Passing Sight Distance Assessment on Rural Roads with Crest Vertical Curves

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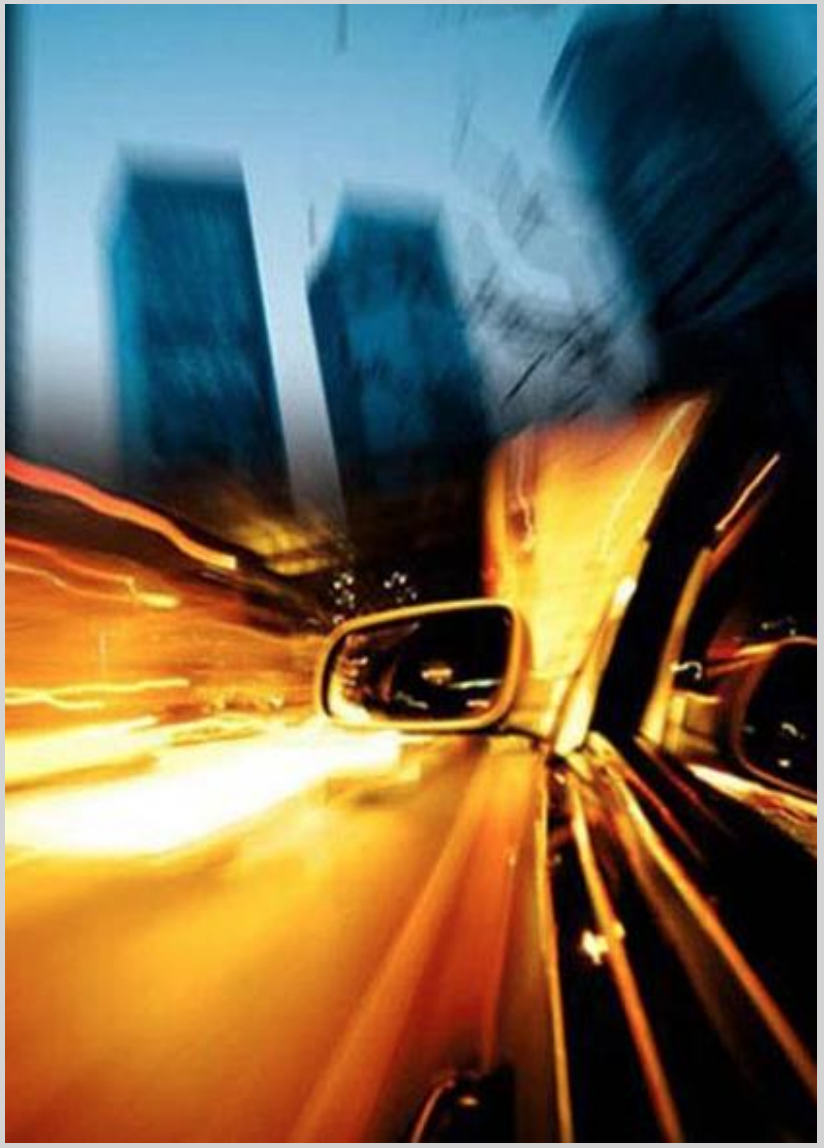
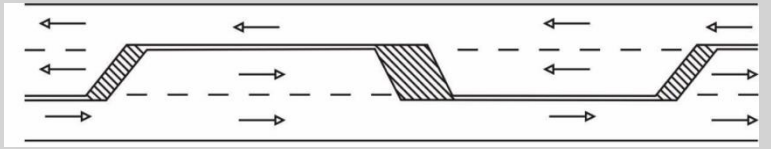
Passing Sight Distance (PSD)

- Distance that drivers must be able to see along the road ahead to safely and efficiently initiate and complete passing maneuvers of slower vehicles
- Critical sight distance parameter
  - Vehicle collisions, generally result to high severity crashes
- Two-lane rural roads



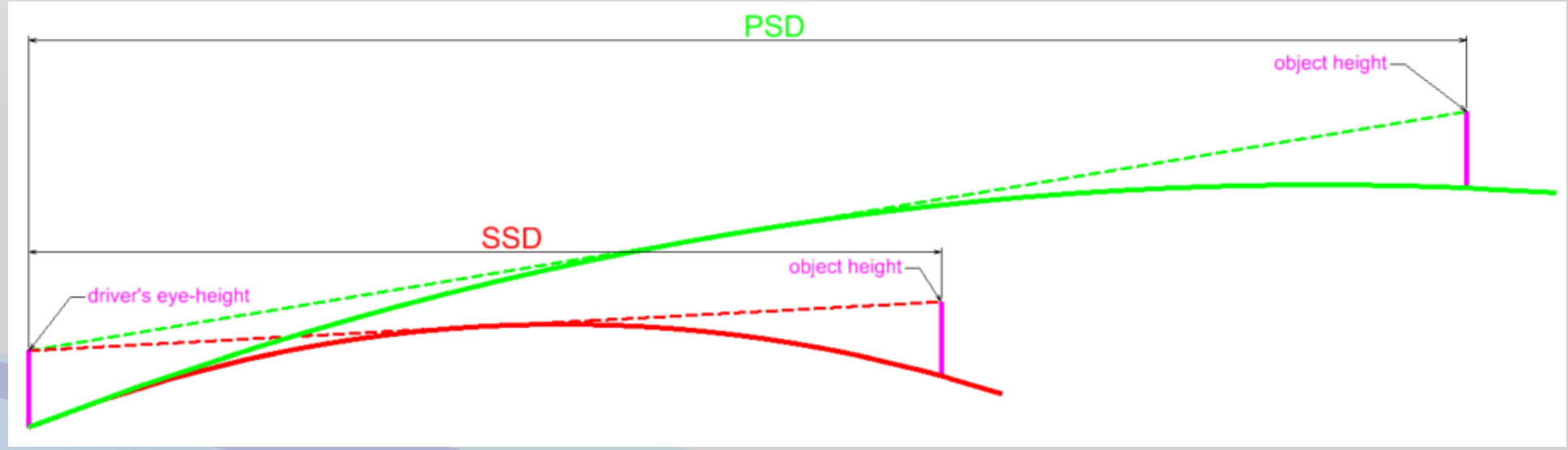
Road Sections with Limited PSD

- **Impose economic, safety and operational considerations**
  - Limited passing opportunities (passing zones) might motivate certain drivers to make risky passing attempts
  - Provision of protected passing zones through continuous 3-lane cross-section (2+1 roads)
    - ✓ Not always possible



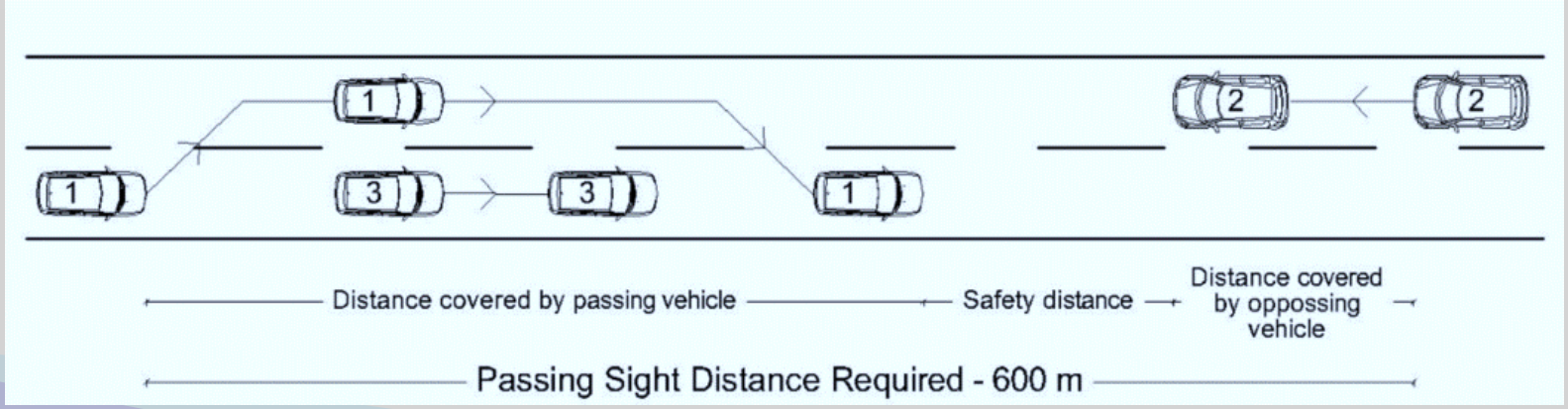
Crest Vertical Curves Effect on PSD

- CVC further obstruct PSD
  - Control CVC based on SSD provision
- In various design guidelines amended crest vertical curvature rates based on PSD requirements are proposed
  - Expensive designs (+double CVC rates)



PSD Provision on Two-Lane Rural Roads

- Highly prioritized
- Requirement for PSD sufficiency 20%-25% of total length
- RAL, 2012
  - PSD is currently dependent on the homogeneousness of the proposed road design classes and no longer on speed
    - ✓ PSD is set to 600m



Objectives

- Identification of areas with inadequate PSD, has not been analyzed adequately
  - Interaction of the involved geometric parameters
- PSD adequacy assessment for 2-lane rural road segments with CVC rates for SSD provision
- Quantify PSD availability and deliver a “ready-to-use” tool for practitioners

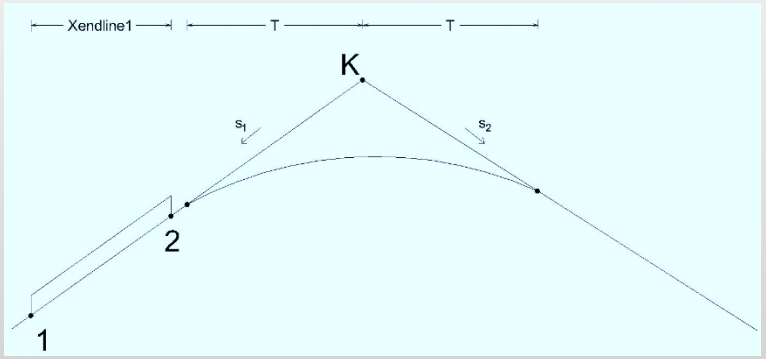
Methodology (1/4)

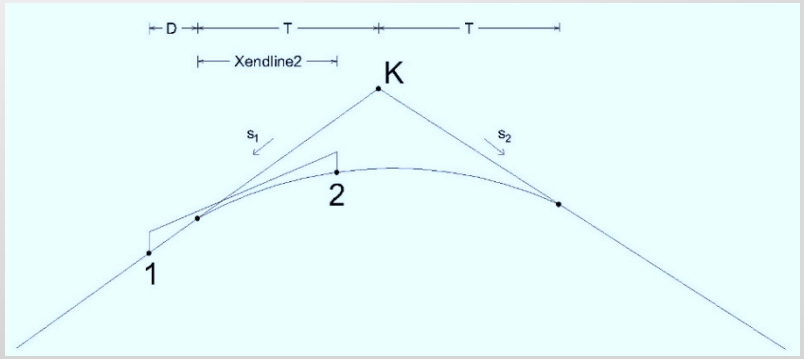
- **RAL 2012 guidelines**
  - Design classes (EKL1 excluded)
  - line of sight between passing - opposing vehicle, set to 600m
  - h_A= 1.00m (driver's sightline height)
  - h_Z= 1.00m (height of the opposing vehicle – object)

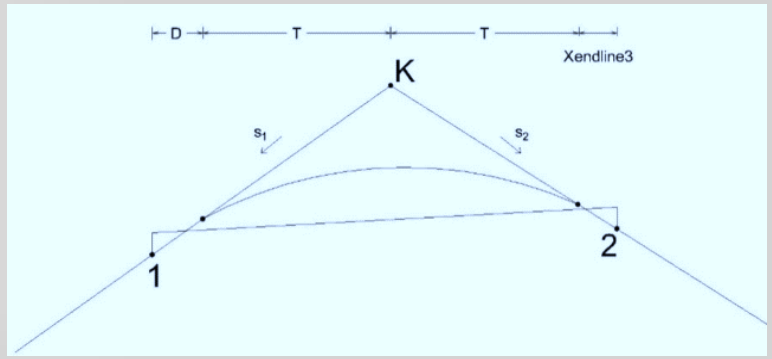
Design Class	Design Speed (km/h)	max s (%)	CVC Rate (H_k) (m)	Tangent length T (m)	Cross-section
EKL2	100	5.5	6000	85	RQ 11,5+
EKL3	90	6.5	5000	70	RQ 11
EKL4	70	8.0	3000	55	RQ 9

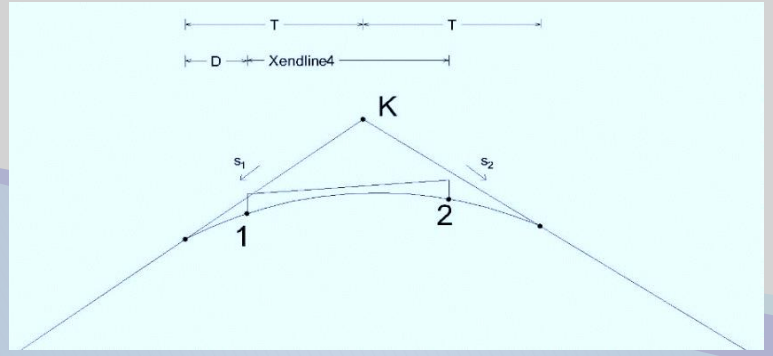
Methodology (2/4)

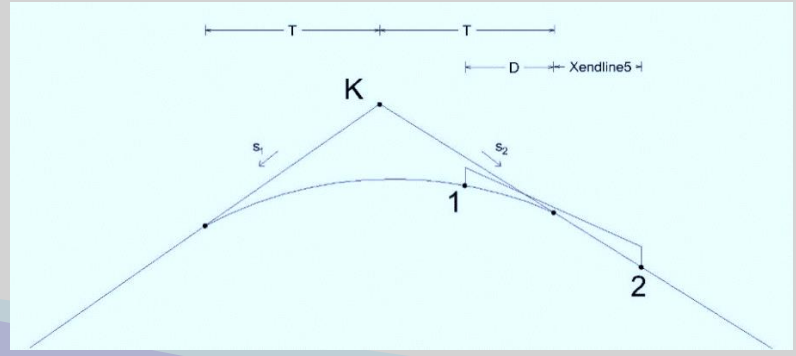
- **6 different cases analysed**
  - **Position of the passing vehicle in advance and beyond of CVC where line of sight blocked**

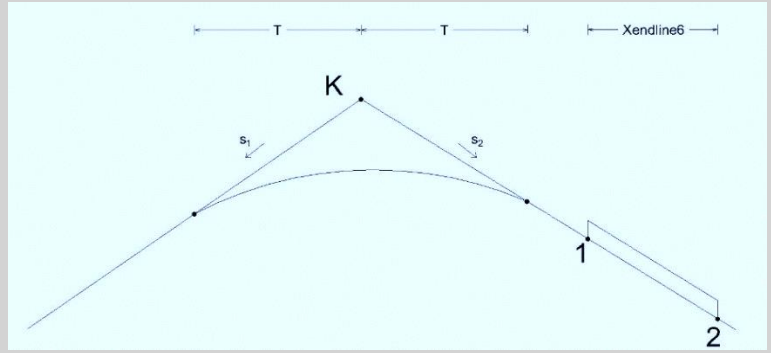






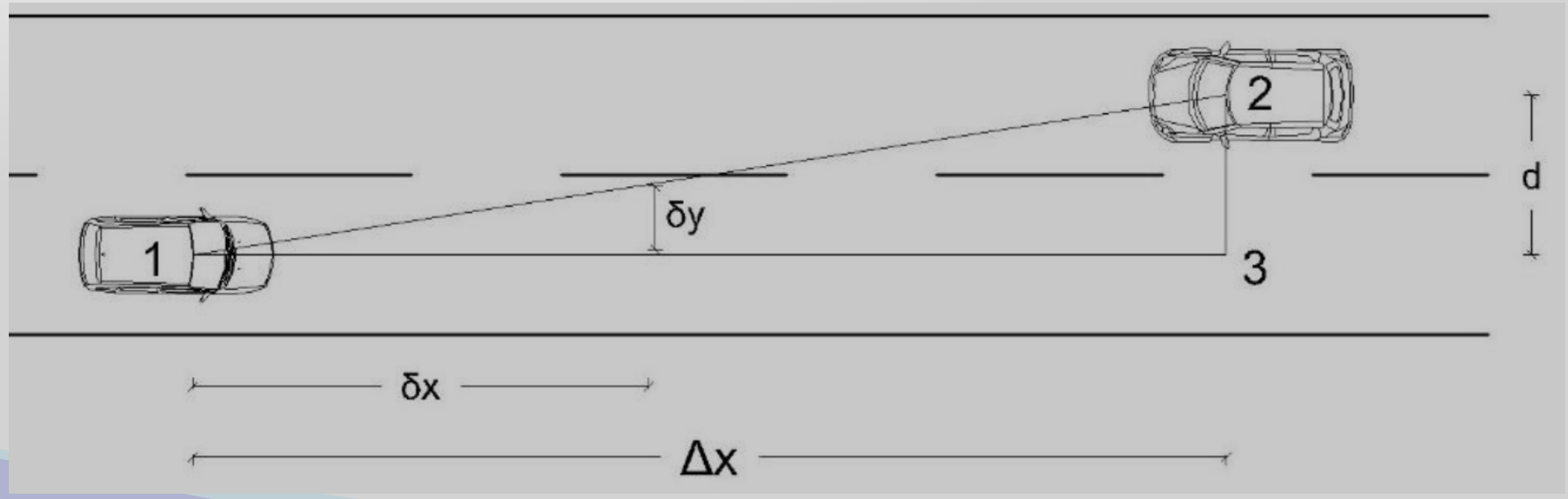




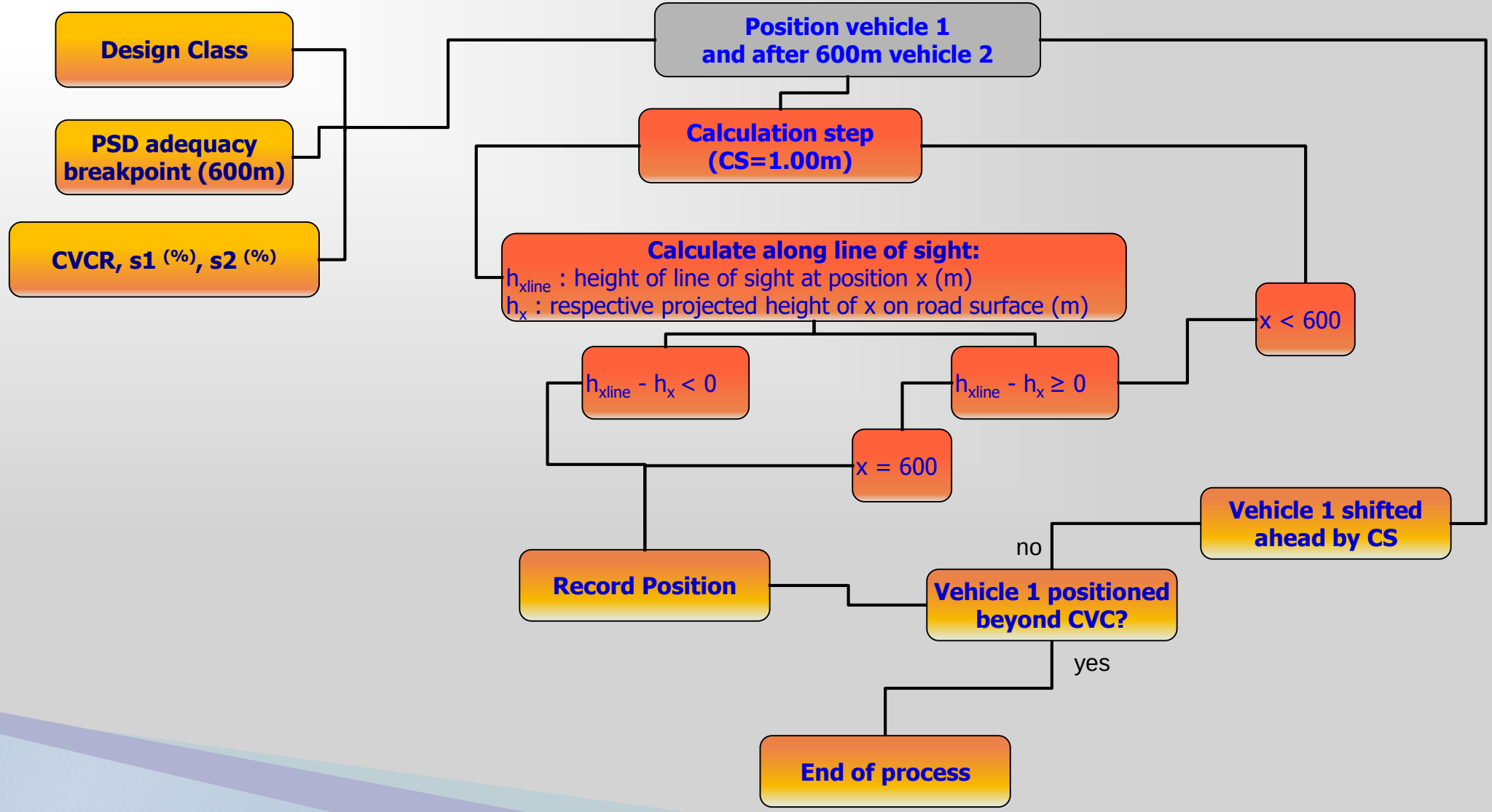


Methodology (3/4)

- **Superelevation impact investigation**
  - **Roadway's cross-slope delivers (slightly) more conservative results**

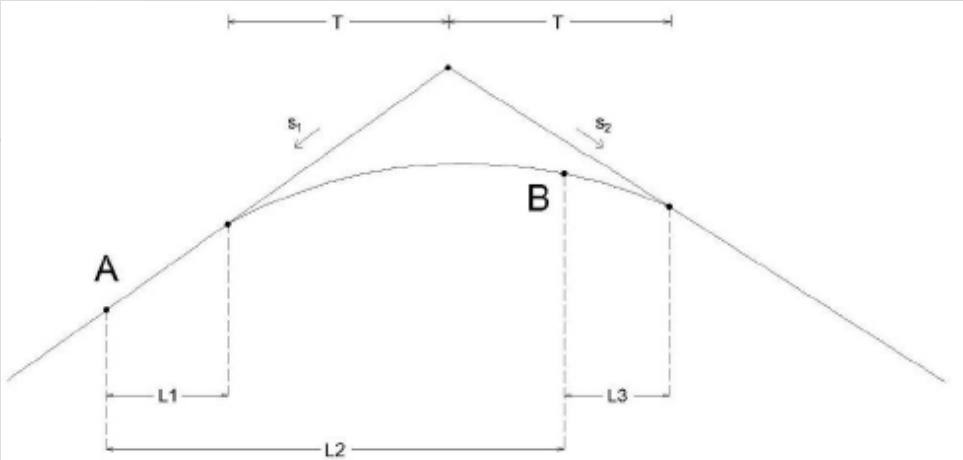


Methodology (4/4)

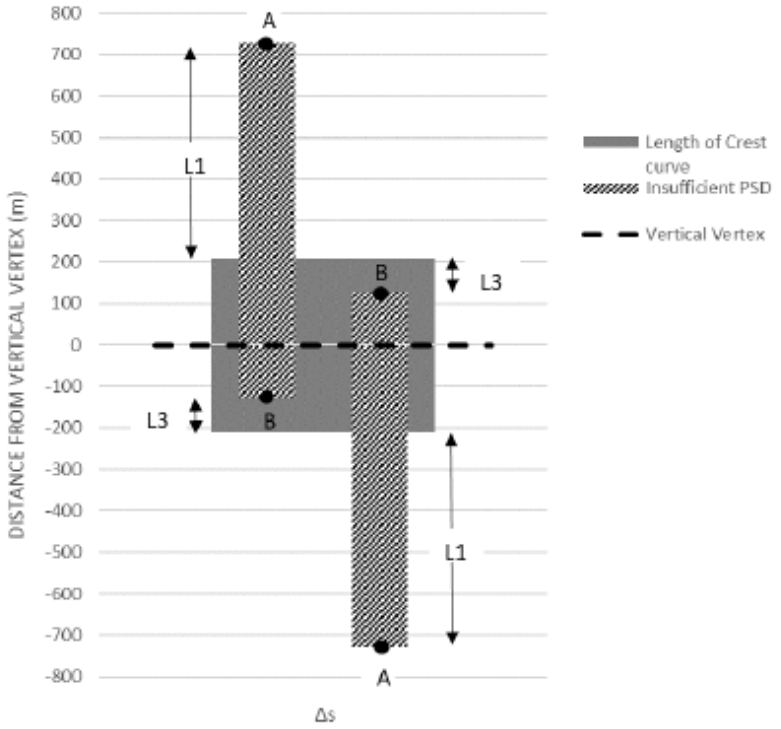


Outputs (1/8)

- For every set of parameters area with inadequate PSD delivered (area between A and B)
  - L_1, distance of point A from the beginning of the curve
  - L_2, area with PSD inadequacy (distance between A and B)
  - L_3, distance of point B from the end of the curve



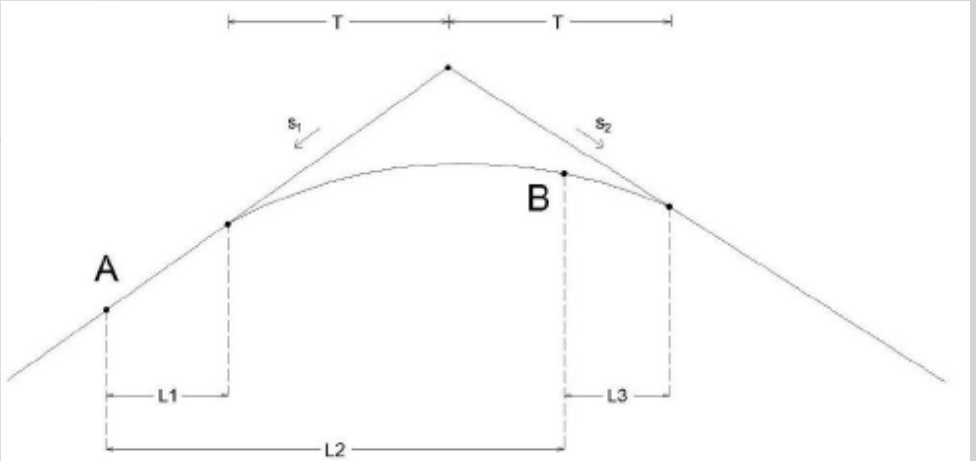
(a) representation of PSD inadequacy in accordance with L_1, L_2 and L_3



(b) representation of PSD inadequacy for both traffic directions

Outputs (2/8)

- Critical lengths L_1 and L_2, calculated as a function
  - Grade difference (absolute) Δs between the beginning (s_1) and ending (s_2) grade values ($\Delta s = s_2 - s_1$)
  - CVCR



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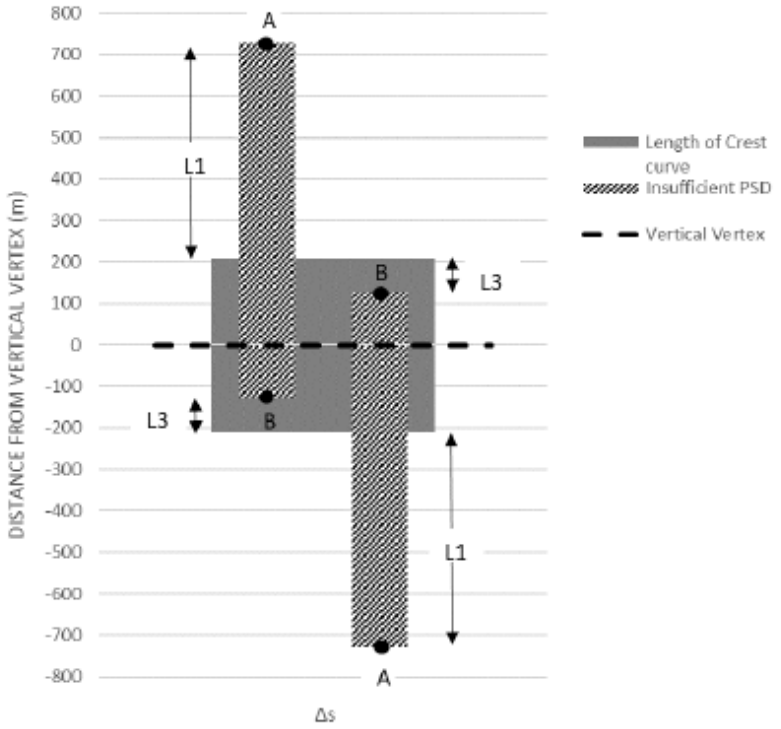
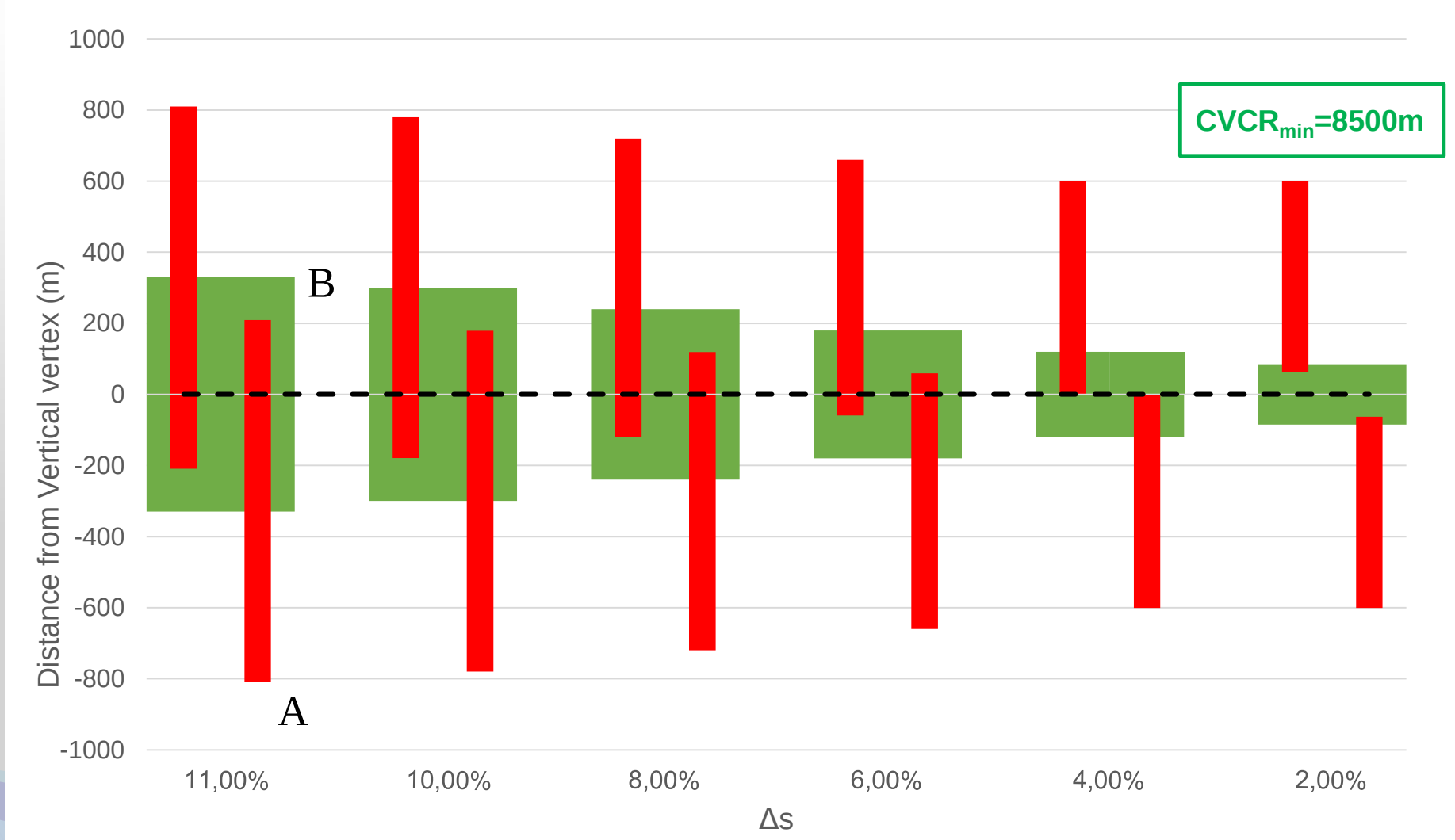


(b) representation of PSD inadequacy for both traffic directions

Outputs

(3/8)

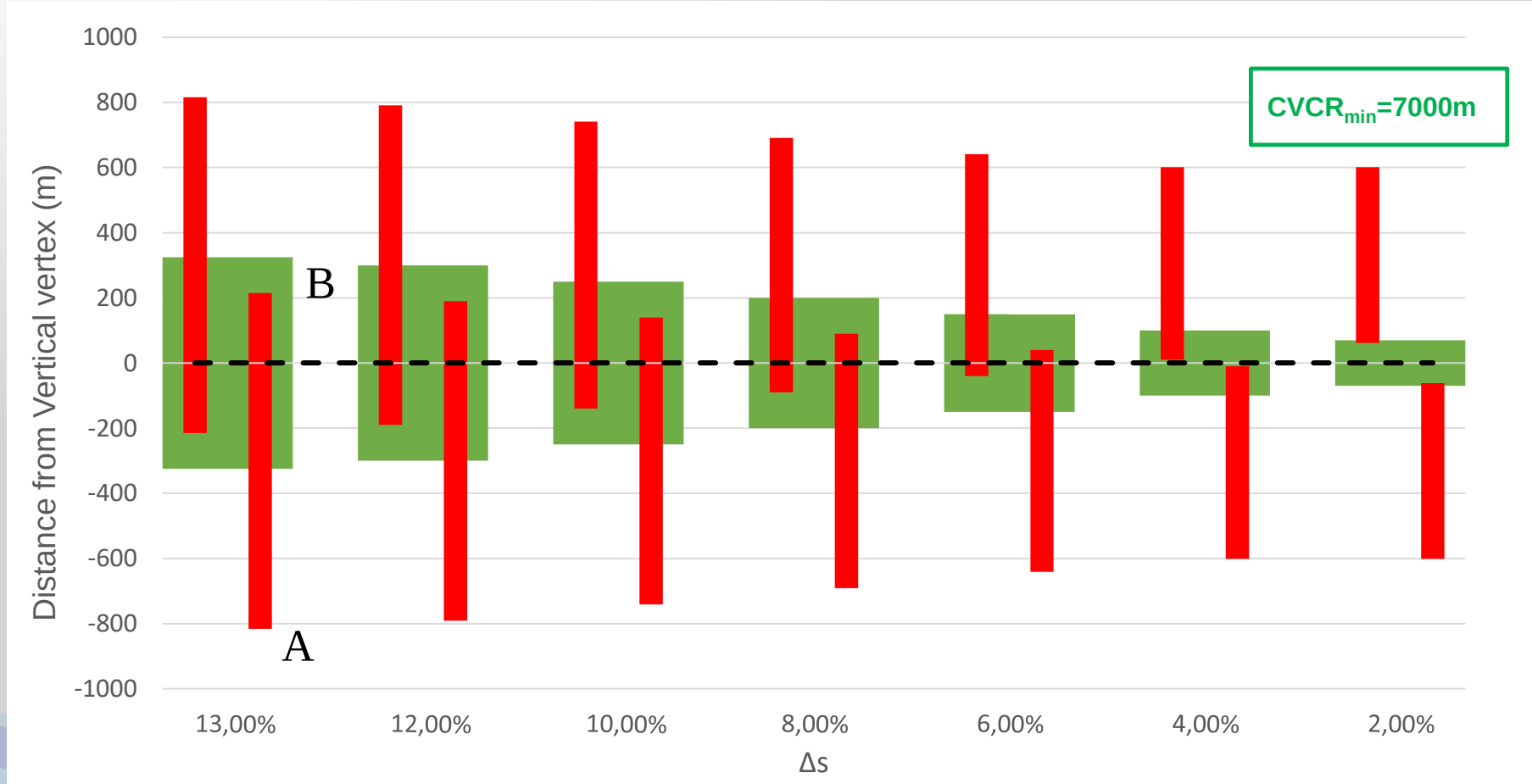
- EKL2, 100km/h, $CVCR_{min}$=6000m



Outputs

(4/8)

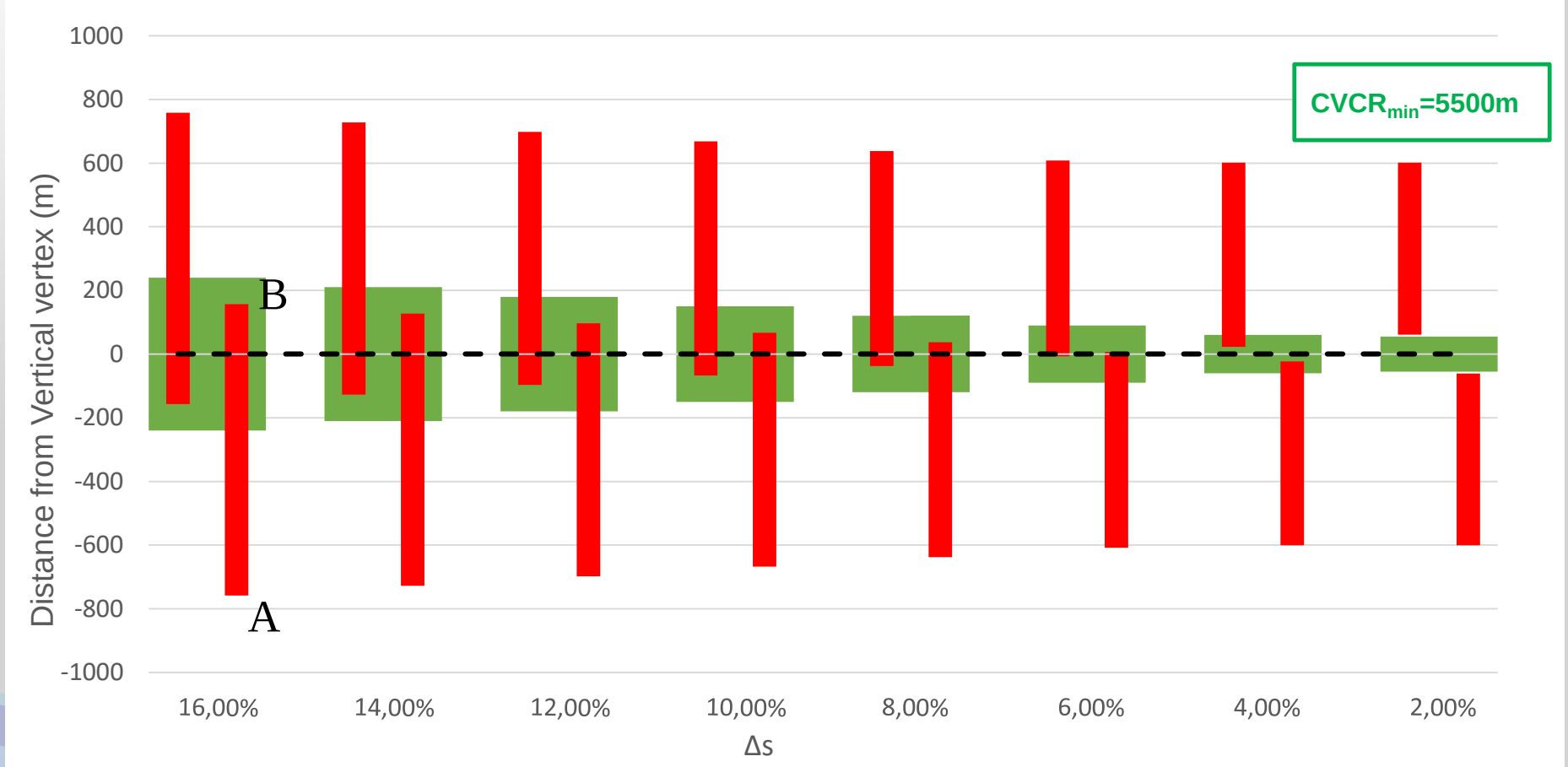
- EKL3, 90km/h, $CVCR_{min}$=5000m



Outputs

(5/8)

- EKL4, 70km/h, $CVCR_{min}$=3000m



Outputs

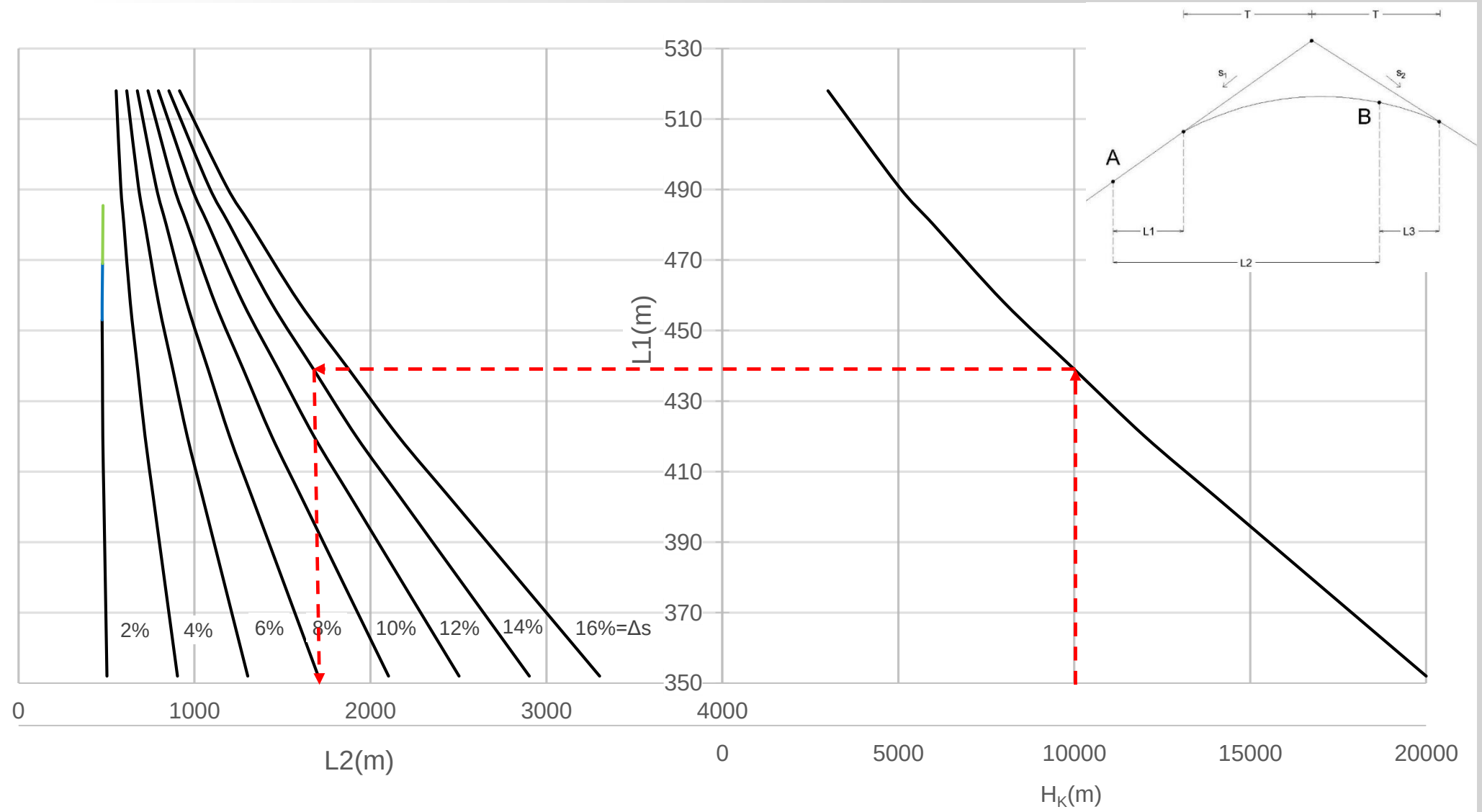
(6/8)

CVCR=10000 m →

L_1=439 m →

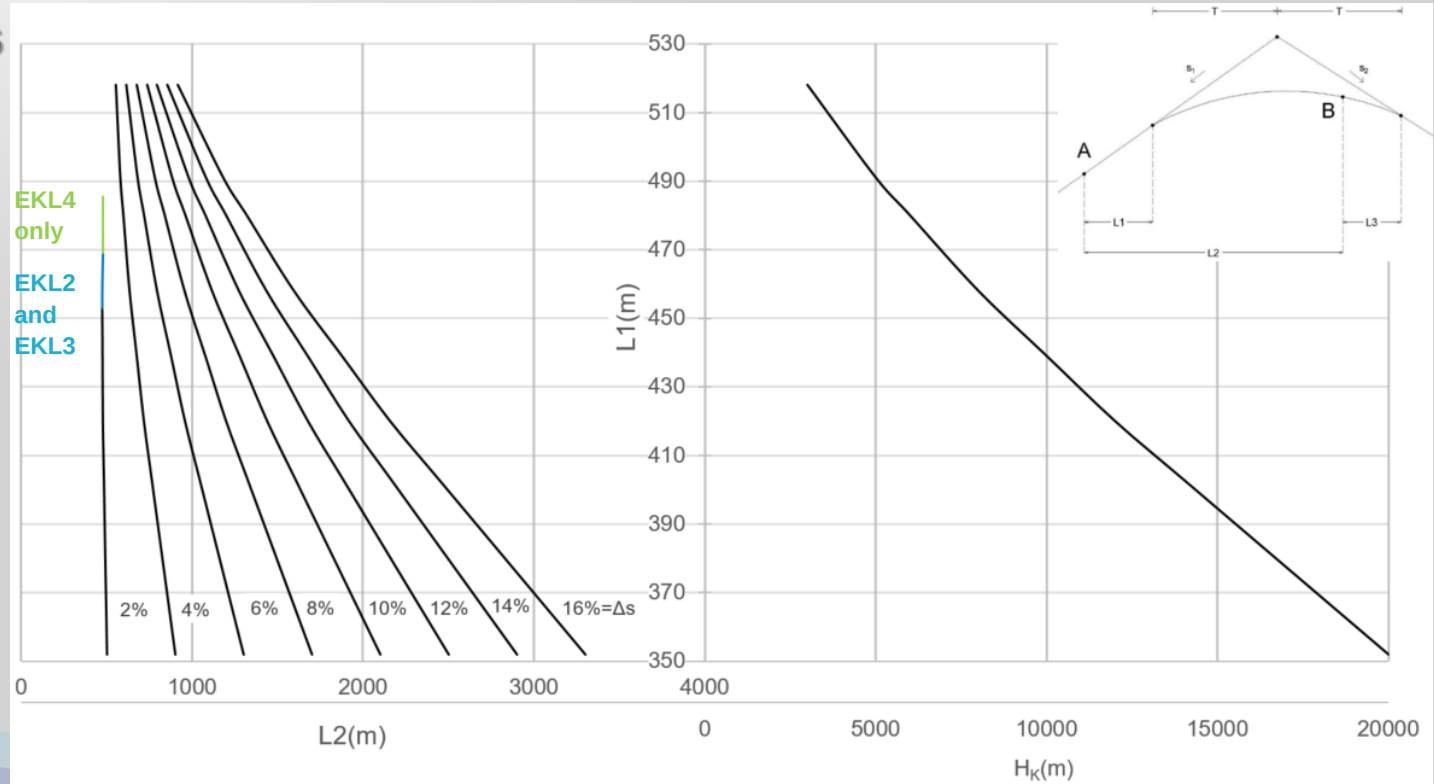
(Δs=14%) →

L_2=1677 m



Outputs

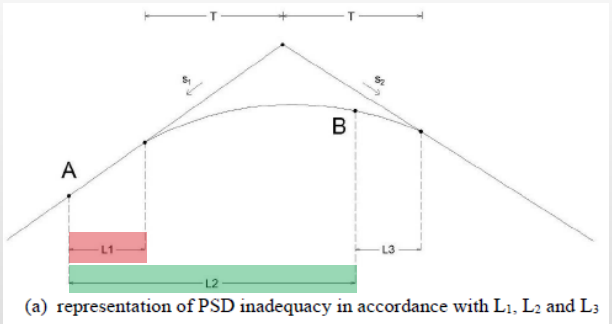
- **Graph valid for EKL2, EKL3, EKL4**
  - Entrance defined by control values (e.g. EKL3: CVCR ≥6000 and Δs ≤13.0%)
  - Colored parts in Δs=2.0% aligned with min. tangent length requirements
    - ✓ $CVCR_{min,EKL2}$ = 8500m
    - ✓ $CVCR_{min,EKL3}$ = 7000m
    - ✓ $CVCR_{min,EKL4}$ = 5500m



Outputs

(8/8)

- Values of L_2 as a function of L_1, CVCR and Δs



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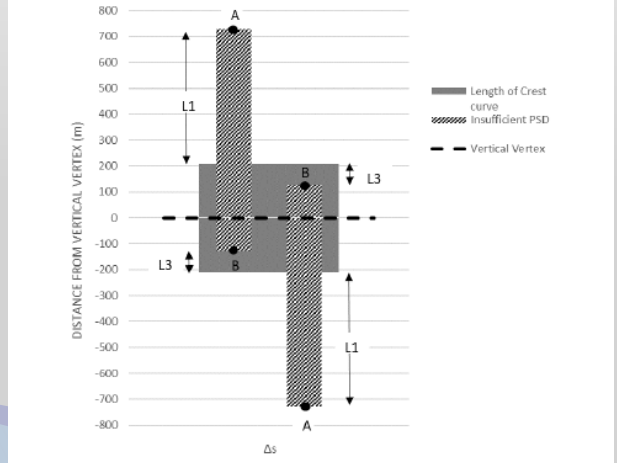


(b) representation of PSD inadequacy for both traffic directions

CVCR (m)	Δs (%) / L_1 (m)	2	4	6	8	10	12	14	16
3000	518	-	555	615	675	735	795	855	915
5000	491	-	581	681	781	881	981	1081	1181
5500	485	479	589	699	809	919	1029	1139	1249
6000	480	479	599	719	839	959	1079	1199	1319
8000	458	475	635	795	955	1115	1275	1435	1595
10000	439	477	677	877	1077	1277	1477	1677	1877
12000	420	479	719	959	1199	1439	1679	1919	2159
14000	403	485	765	1045	1325	1605	1885	2165	2445
16000	386	491	811	1131	1451	1771	2091	2411	2731
18000	369	497	857	1217	1577	1937	2297	2657	3017
20000	352	503	903	1303	1703	2103	2503	2903	3303

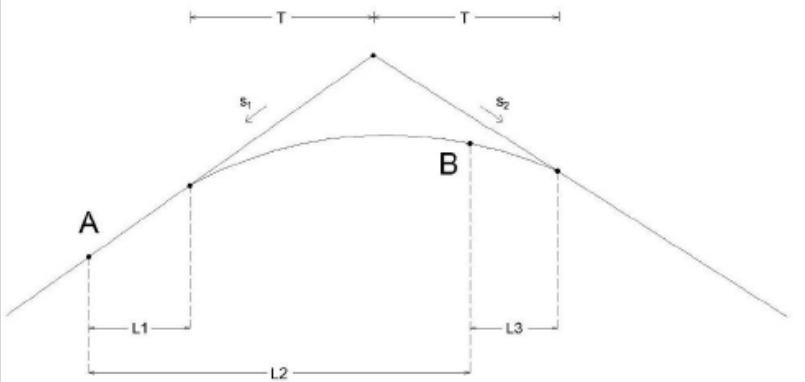
Conclusions

(1/3)

- The paper quantifies areas with PSD adequacy for road segments with CVCR based on SSD provision
  - Analysis of involved geometric parameters impact
- The methodology can be implemented for any road design guideline by introducing the required PSD and the respective control values
  - Driver's eye height, object height, control CVCR, grade values, etc.

Conclusions (2/3)

- Methodology tailored for RAL 2012 guidelines
  - EKL2, EKL3, EKL4
- The boundaries of PSD inadequacy, excluding one situation for EKL4, were concentrated in advance and inside the vertical curve, and depend only on the CVCR value (not on Δs)
  - However, the length where passing is restricted, depends on the grade difference since the length of the vertical curve depends on Δs



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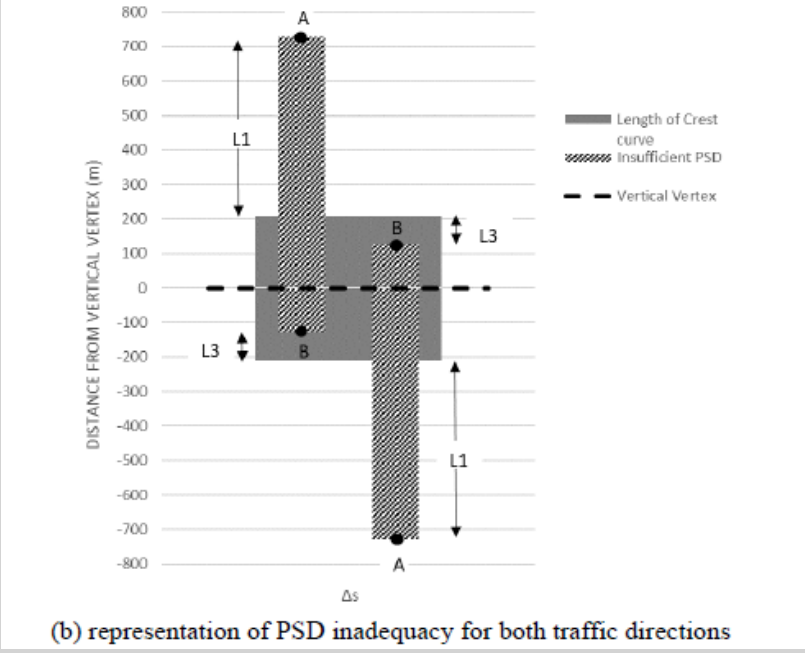
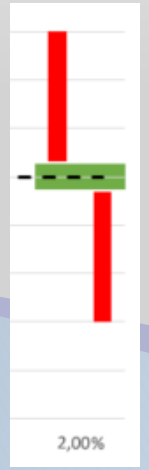


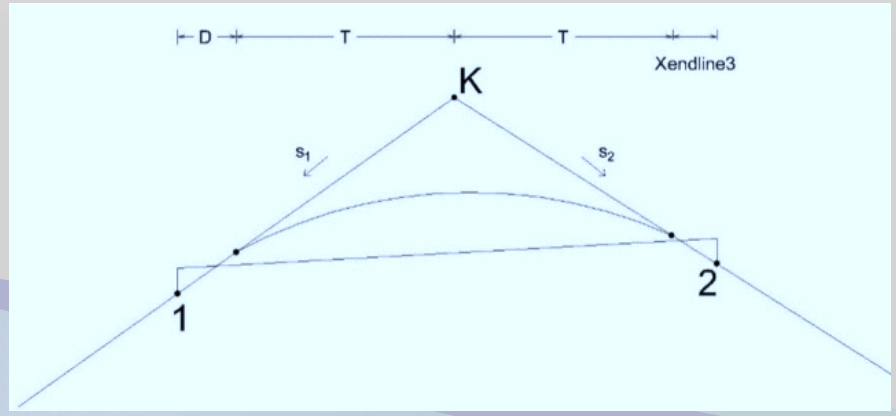
(b) representation of PSD inadequacy for both traffic directions

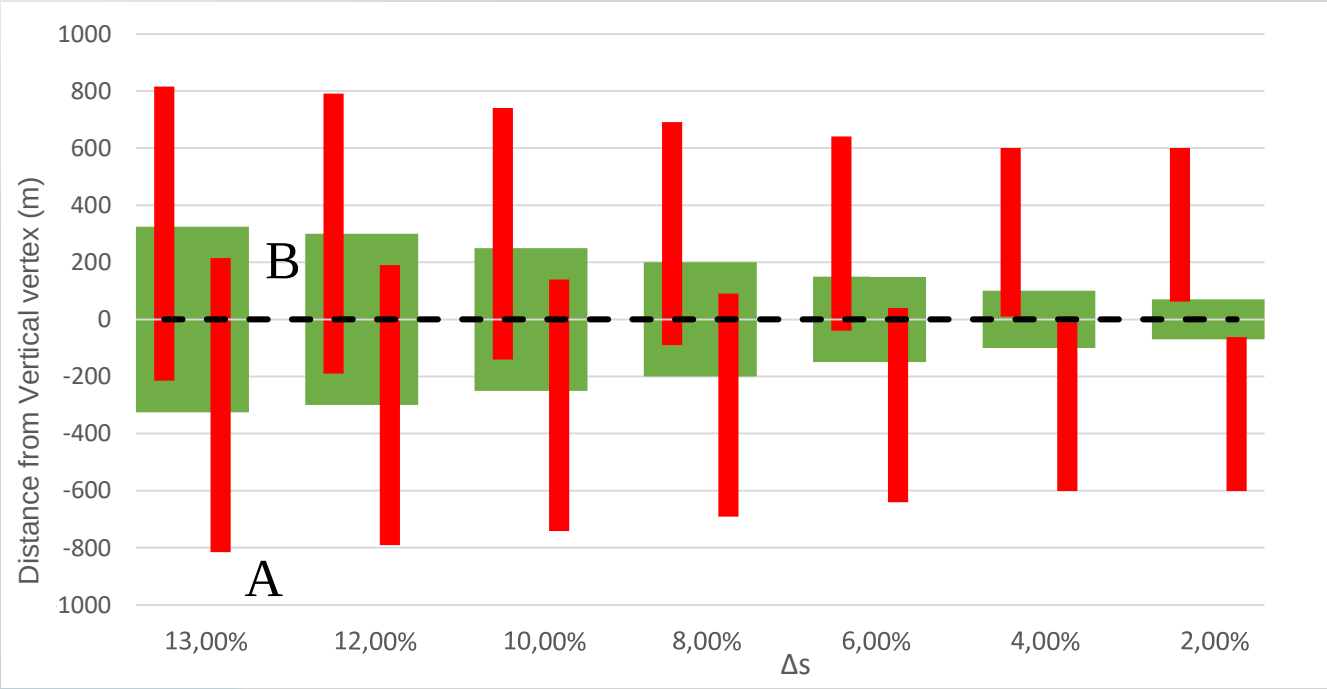
Conclusions (3/3)

- For the same CVCR, the boundaries with insufficient PSD for the passing vehicle, were found to have the same relative distances from the starting and ending point of the vertical curve
  - Only for Case 3, PSD inadequacy is grade dependent, (Case 3 applies only for EKL4 combined with Δs=2%)

EKL4







Further Analysis

- Assess the impact of combined horizontal and vertical alignment
- Link more closely the passing process to the traffic volumes in order to understand further the breakpoint for introducing additional passing lanes

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