A review of design speed based on observed behaviour

Zita Langenbach
Arup
Paul Lewis
NUI Maynooth

NUIM Research Team
Tim McCarthy
Lars Pforte
Paul Lewis

NRA An tÚdarás um Bóithre Náisiúnta National Roads Authority

ARUP

What is Design Speed?

- The speed which determines the layout of a new road in plan, being the speed for which the road is designed, taking into account anticipated vehicle speed on the road (**PIARC**)
- A speed selected as a basis to establish appropriate geometric design elements for a particular section of road (**TAC**)
- The maximum safe speed that can be maintained over a specified section of highway when conditions are so favourable that the design features of the highway govern. (**AASHTO**)

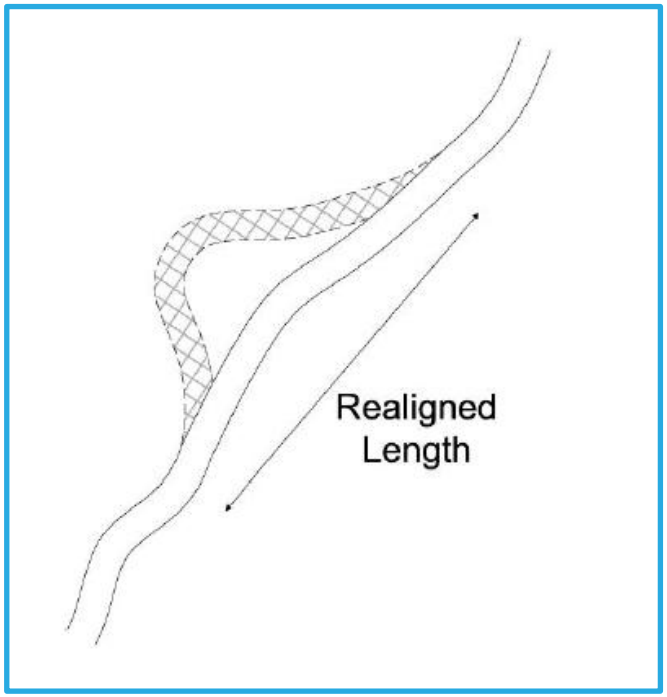
What is Operating Speed?

- The speed at which free-flowing vehicles choose to drive on a section of roadway (TRB)

- The highest overall speed at which a driver can travel on a given highway under favourable weather conditions and under prevailing traffic conditions without at any time exceeding the safe speed as determined by the design speed on a section-by-section basis. (AASHTO)

What is Design Consistency?

- The conformance of a highway's geometric and operational features with driver expectancy (Wooldridge et al. 2003)
- The road alignment shall be designed to ensure that standards of curvature, visibility, superelevation etc. are provided for a Design Speed which shall be consistent with the anticipated vehicle speeds on the road (NRA TA 85/13)



Current NRA TD 9 approach to Design Speed

NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

ARUP

Alignment Constraint Calculation, Ac

For Single Carriageways

Ac = 12 - VISI/60 + 2B/45

where:

B = Bendiness degrees/km

VISI = Harmonic Mean Visibility, m

Layout Constraint Calculation, Lc

Road Type	S2						D2AP		D3AP	D2M		D3M
Carriageway Width (ex. hard strips)	6m		7.0m		7.3m		Dual 7.0m		Dual 10.5m	Dual 7.0m	Dual 7.5m	Dual 10.5m or 11.25m
Degree of Access and Junctions	H	M	M	H	M	L	M	L	L	L	L	L
With hard shoulders					21	19	10	9	5	5	4	0
Without hard shoulders:												
With 3.0m Verge	(29)	(26)	25	23	(23)	(21)	(12)	(11)	(6)			
With 1.5m Verge	(31)	(28)		(27)								
With 0.5m Verge	(33)	(30)	For Type 2 and Type 3 Dual Carriageways see NRA TD10.									

L	**Low Access ≤5 per km**
M	**Medium Access 6 to 8 per km**
H	**High Access ≥9 per km**

Selection of Design Speed

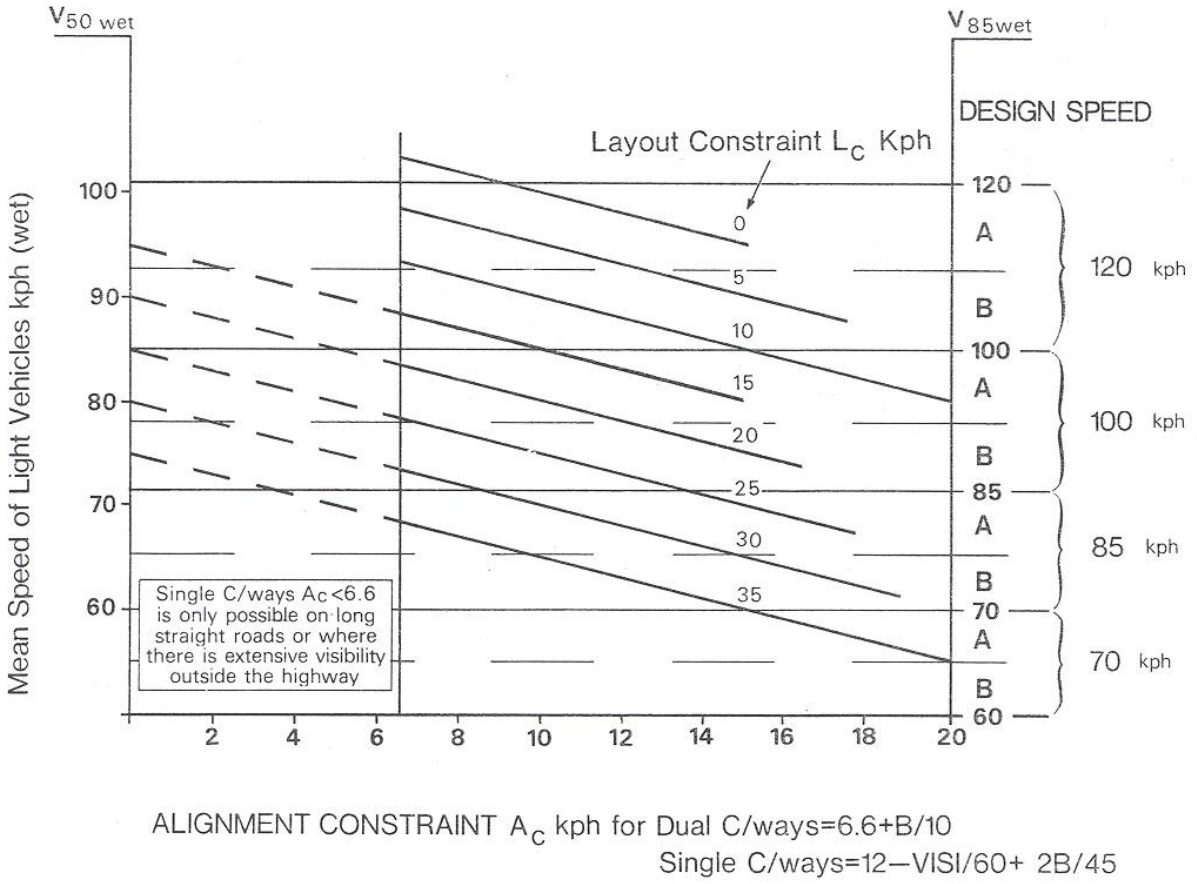


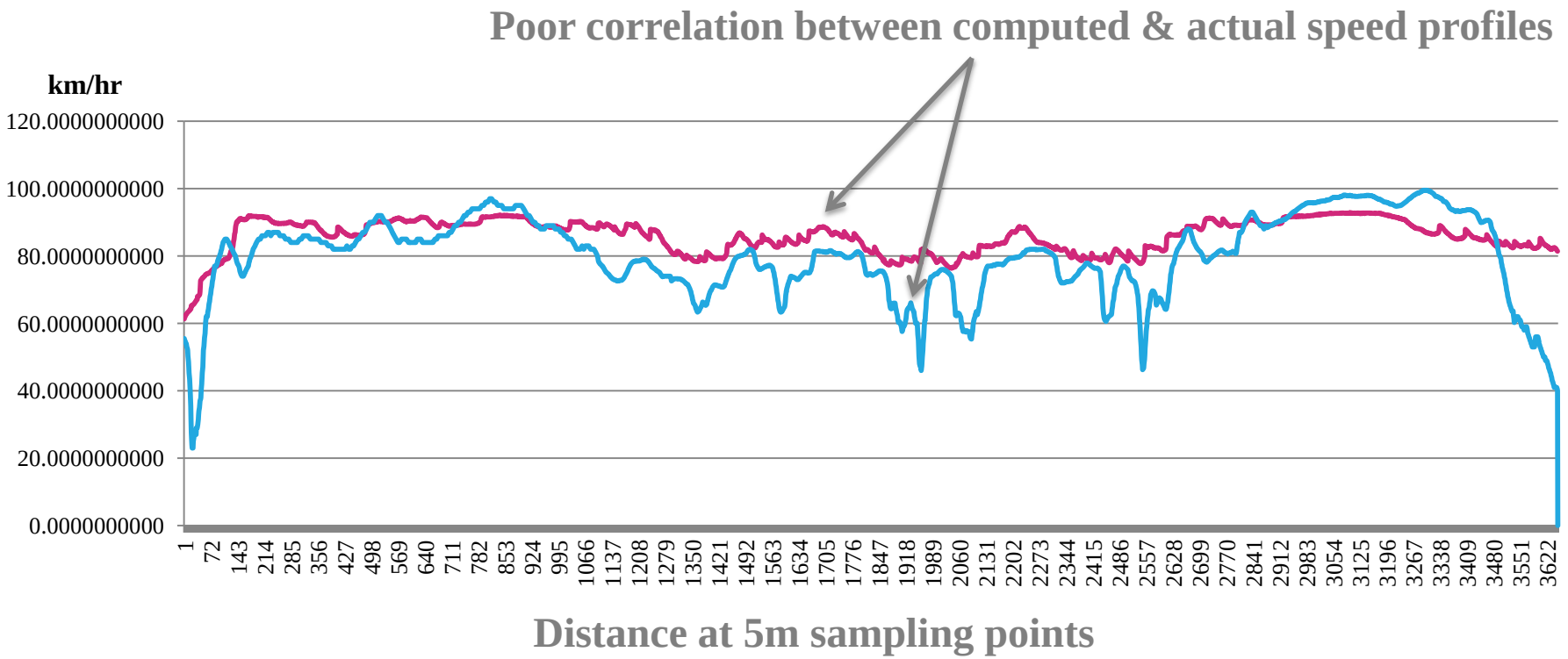
Table 1/1 Selection of Design Speed (Rural Roads)

NRA An tÚdarás um Bóithre Náisiúnta National Roads Authority

ARUP

Difficulty with current TD 9 approach

N52 Mullingar to Delvin



Contemporary Approaches to Design Speed Calculation in other Countries

NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

ARUP

Different Approaches to Design Speed Calculation

Author	Country	Year	Model	Parameters
Wooldridge et al	USA	2003	V_{85}	R,
Fitzpatrick et al	USA	2000	V_{85}	R,K,G
Krammes et. al	USA	1998	V_{85}	DC, L_C, D_F, L, V_T
TAC	Canada	2013	V_{85}	L_C,R
Dell' Aqua et al.	Italy	2012	V_{85}	C_P, V_{env},CCR,L_W, L_T
BAST	Germany	1984	V_{85}	CCR,L_W
Setra	France	1986	V_{85}	CCR
Lamm et al.	Greece	1995	V_{85}	CCR
McLean et al	Australia	1979	V_{85}	R, V_F

Leisch and Leisch (1975) – Operating-speed-based rural alignment consistency procedure

16 km/h (10mph) rule

1. Within design speed, the potential average automobile speeds should not vary more than 16 km/h.
2. When a reduction in design speed is necessary it should be no more than 16 km/h.
3. Average truck speeds should be no more than 16 km/h lower than average automobile speed.

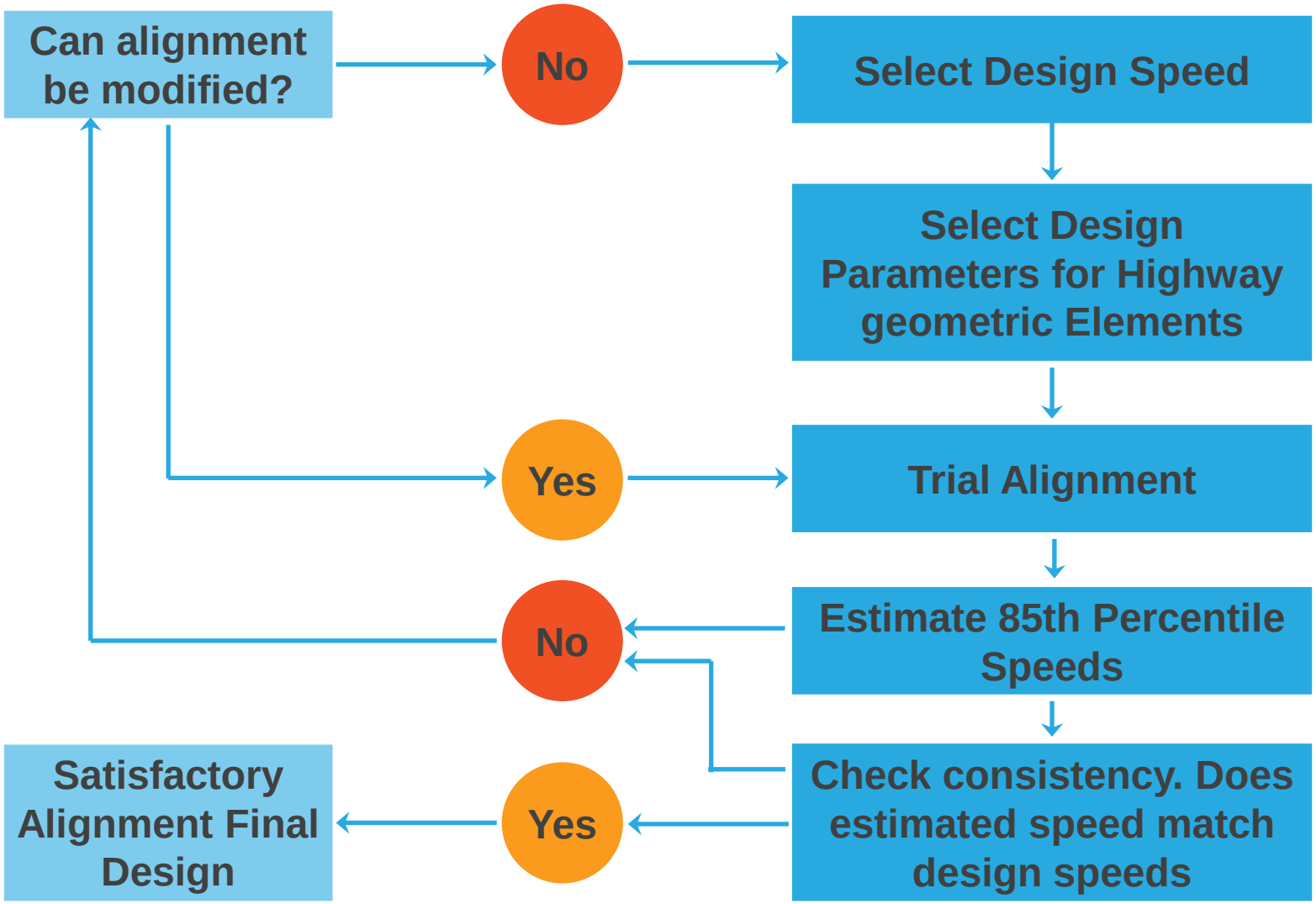
Further Operating Speed Models

- Lamm et al (1988)
  - Refined German scheme applied in USA

Rating	ΔD	ΔV_{85}
Good	$\Delta D \leq 5^o$	$\Delta V_{85} \leq 10$km/h
Fair	$5^o < \Delta D \leq 10^o$	10km/h $< \Delta V_{85} \leq 19$km/h
Poor	$\Delta D > 10^o$	$\Delta V_{85} > 19$km/h

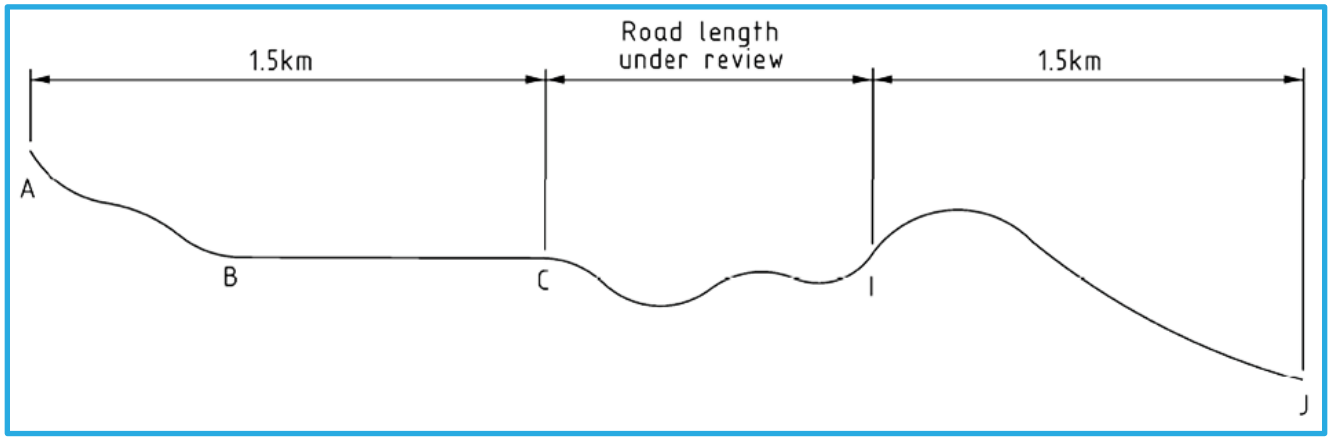
- Faghri et al (2004)
  - Maximum 10km/h difference between two successive sections recommended

Canadian Operating Speed Approach (2007)

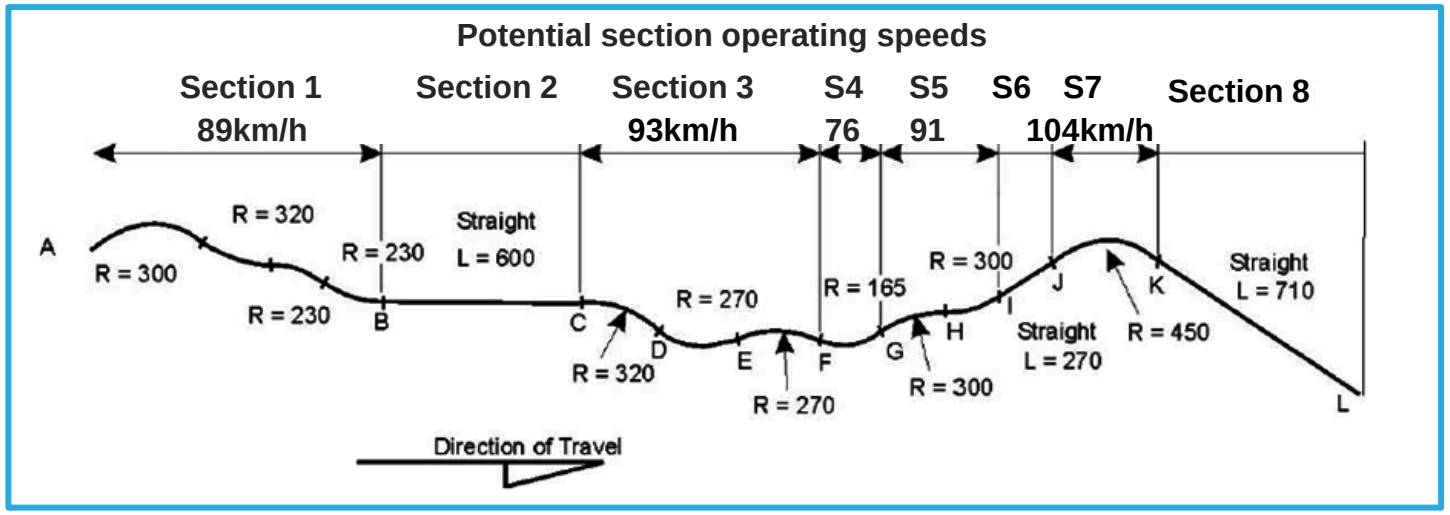


Operating Speed Model – Austroads – 2003

1. Length of Road to be analysed

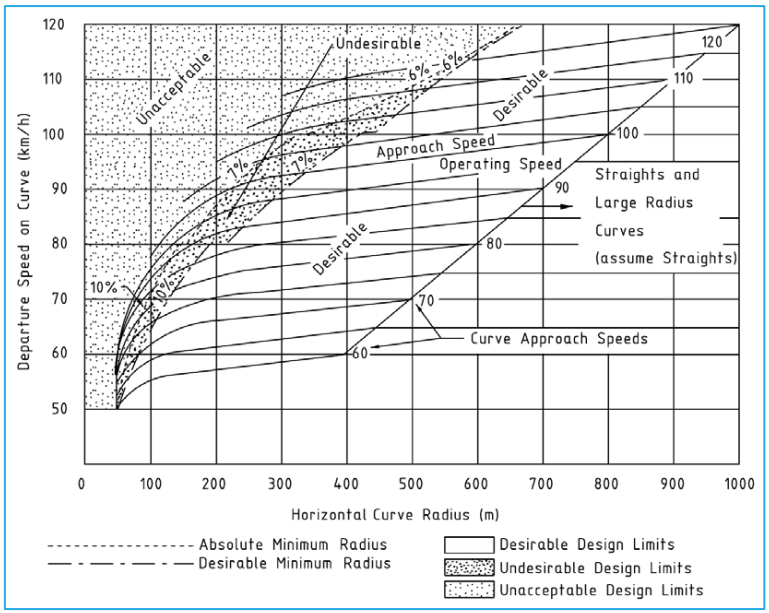


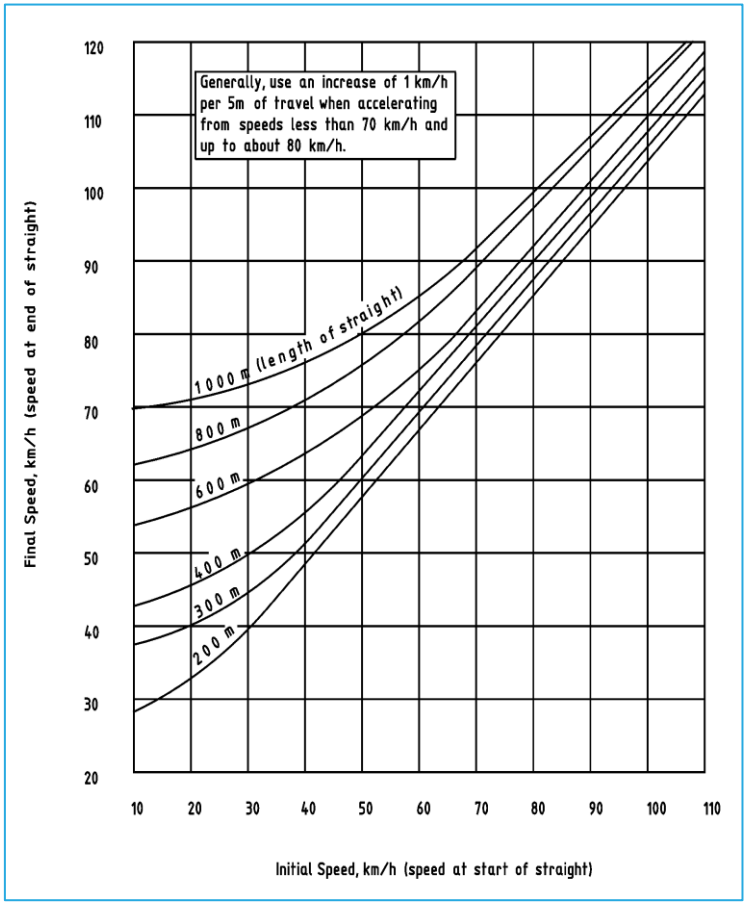
2. Section Operating speeds



Operating Speed Model – Austroads – 2003

3. Acceleration on straights





4. Deceleration on curves

Operating Speed Model – Austroads – 2003

5. Predicted operating speeds are finalised

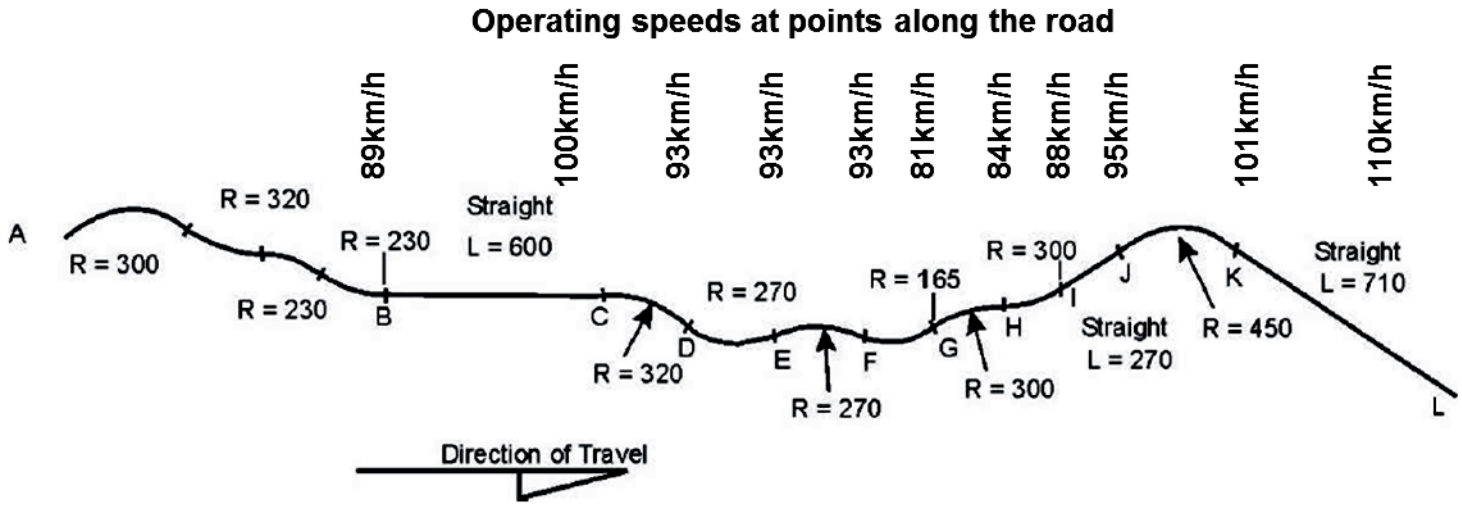


Figure C 7: Predicted Operating Speeds Along the Road

New Methodology For Design Speed Calculation

Interim Results

NRA An tÚdarás um Bóithre Náisiúnta National Roads Authority

ARUP

Safe Profile Velocity (V_{sp})

Represents the average safe profile velocity of any route captured under ideal conditions:

- Good Weather & illumination
- Traffic free
- Alert driver, Low workload
- Safe but progressive driving (remain under posted speed limits)
- Over-taking not allowed
- V_{sp} can be loosely compared with V_{85}

How to generate Safe Profile Velocity (V_{sp})

It is difficult to generate V_{sp} for any route with a single pass since, in reality, we experience

- Slow vehicular traffic
- Other road users (pedestrians, cyclists, agriculture machinery)
- Traffic movement at Junctions, entrances
- Animals & Other transient events

How to generate Safe Profile Velocity (V_{sp})

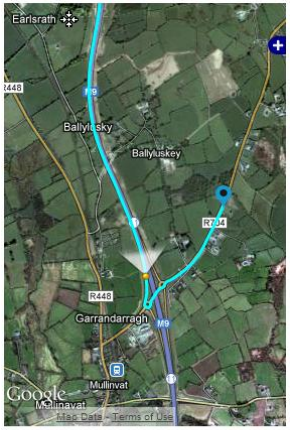
- Drive 2 or 3 times
- Different drivers
- Different dates and times
- GPS trace of route
  - Recording video can help significantly (e.g. Ubipix)
- Stack all GPS traces
- Compute maximum velocity (in this case at 5m)

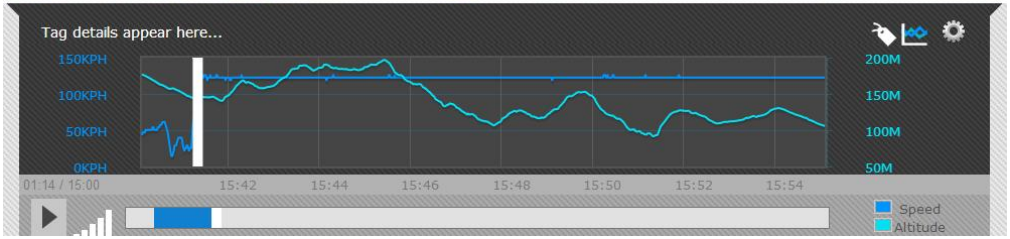
Using Ubipix to acquire GPS encoded road video

Support Multiple Mobile devices

GPS + Video

Cloud-based GeoMedia Platform





Automated Upload & Publishing

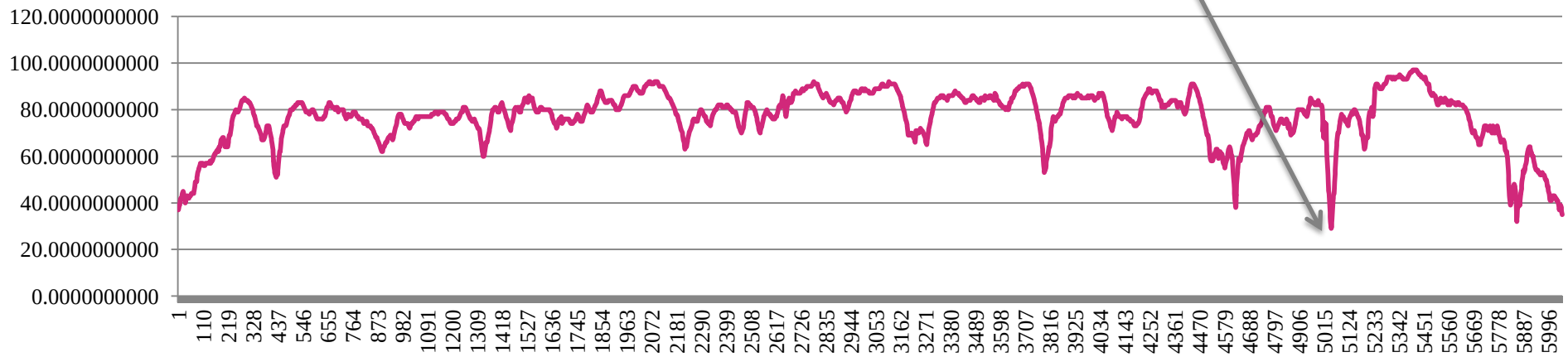
http://www.ubipix.com

NRA An tÚdarás um Bóithre Náisiúnta National Roads Authority

ARUP

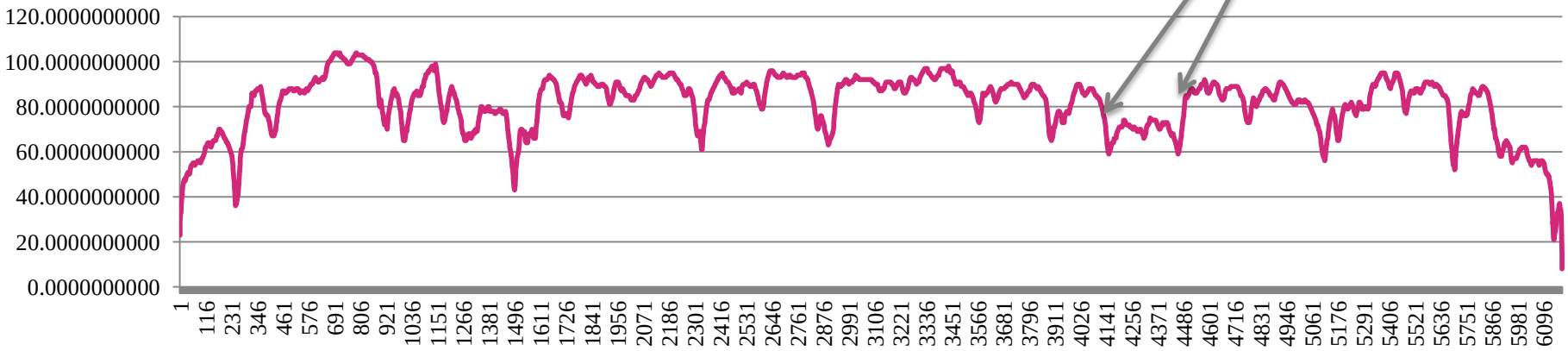
Ubipix used to capture V_{sp}

- Passing-out cyclist



Ubipix used to capture V_{sp}

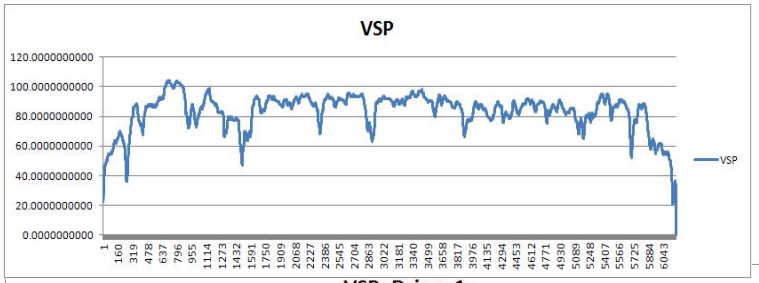
- Slow Traffic in front



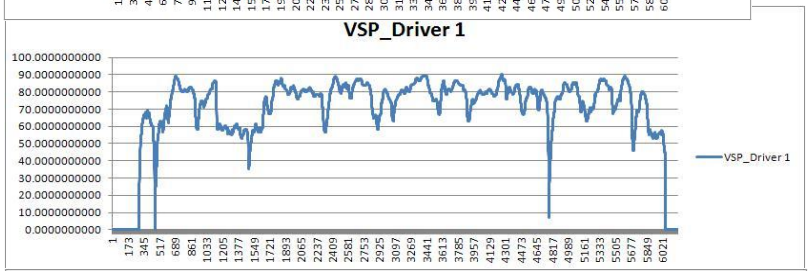
How to generate Safe Profile Velocity (V_{sp})

N81 Blessington to Baltinglass

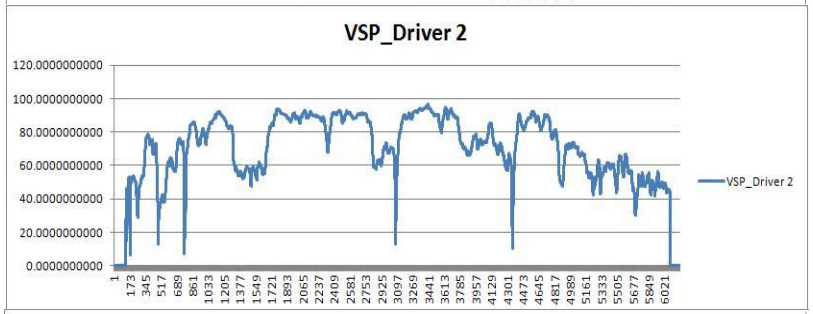
Resulting V_{sp}



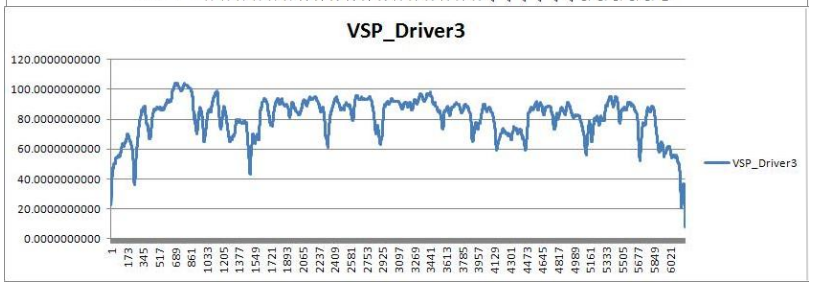
GPS stack of 3 X GPS Traces



Driver-1



Driver-2



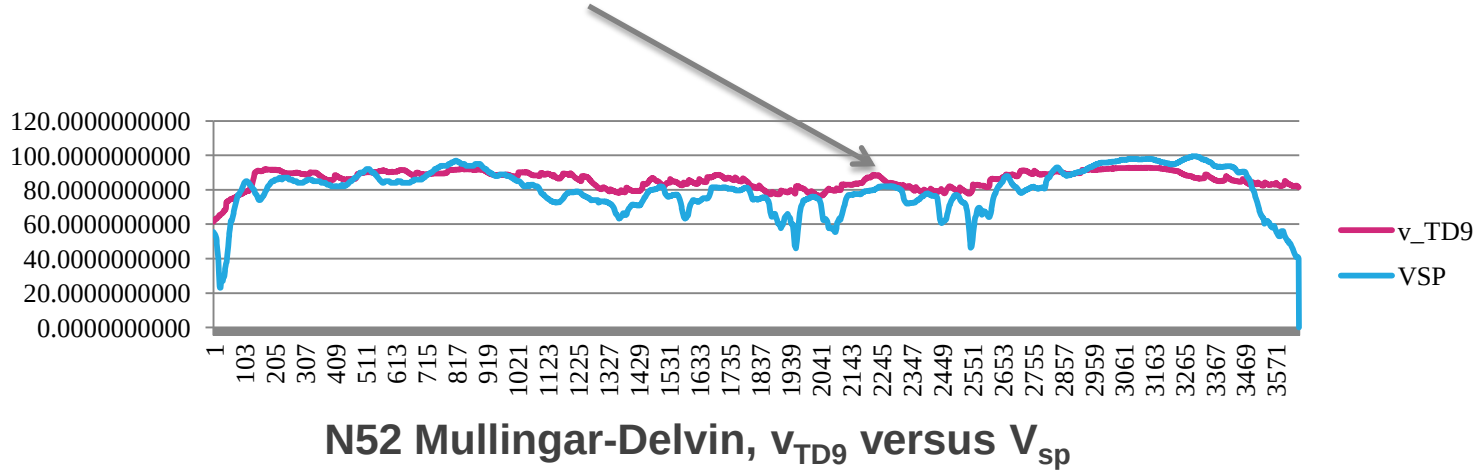
Driver-3

Existing design speed (V_{TD9}) computation

Shortcomings of current TD 9 Approach

Existing (TD9) approach determines design speed v_{TD9} based on horizontal alignment, sight distance, entrances and road width on sections of at least 1 km length

Even though it works well at high speeds, it misses local variability, since values above are averaged over the 1km section



N52 Mullingar-Delvin, v_{TD9} versus V_{sp}

Enhanced theoretical design speed (V_{design}) computation using Sight Distance

Background to an enhanced design speed (V_{design}) computation

- Sight distance is a critical component to safe driving
- A velocity is safe if the stopping distance is less-than or equal-to the sight distance so, we find velocity v_{max} such that stopping distance equals sight distance, using the following formula:

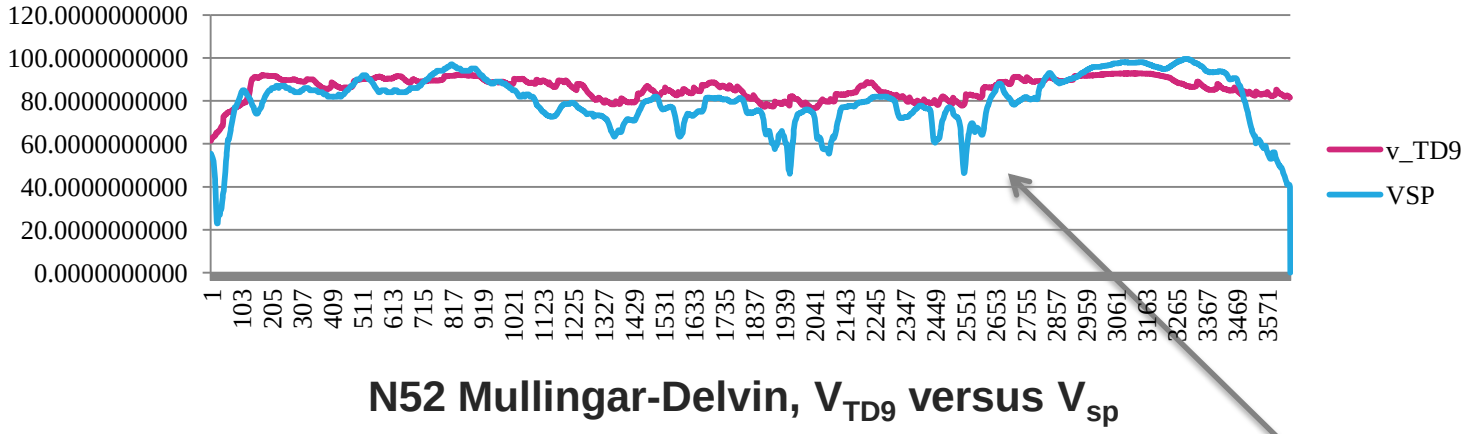
$$v_{max} = \sqrt{(d \cdot t)^2 + 2 \cdot d \cdot s} - d \cdot t$$

where *s* is sight distance in metres, *d* is deceleration in m/sec^2 and *t* is Reaction Time in seconds

- A deceleration of *d*=5 m/sec^2 and a reaction time of *t*=1.5 sec are used

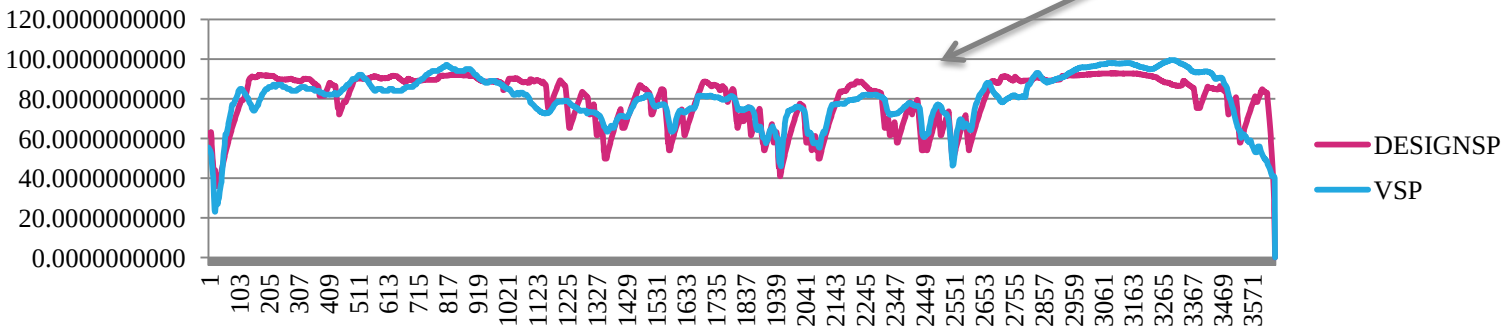
- Enhanced $v_{design} = \min(v_{TD9}, v_{max})$

Enhanced theoretical design speed (V_{design}) computation using Sight Distance



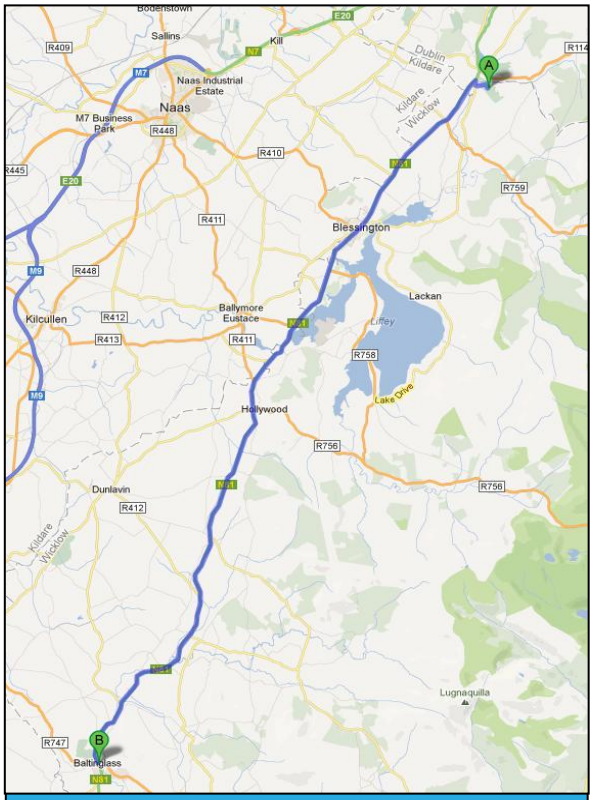
N52 Mullingar-Delvin, V_{TD9} versus V_{sp}

Improved correlation

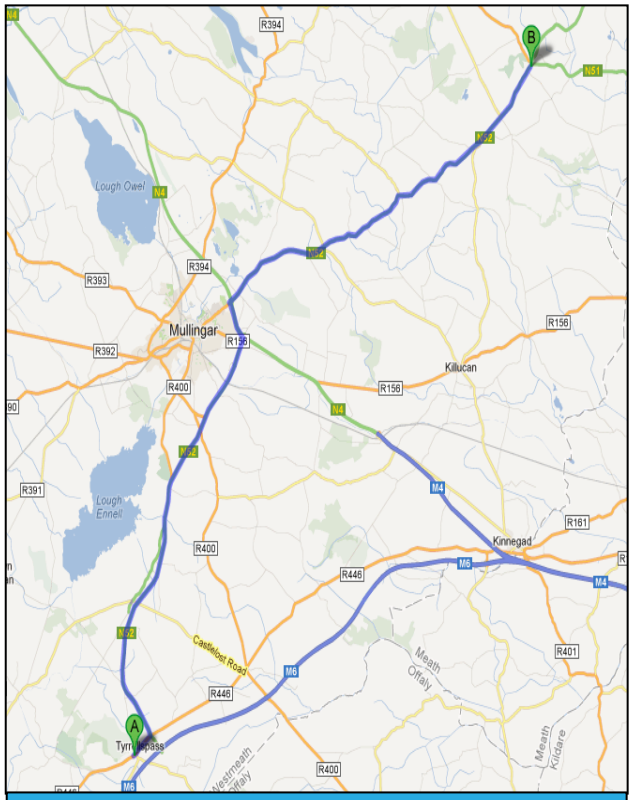


N52 Mullingar-Delvin, V_{design} versus V_{sp}

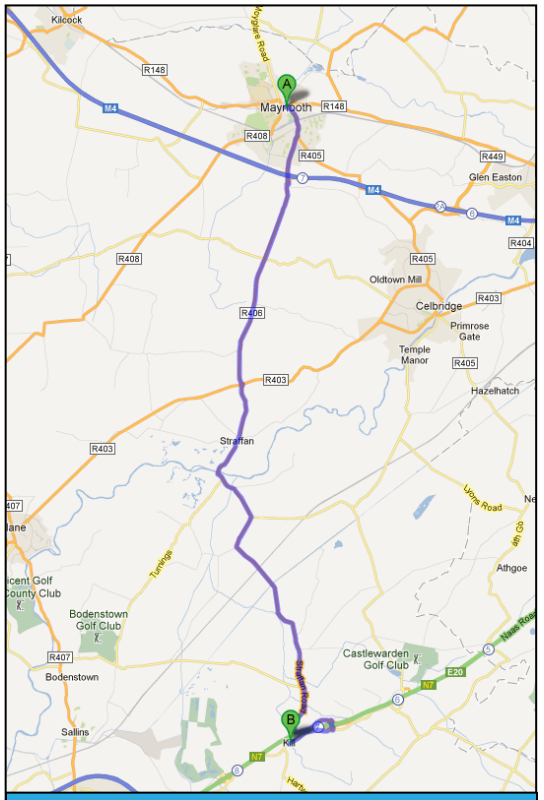
Research Test Routes



N81 Brittas-Blessington-Baltinglass



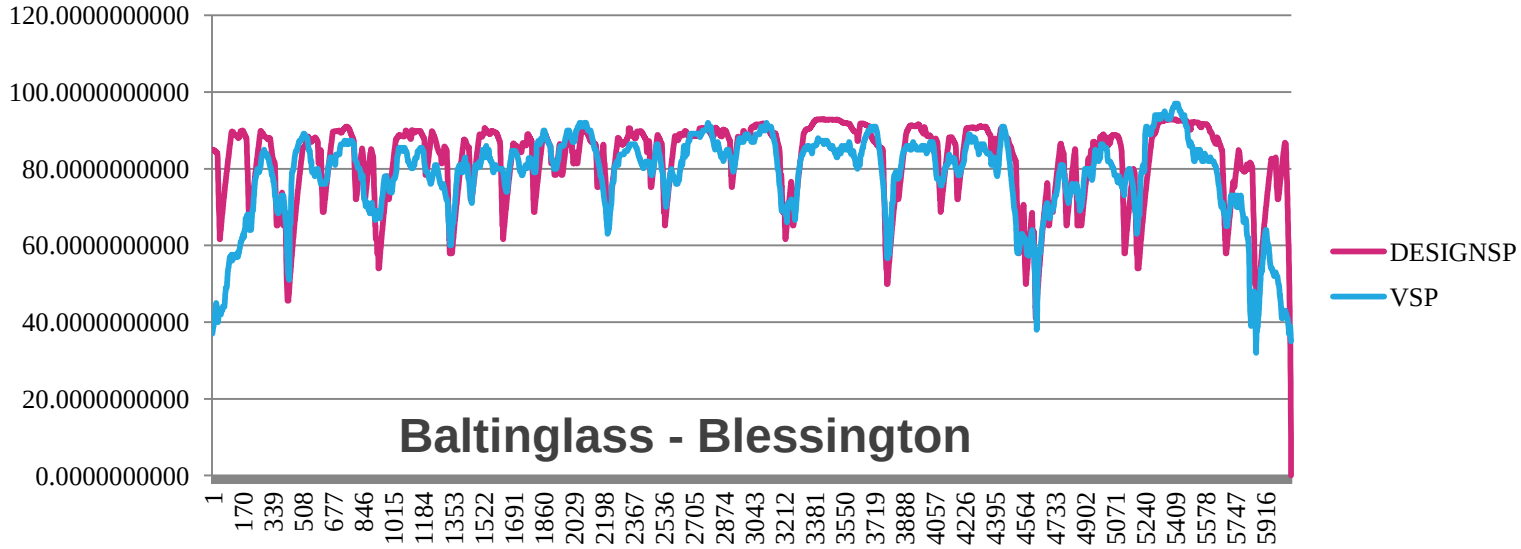
N52 Tyrrelspass-Mullingar-Delvin

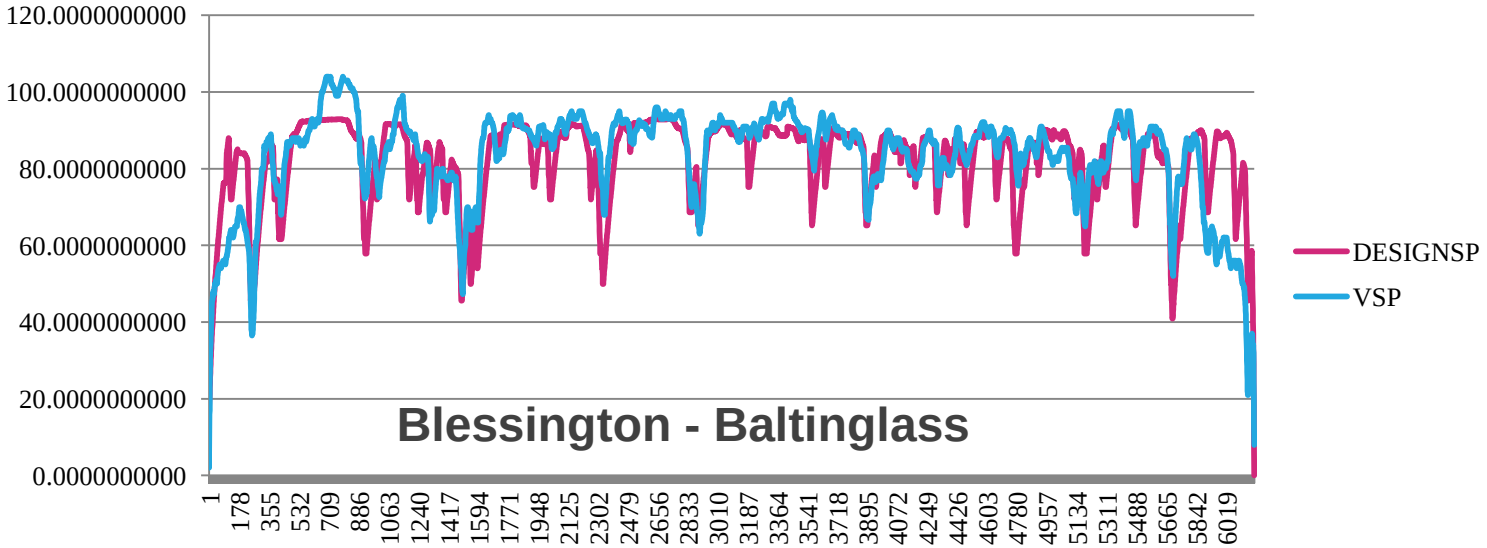


R406/405 Maynooth-Straffan-Kill

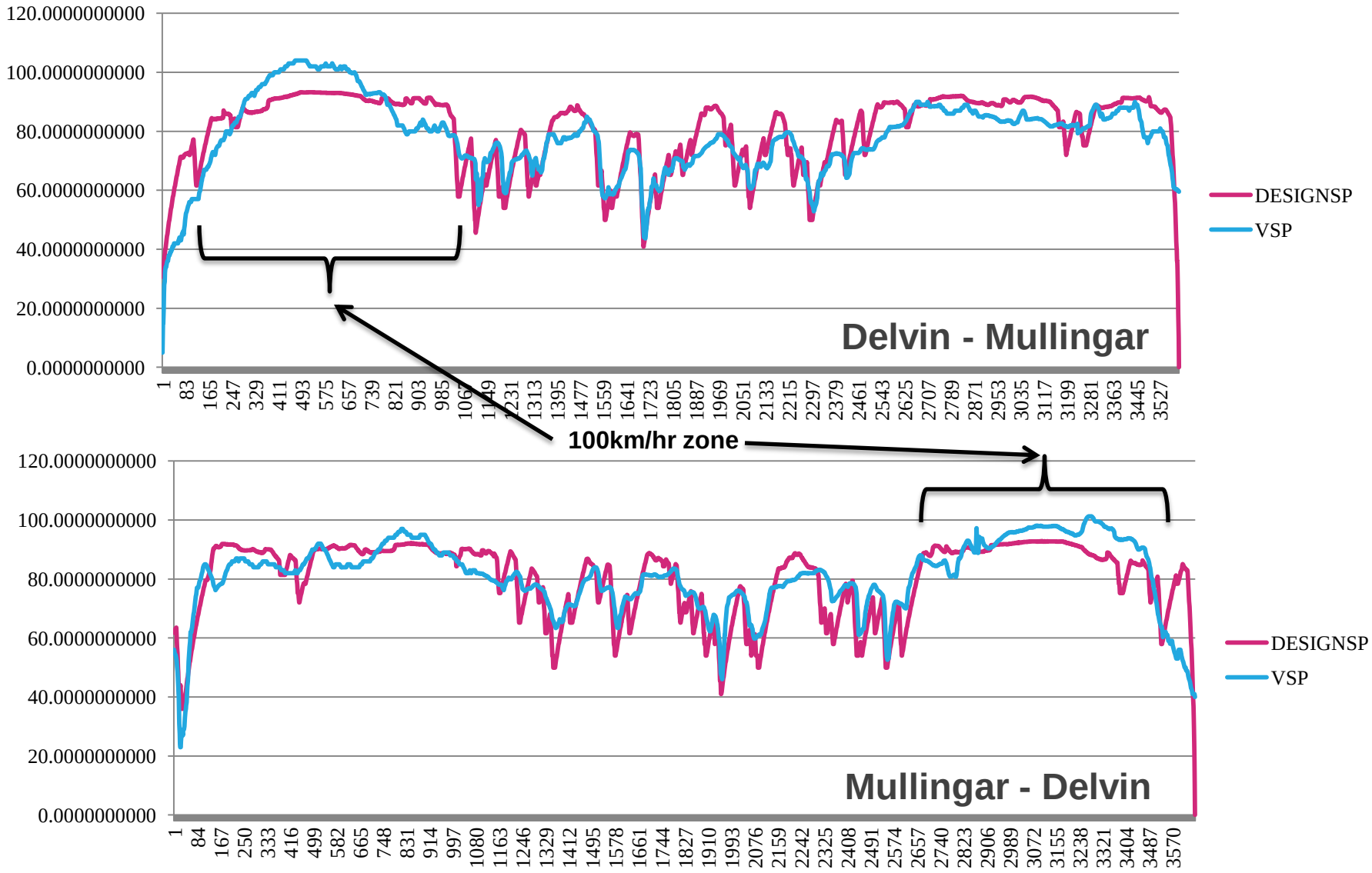
National Routes reviewed

Results N81 Blessington–Baltinglass V_{sp} versus V_{design}

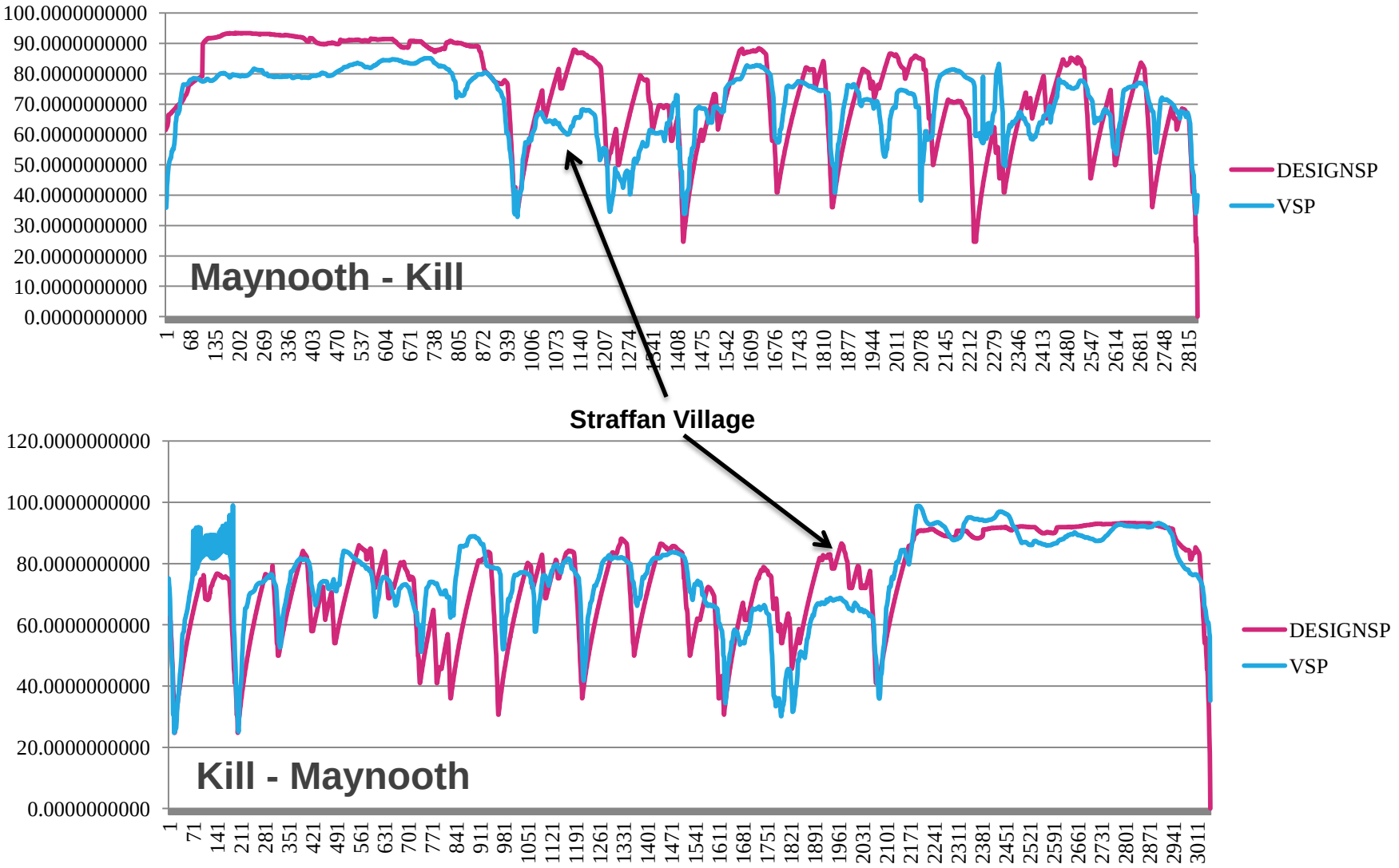




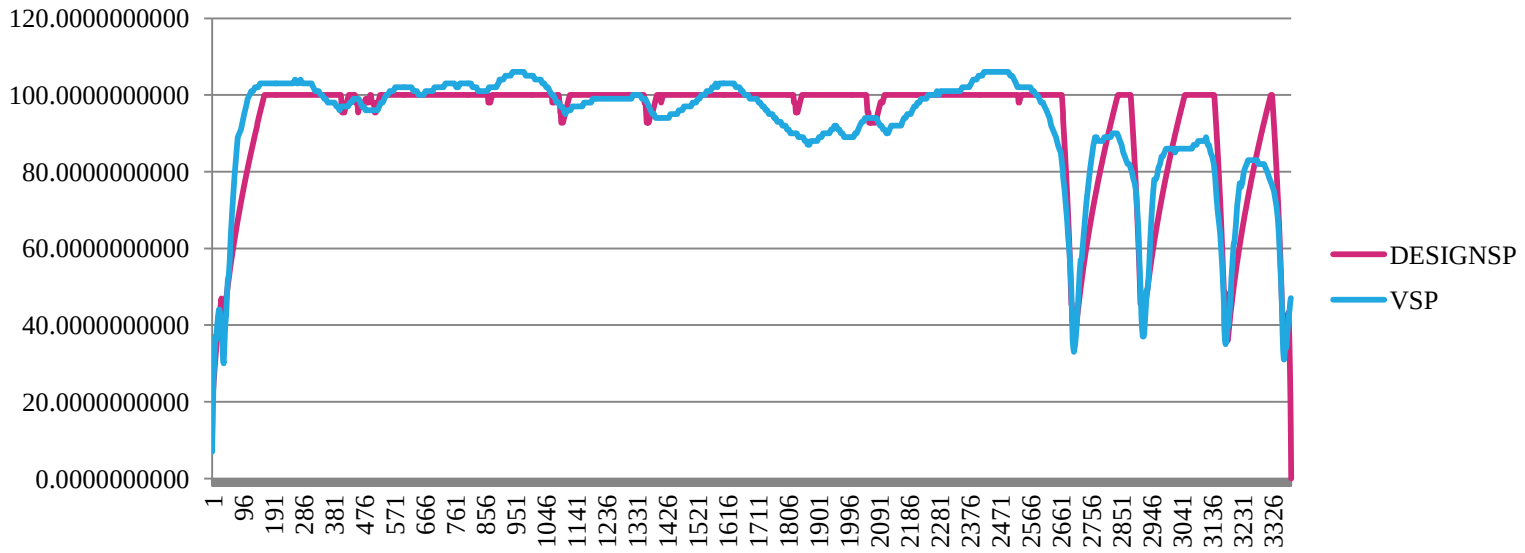
Results N52 Delvin to Mullingar V_{sp} versus V_{design}



Results Maynooth – Kill (Naas) V_{sp} versus V_{design}

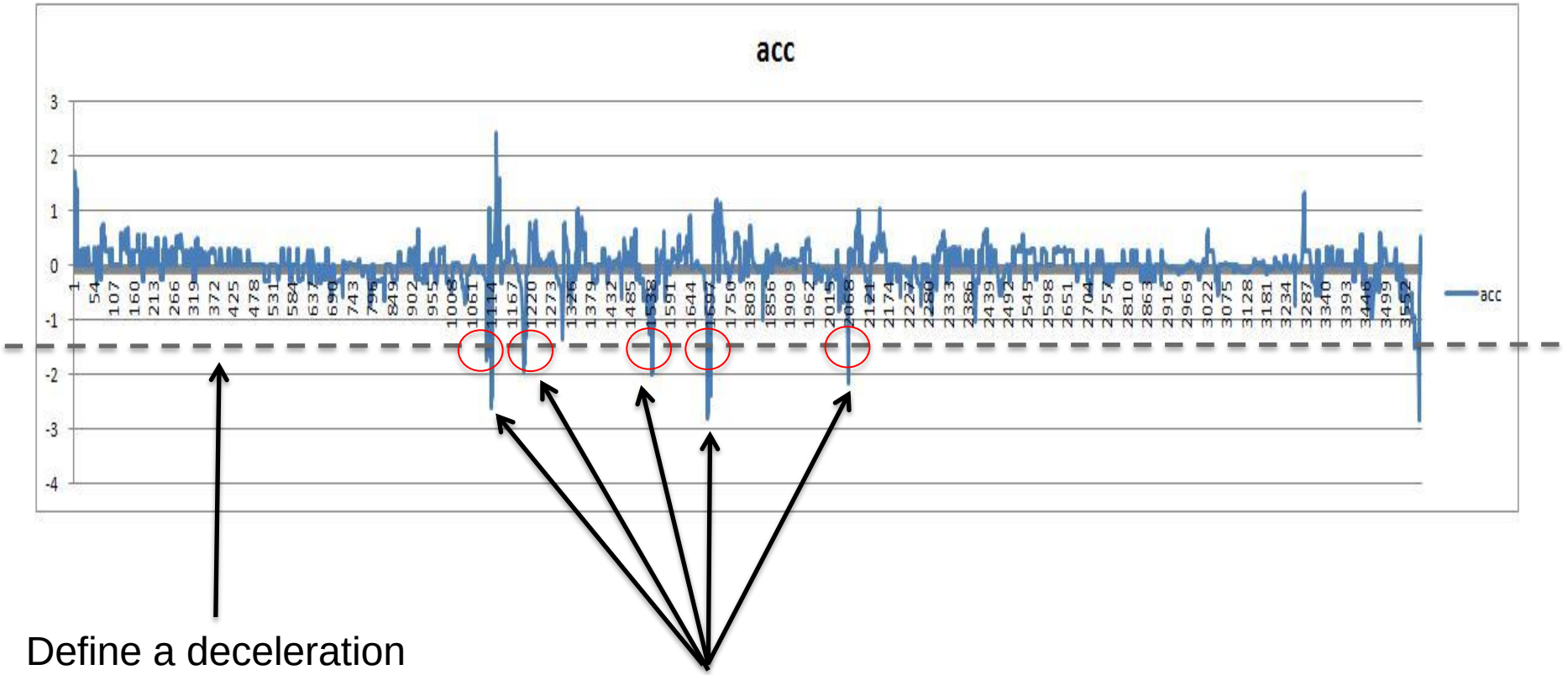


Results N52 Tyrellspass to Mullingar V_{sp} versus V_{design}



Consistency Measured using severe Deceleration

Delvin to Mullingar Acceleration derived from V_{sp} profile



Define a deceleration threshold value of say, -1.5m/sec^2

These zones require closer examination

Summary

NRA initiated a research project to develop a new approach to computing Design Speed along National Roadways

- Developing a methodology for collecting and processing safe profile velocity (V_{sp}). Need to ensure robust minimum sample size
- Devising a more comprehensive theoretical approach to computing Design Speed based on Sight Distance. This needs to be enhanced to take into account vertical alignment, width, entrances etc.
- Examining Design Consistency along route using deceleration derived from V_{sp}. Need to extend this to include road geometric elements, sight distance etc
- Can now begin to compare all of the above dynamic & static information to get a better understanding of the safety performance of road networks

NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

ARUP