.3%)
127m - 180m	Beyond Standard (5 Steps Below Des Min)	3 (3.5%)
180m - 255m	Four Steps Below Desirable Minimum	15 (17.4%)
255m - 360m	Three Steps Below Desirable Minimum	12 (14.0%)
360m – 510m	Two Steps Below Desirable Minimum	7 (8.1%)
510m – 720m	One Steps Below Desirable Minimum	4 (4.7%)
>720m	Desirable Minimum	43 (50.0%)

20 of 86 (23.3%) of horizontal curves are more than 3 Steps below Des. Min. for Type 2 Single Carriageway

N14 – Existing Alignment Risk Profile

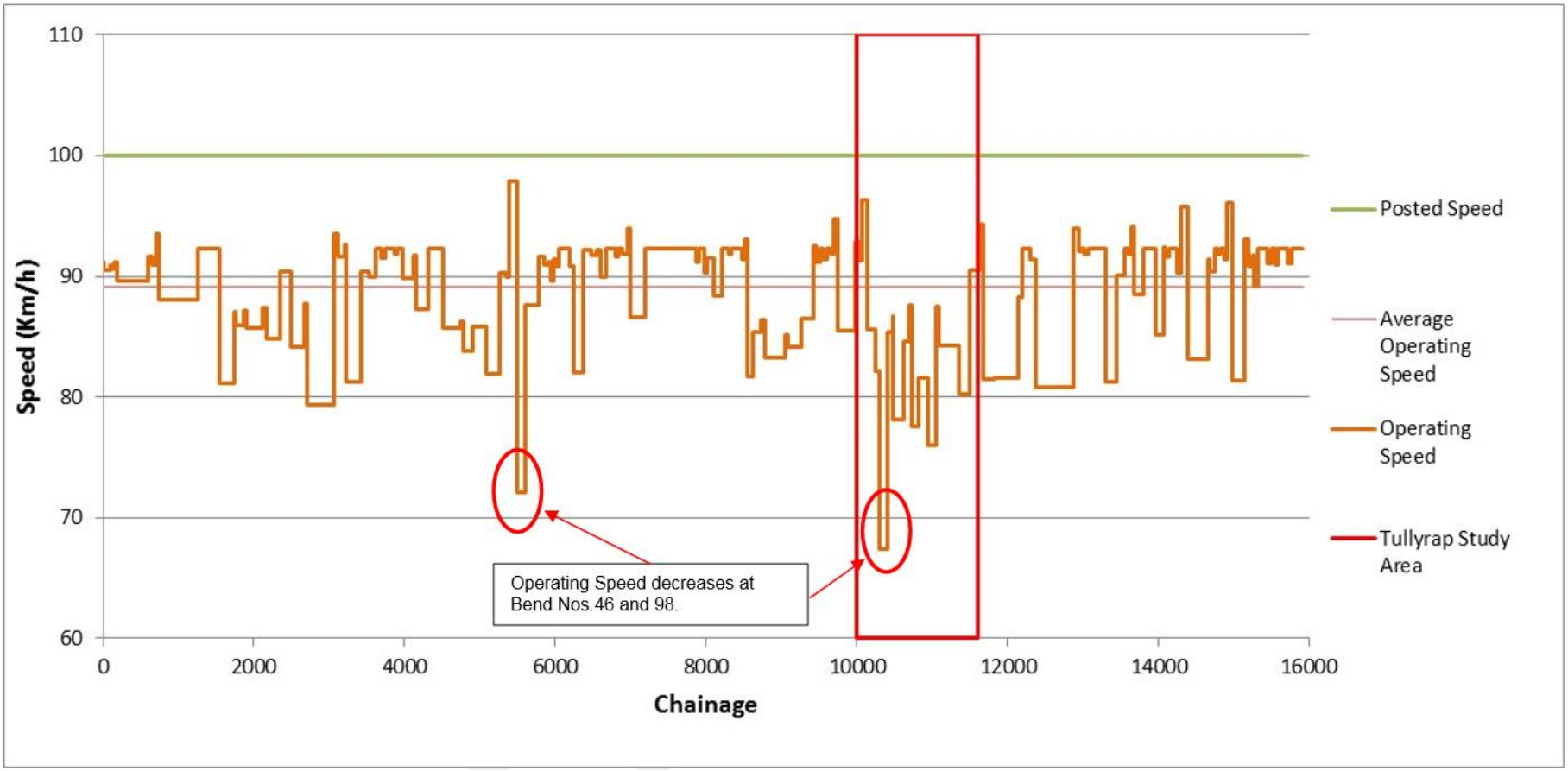
- **Existing N14 alignment Risk Profile determined from Risk Model**



The Risk Ratings at Tullyrap are generally higher and more extensive than elsewhere on the route

N14 – Existing Alignment Speed Profile

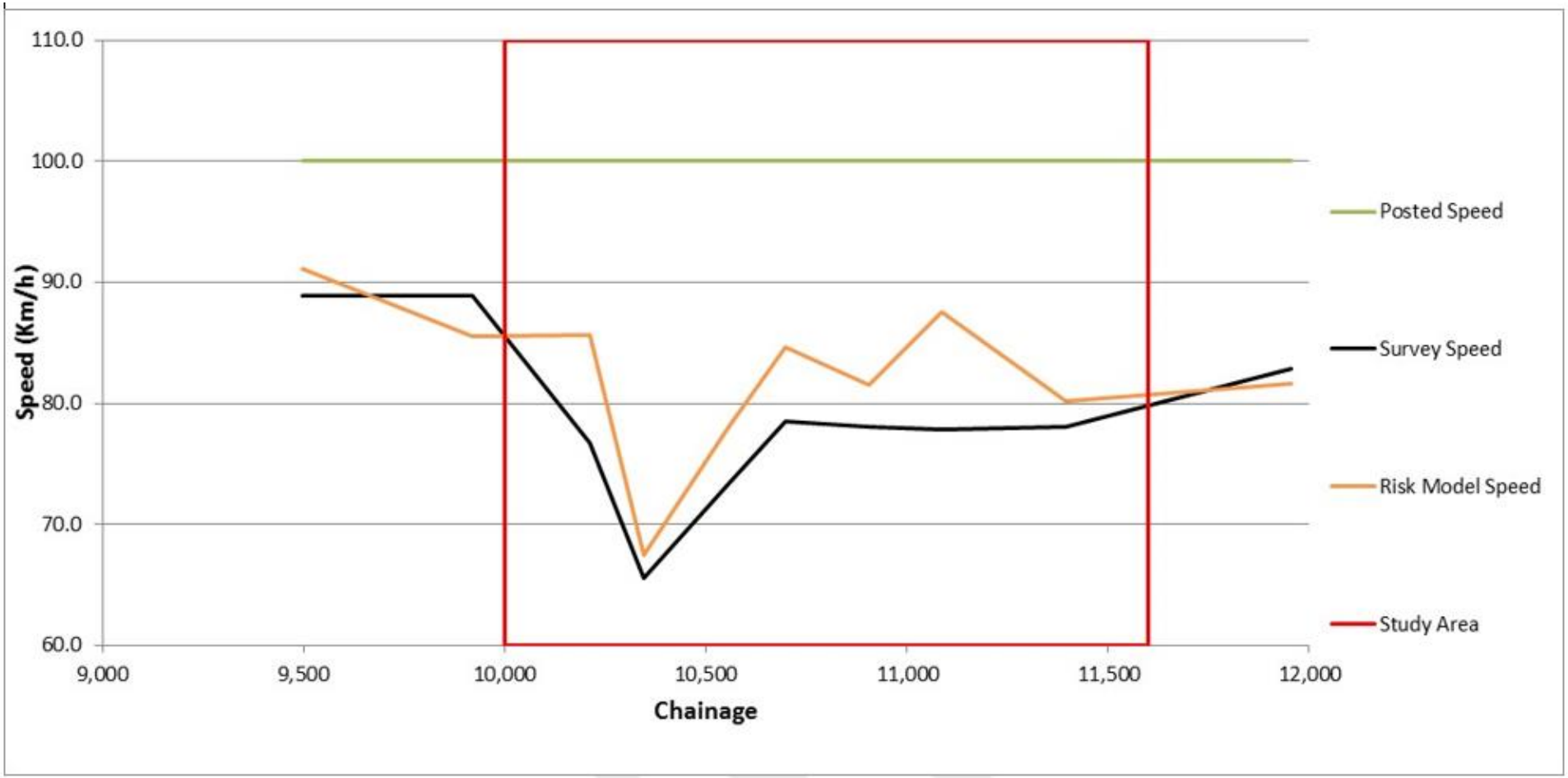
- **Existing N14 alignment Operating Speed Profile determined from Risk Model**



The Speed Variation along the N14 at Tullyrap was calculated at 29km/h

N14 – Existing Alignment Speed Profile Validation

- **The predicted existing N14 alignment Operating Speed Profile was compared to Speed Survey results taken at 12 locations.**

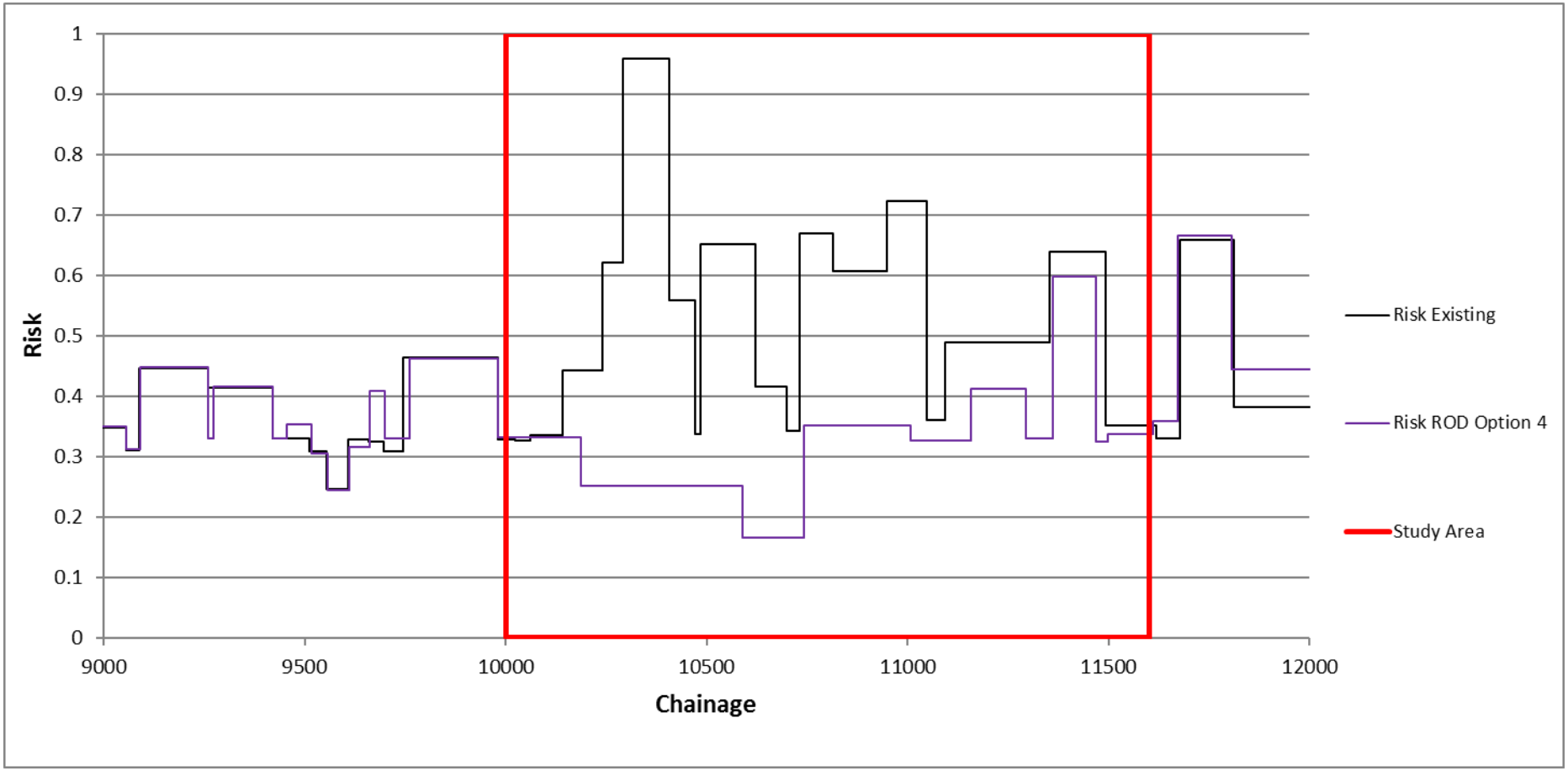


N14 – Indicative Realignments

- **4 No. horizontal realignment options were developed at Tullyrap.**
- **Options were remodeled for Collision Risk to determine the optimal solution consistent with the adjacent sections of road.**
- **The optimal indicative realignments comprised a realignment scheme totaling 1.35km in length = 20% shorter than initially proposed.**

N14 – Realignment Risk Profile

- **N14 realignment Risk Profile determined from Risk Model**

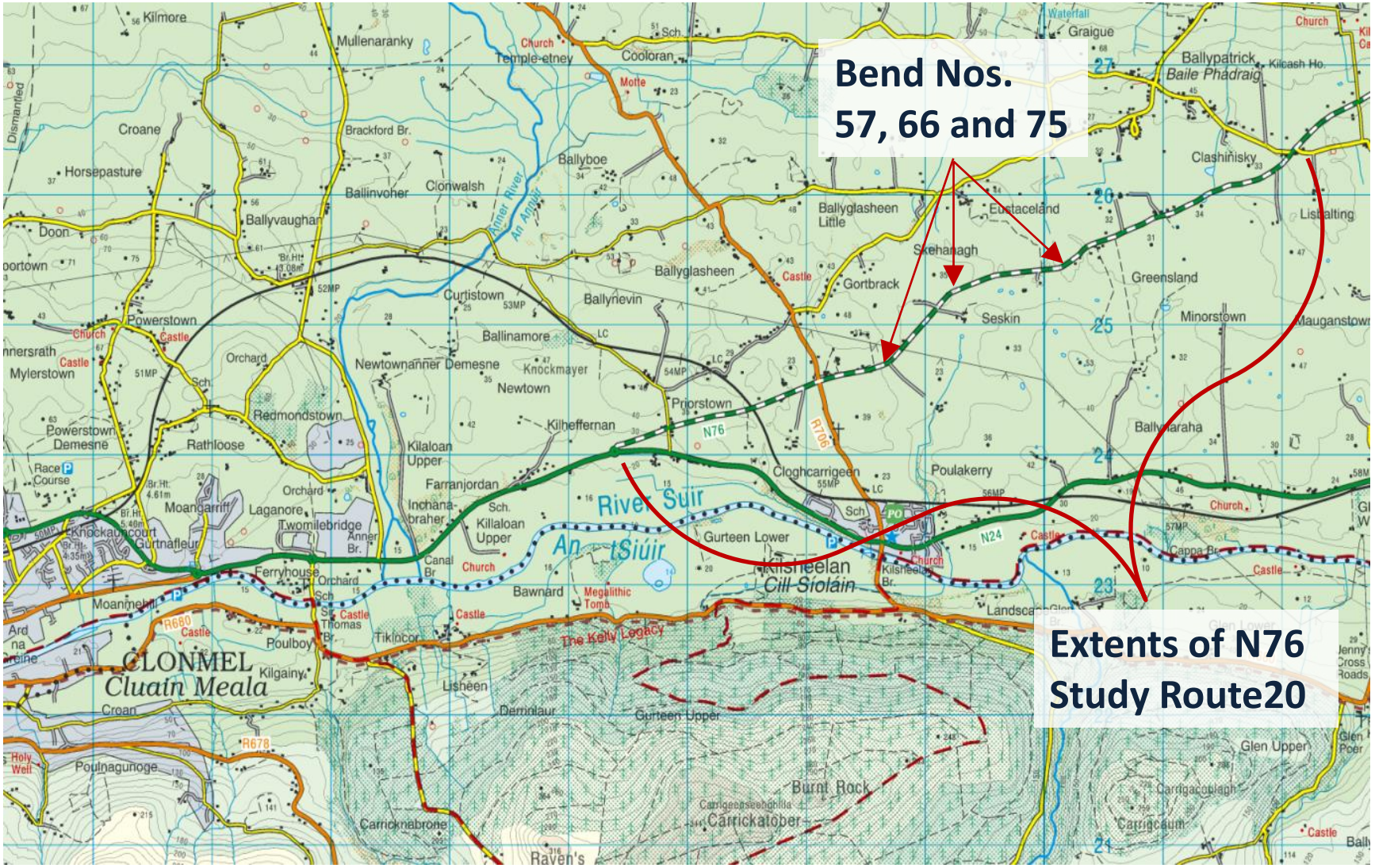


Risk Rating at Tullyrap reduces from 0.96 to 0.6 max and typically 0.35

Case Study No.2

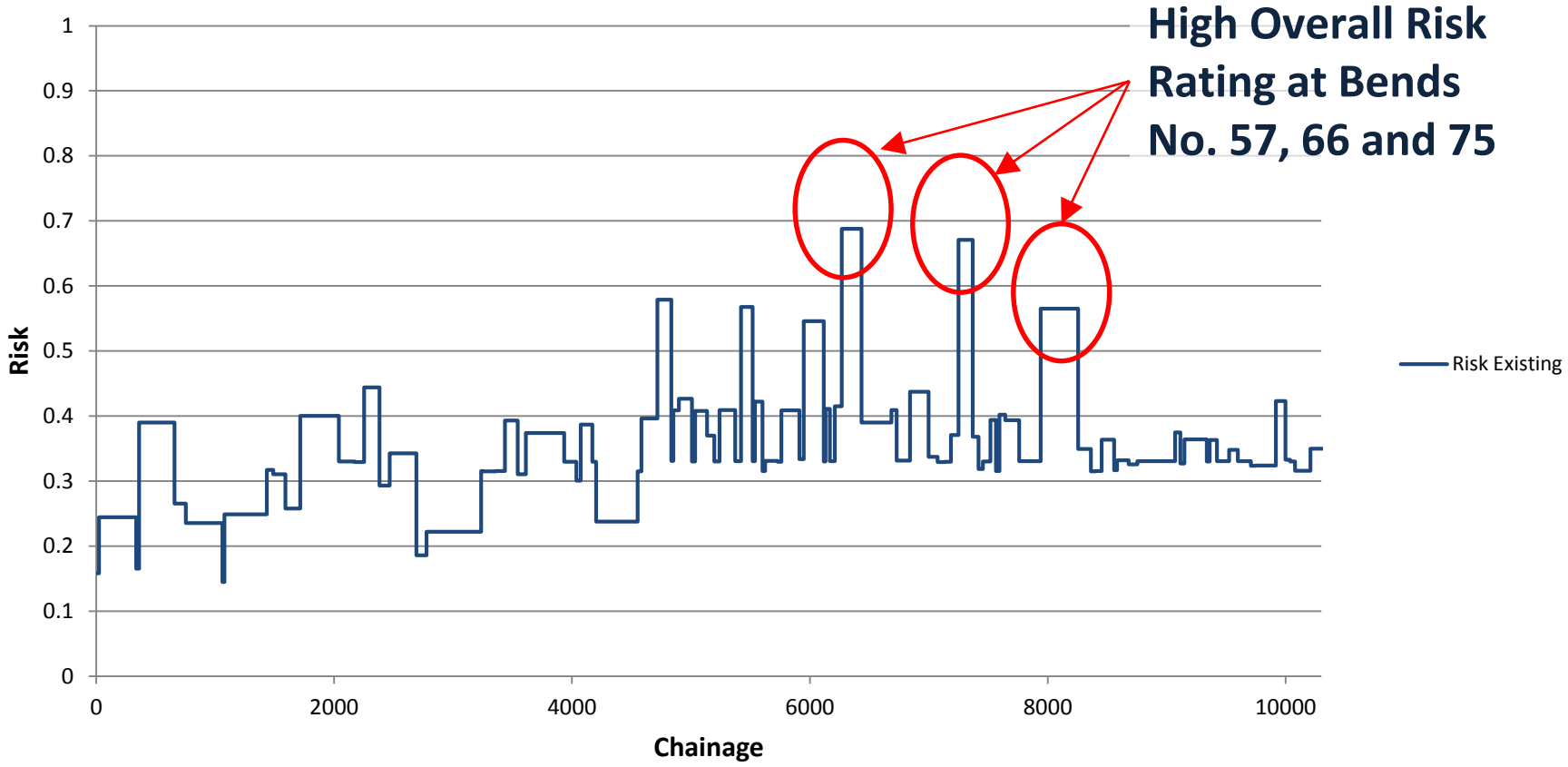
N76 at Seskin, Co. Tipperary

N76 – Case Study Route



N76 – Existing Alignment Risk Profile

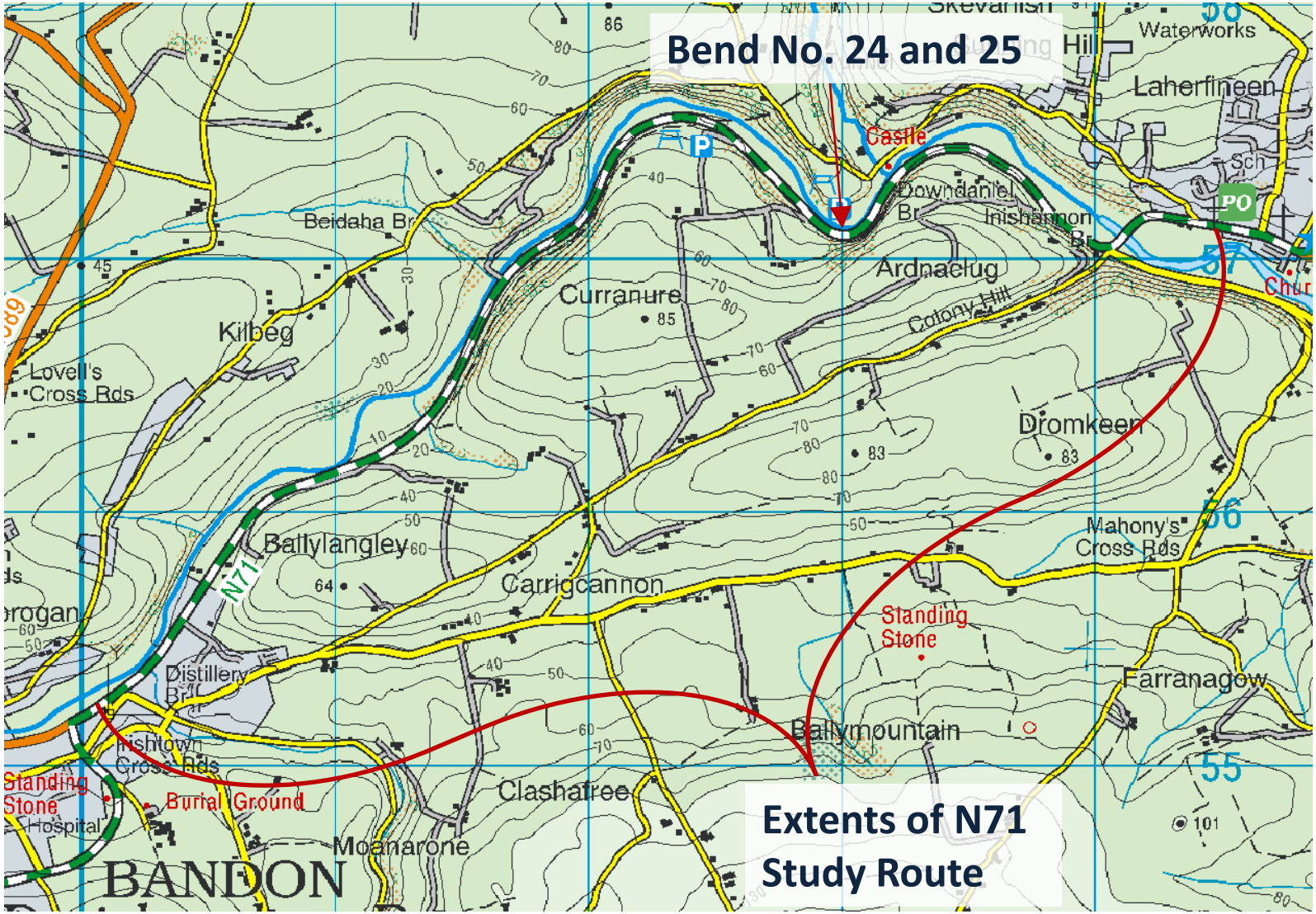
- **Existing N76 alignment Risk Profile determined from Risk Model**



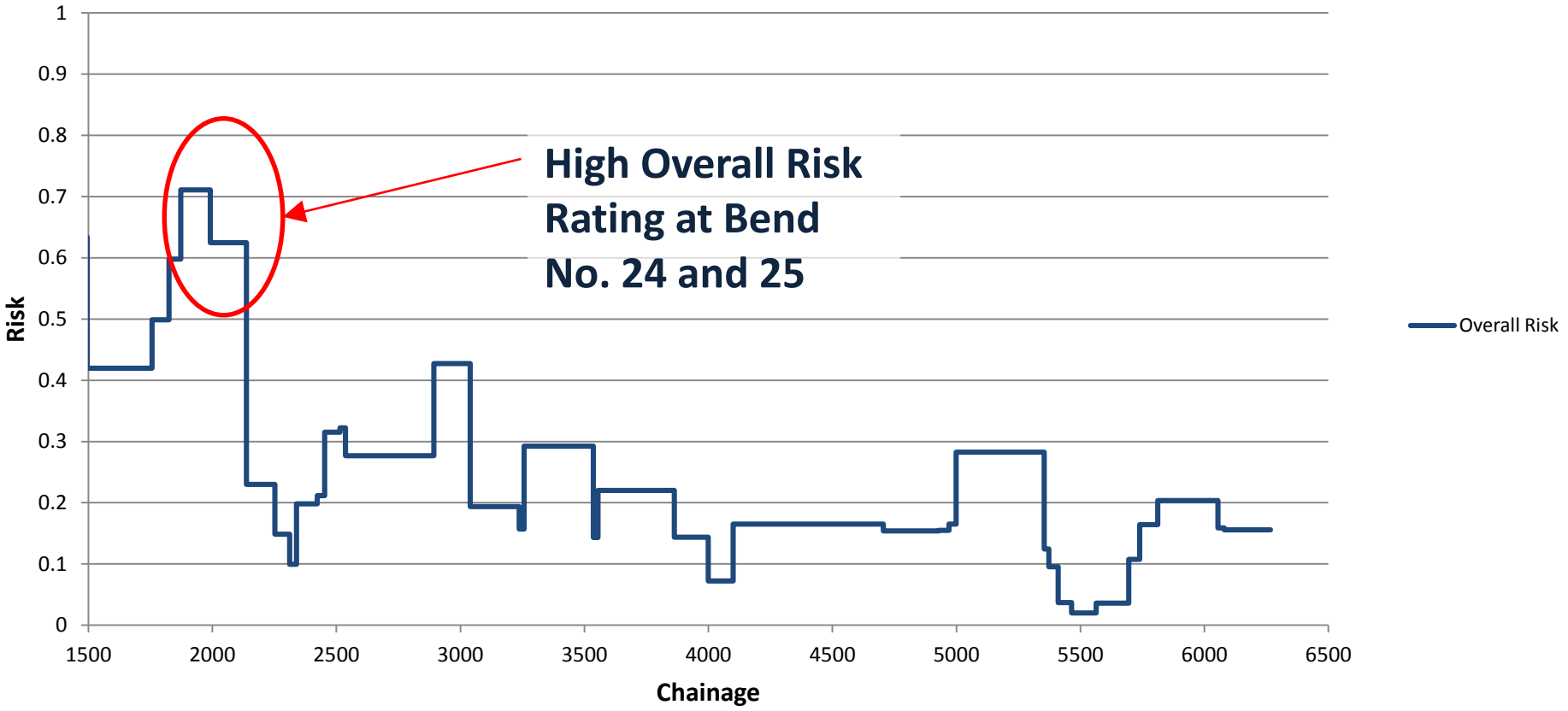
Case Study No.3

N71 Innishannon to Bandon, Co. Cork

N71 – Case Study Route



N71 – Existing Alignment Risk Profile



Conclusions

Risk-Based Geometric Design

➢ Conclusion

The project has obtained:

1. **A Risk Analysis Model capable of preforming risk analysis at multiple scales (i.e. National, Regional, Local).**
2. **Automated procedures & models to provide:**
   a. **Alignment definition (horizontal & vertical)**
   b. **Stopping Sight distances**
   c. **Operating speeds**
3. **Coupling of these models provides the means to:**
   a) **perform risk screening exercises and develop roads needs studies at National and Regional levels; and to**
   b) **Optimise route planning (rolling programmes) and phasing of improvements to optimise (i) Risk, (ii) Performance (consistency) and (iii) Cost.**

TII Publications

Future Inclusion