ROLE OF INFRASTRUCTURE DESIGN IN ACHIEVING SUSTAINABLE ROAD SAFETY

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Structure of Presentation

- Background
- Safe System Adaptation to Road Design

BACKGROUND

European Union 2010 - 2020

Road fatalities per million population

www.nrso.ntua.gr

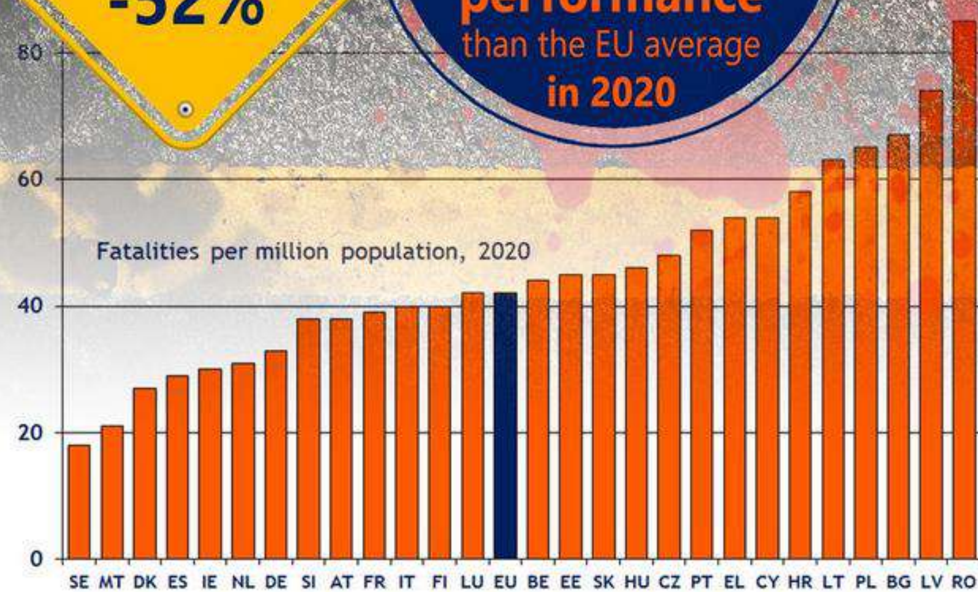
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2010-2020
AT	66	62	63	54	51	56	50	47	46	47	*38*	-42.4%
BE	77	80	69	65	65	65	56	54	53	56	*44*	-42.9%
BG	105	89	82	83	91	98	99	96	87	90	*67*	-36.2%
CY	73	85	59	51	52	67	54	62	57	59	*54*	-26.0%
CZ	77	67	71	62	65	70	58	55	62	58	*48*	-37.7%
DE	45	50	45	41	42	43	39	39	40	37	*33*	-26.7%
DK	48	40	30	34	32	31	37	30	30	34	*27*	-43.8%
EE	59	76	66	61	59	51	54	36	51	39	*45*	-23.7%
EL	113	103	89	80	73	73	76	69	65	64	*54*	-52.3%
ES	52	44	41	36	36	36	39	39	39	37	*29*	-44.2%
FI	50	54	47	48	42	49	47	42	43	38	*40*	-20.0%
FR	62	61	56	50	51	52	54	51	49	50	*39*	-37.1%
HR	99	97	92	86	73	82	73	80	77	73	*58*	-41.4%
HU	74	64	61	60	63	65	62	64	65	62	*46*	-37.8%
IE	46	41	35	41	42	36	39	33	29	29	*30*	-34.8%
IT	66	64	63	57	56	56	54	56	55	53	*40*	-39.4%
LT	95	97	101	86	91	83	66	67	62	67	*63*	-33.7%
LU	64	64	65	84	64	64	56	42	60	36	*42*	-34.4%
LV	103	86	88	99	106	95	80	70	77	69	*74*	-28.2%
MT	36	51	22	40	24	26	51	41	38	32	*21*	-41.7%
NL	39	40	34	28	28	31	31	31	35	34	*31*	-20.5%
PL	103	110	94	88	84	77	80	75	75	77	*65*	-36.9%
PT	80	74	68	61	61	57	54	58	68	63	*52*	-35.0%
RO	117	100	102	93	91	95	97	99	96	96	*85*	-27.4%
SE	28	34	30	27	28	27	27	25	32	22	*18*	-35.7%
SI	67	69	63	61	52	58	63	50	44	49	*38*	-43.3%
SK	69	61	65	46	54	51	51	51	48	50	*45*	-34.8%
EU	67	65	60	55	54	55	53	53	52	51	*42*	-37.5%

Issued: April 20th, 2021. Figures in italics are provisional data
About the data: *www.nrso.ntua.gr/wp-content/uploads/nrso-data-eu5.pdf*
Sources: *European Commission*
Processing: *NTUA - Road Safety Observatory*

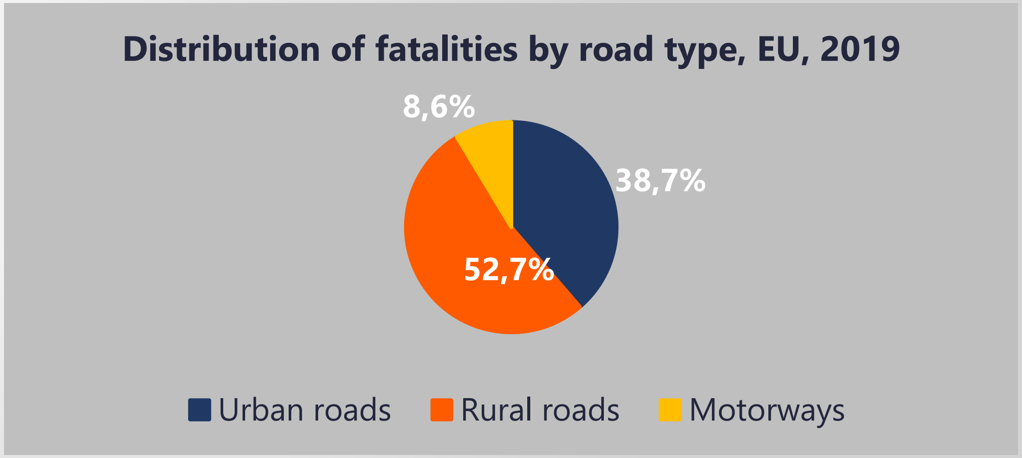
Sweden ranked **first in 2020** with 18 fatalities/mil. inhabitants followed by **Malta** (21) and **Denmark** (27), whereas **Greece** ranked 20th (54) and **Romania** ranked last (85)

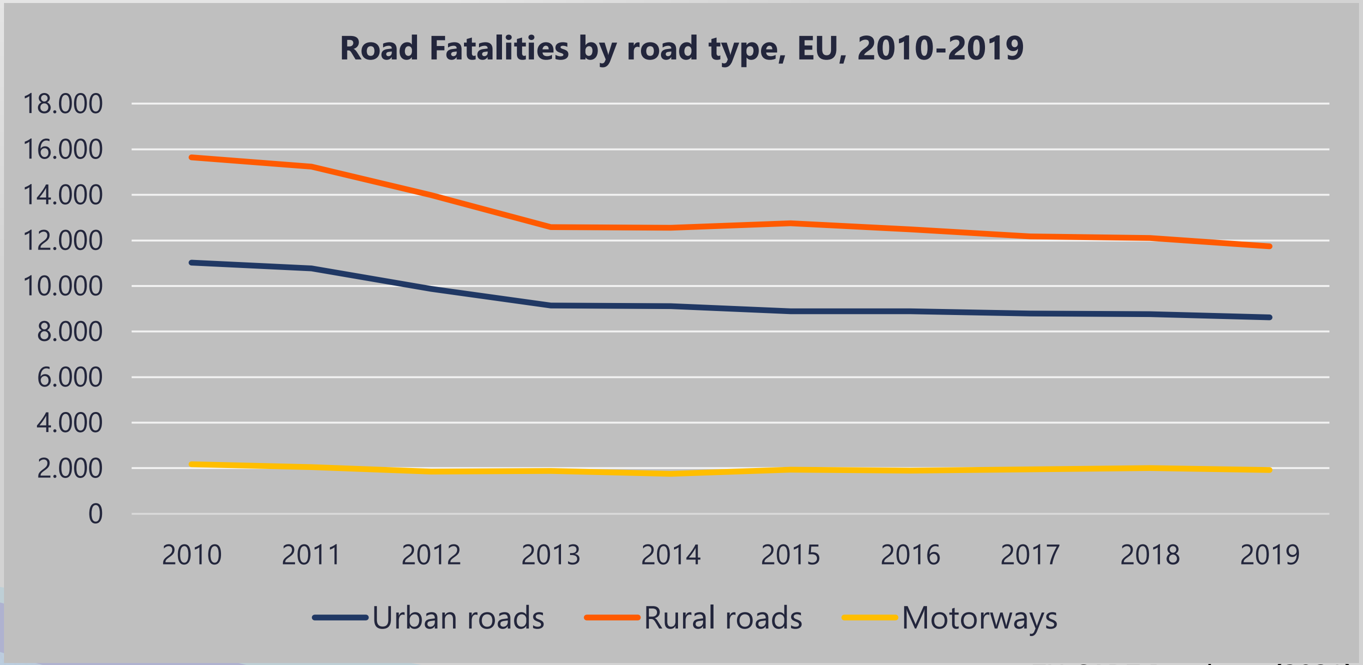
Greece was the only country to achieve the decade 2010-2020 target of 50% road fatalities reduction, with a performance of **-52%**

13 countries **had a better performance** than the EU average **in 2020**



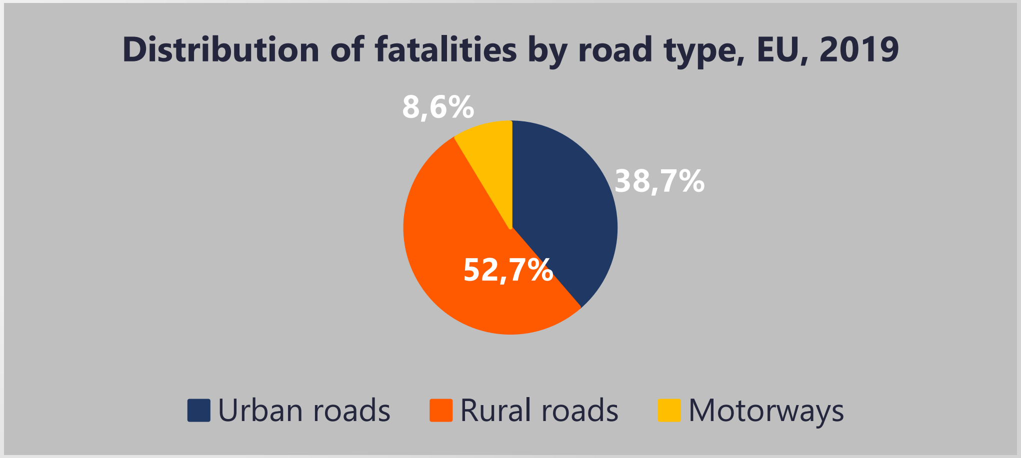
Where Do Accidents Occur?

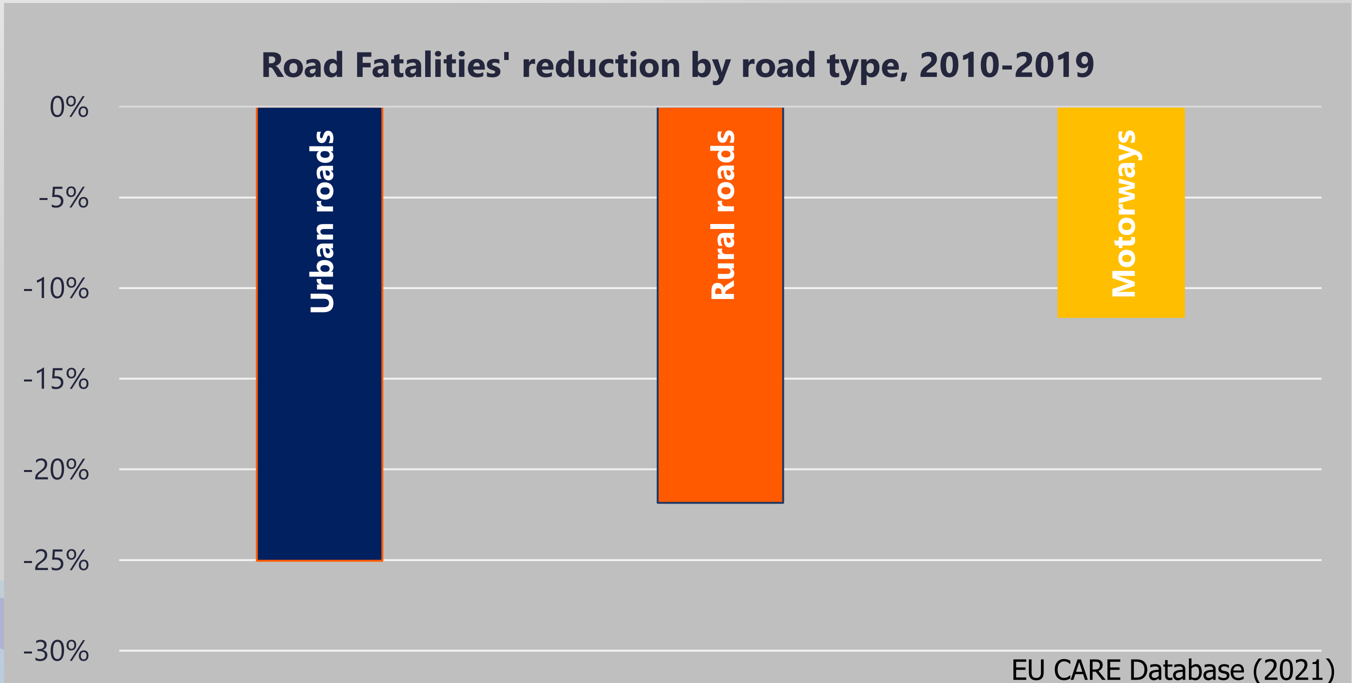




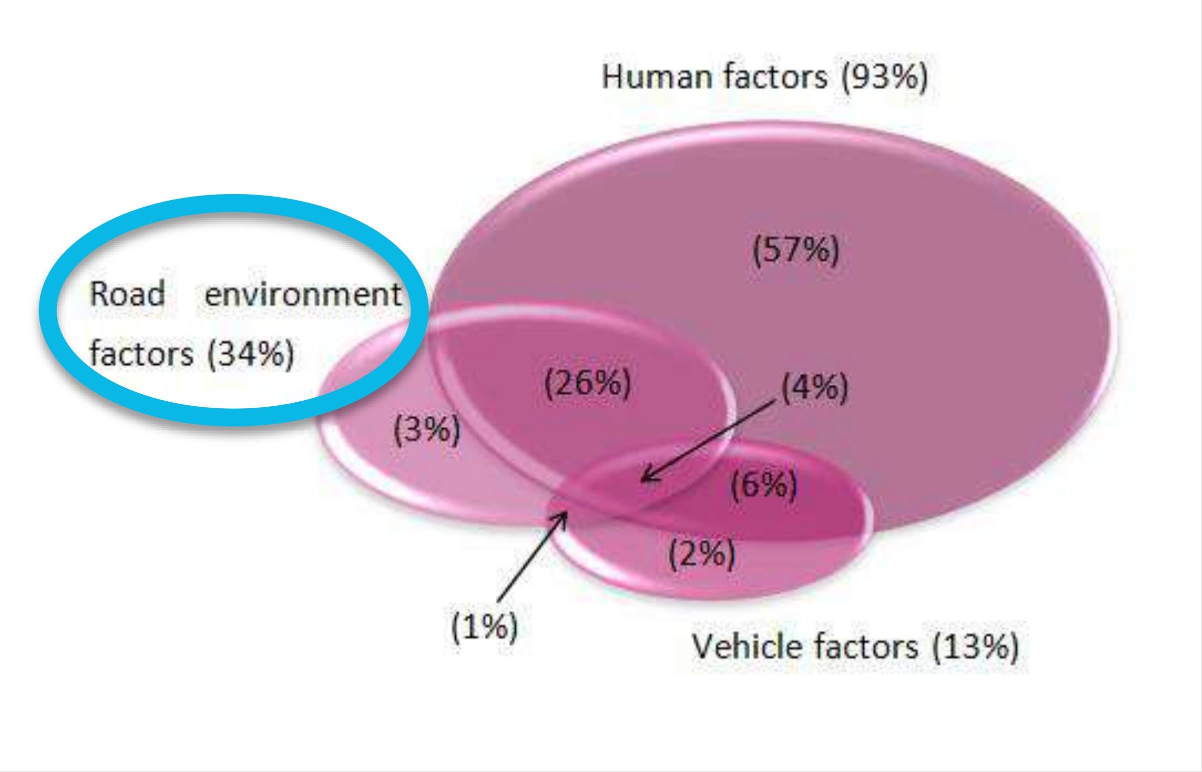
EU CARE Database (2021)

Improvement Rates in EU





Accident Contributing Factors

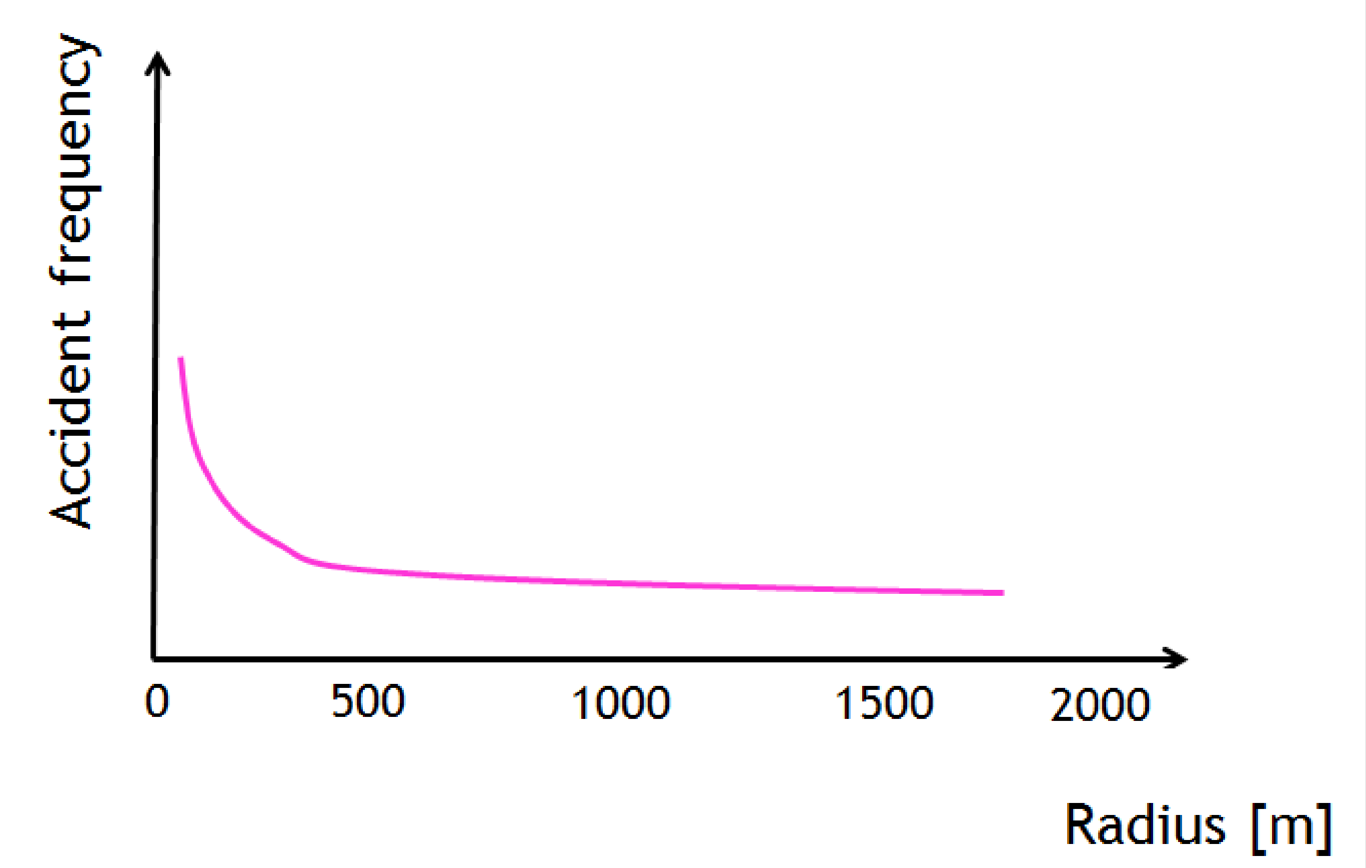


Treat et al. (1979)

Accident Risk in Horizontal Curves

- 1.5 to 4 times higher than in tangents
- Severity is high, 25-30 % of all fatal accidents occur in curves
- Secondary rural roads
  (more and sharper horizontal curves) have higher proportion of accident in curves
- 60% of all accidents to occur on horizontal curves are single-vehicle off-road accidents
- The proportion of accidents on wet surface is high in horizontal curves
- Accidents occur primarily
  at both ends of curves

Accident Risk in Horizontal Curves



PIARC, Road Safety Manual (2003)

List of Accident Contributing Factors - Human

	before the accident	during the accident	after the accident
human	Physical condition • Fatigue, illness, medication, alcohol • handicaps: sight, hearing, etc. Physiological condition • stress, inattention, distraction, attitude Socio-demographic profile • age, sex, professional occupation, level of education Experience and skill • driving experience, knowledge of vehicle and itinerary, knowledge of regulations Action • manoeuvres before collision self-protection • seatbelt, helmet	Physical condition • reflex Error • poor mental image of the road • poor evaluation of distances and speeds • inappropriate manoeuvres Action • speed • braking • positioning • warning	Physical condition • resistance to impact Physiological condition • emotional shock Experience and skill • safety first • protection of accident-scene • raising the alarm Action • manoeuvres after collision

List of Accident Contributing Factors - Vehicle

	before the accident	during the accident	after the accident
vehicle	Physical factors • type and make, colour, horsepower Mechanical condition • brakes, tires, suspension, lights, etc. Damage • external, internal Running state • objects, position of passengers • obstructive luggage	Activation of passive safety • resistance to deformation • airbag • mayday	Handling of damaged vehicles

List of Accident Contributing Factors - Road Environment

	before the accident	during the accident	after the accident
road environment	Geometry • vertical alignment, cross-section horizontal alignment Surface characteristics • skid resistance, roughness • debris, contamination Surroundings • urban, rural • advertising, shops • traffic volumes • main users Equipment • signs, markings, etc.	Recovery area • shoulders, emergency lane • central refuge Roadside conditions Critical zone • transition zone • work zones, unusual surroundings defect • maintenance • obstacle on roadway	Accident warning Cleaning up the road

Engineering Approach to Road Safety

- **Assess potential risk**
  - reactive approach
    - ✓ analysis of crash data – traditional approach
  - proactive approach
    - ✓ data is poor or need to supplement crash data
- **Approaches to risk assessment**
  - reactive approach
    - ✓ crash- based identification
  - proactive approach
    - ✓ based on impact assessment, road safety audit and road safety inspection

Reactive Approach

Crash-based identification

- Accident investigation or treatment of 'black spots' or sites with potential for safety improvement
- Approach: select location with highest potential for reductions in crashes through targeted safety improvements
- Relies on crash analyses to identify safety problems
- Requires a good and reliable crash database

Proactive Approach

- Suitable to LMIC where accurate crash data may not be available
- Cover a range of techniques for assessing risk
- Aims to avoid crashes by
  - safe road design construction
  - proposed road infrastructure designed and built to minimise road safety problems
  - treating safety issues on existing roads before crashes occur

Proactive Approach - Road Safety Checks

Design Stages

Concept

↓

Draft

↓

Detailed design

↓

Construction

↓

Open to Traffic

↓

Maintenance

Road Safety Impact Assessment

Road Safety Audit

Road Safety Inspections

PIARC

Why Perform Road Safety Checks?

- Future minimisation of crash risk, severity and occurrence at the site and on adjacent roads
- Recognising the importance of considering safety in road design
- Reducing long-term operating/maintenance costs and the need for remedial work (via efficient and safe design selection)
- Bringing an increased awareness to road safety issues and solutions amongst policy-makers and scheme designers

The Road Safety Checks

- **Road safety impact assessments (RSIA)**
  - allows a comparison of the impact
    of different road or traffic schemes
    on safety performance
    (new road or modification to existing road)
  - used to ensure the scheme is selected
    (out of a number of alternative schemes)
    that has the best outcome for road safety

The Road Safety Checks

- **Road safety audits (RSA)**
  - formal and independent technical check of a road scheme design and construction
  - identify any unsafe features or potential hazards and to provide recommendations for rectifying them
  - applied during all stages, from planning to early operation
  - checks that the selected scheme is designed and constructed in such a way as to yield the greatest road safety benefits, and to detect any potential hazards throughout the design and construction

Large amount of RSA literature techniques and examples

The Road Safety Checks

- **Road safety inspections (RSI)**
  - **a systematic, on-site review of an existing road with the aim of identifying hazardous conditions, faults and deficiencies that may lead to serious crash outcomes**

The PIARC Road Safety Inspection Guideline
for Safety Checks of Existing Roads (2012a)

The Road Safety Checks

- **Road assessment programmes (RAP)**
  - **undertaken on existing roads to quantify the expected outcomes for a network, route or location**
  - **numerous RAP programmes**
    EuroRAP, AusRAP, USRAP
    (iRAP – International RAP the global face)

iRAP

Combination Approach

- Provides a full picture of the risk locations and where fatal and serious injuries will occur in the future

- Some countries trying to merge the 2 approaches to identify risk
  - USA (Preston et al 2013) – ‘systematic’ safety project approach

- Used with or without crash data
  - Harwood et al (2014) – reviewed the approach

Safe System Approach

The Safe System approach works on the principle that it is not acceptable for a road user to be killed or seriously injured if they make a mistake.

The Safe System approach aims to create a forgiving road system based on 4 principles:

- **People make mistakes**
  - as a result some crashes are inevitable
- **People are vulnerable**
  - our bodies have a limited ability to withstand crash forces without being seriously injured or killed
- **We need to share responsibility**
  - system designers and people who use the roads must all share responsibility for creating a road system where crash forces do not result in death or serious injury
- **We need to strengthen all parts of the system**
  - we need to improve the safety of all parts of the system – roads and roadside environment, speeds, vehicles, and road use so that if one part fails, other parts will still protect the people involved

Under a Safe System, designers create and operate a transport system where people are protected from death and serious injury

Safe Systems Approach

The concept of the safe system approach evolves from the Vision Zero and Sustainable Safety concepts that were introduced in the mid-1990s

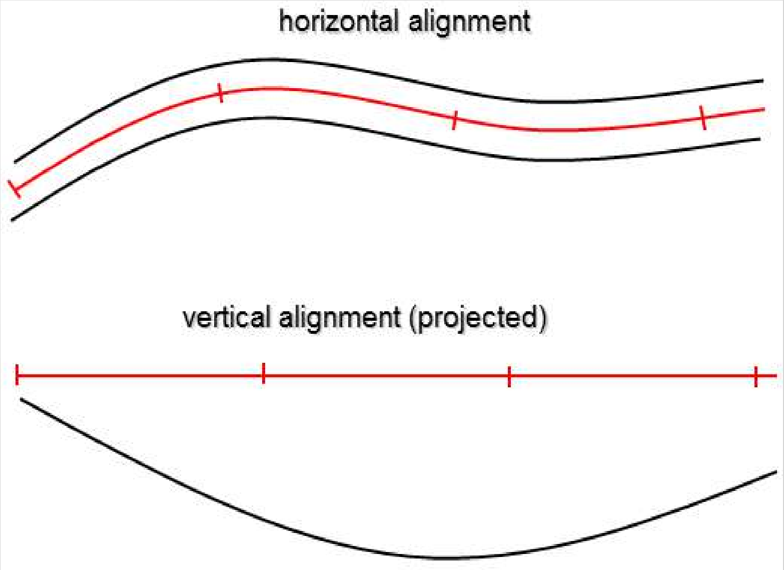
Safe System Principles and Road Design

- **Creating a forgiving road system**
  - hierarchizing road network
  - setting safe system speeds
  - managing the key crash types
  - ranking system
    - consider crash severity, crash exposure and crash likelihood
    - rate the risks identified in RSAs

SAFE SYSTEM ADAPTATION TO ROAD DESIGN

Basic Considerations

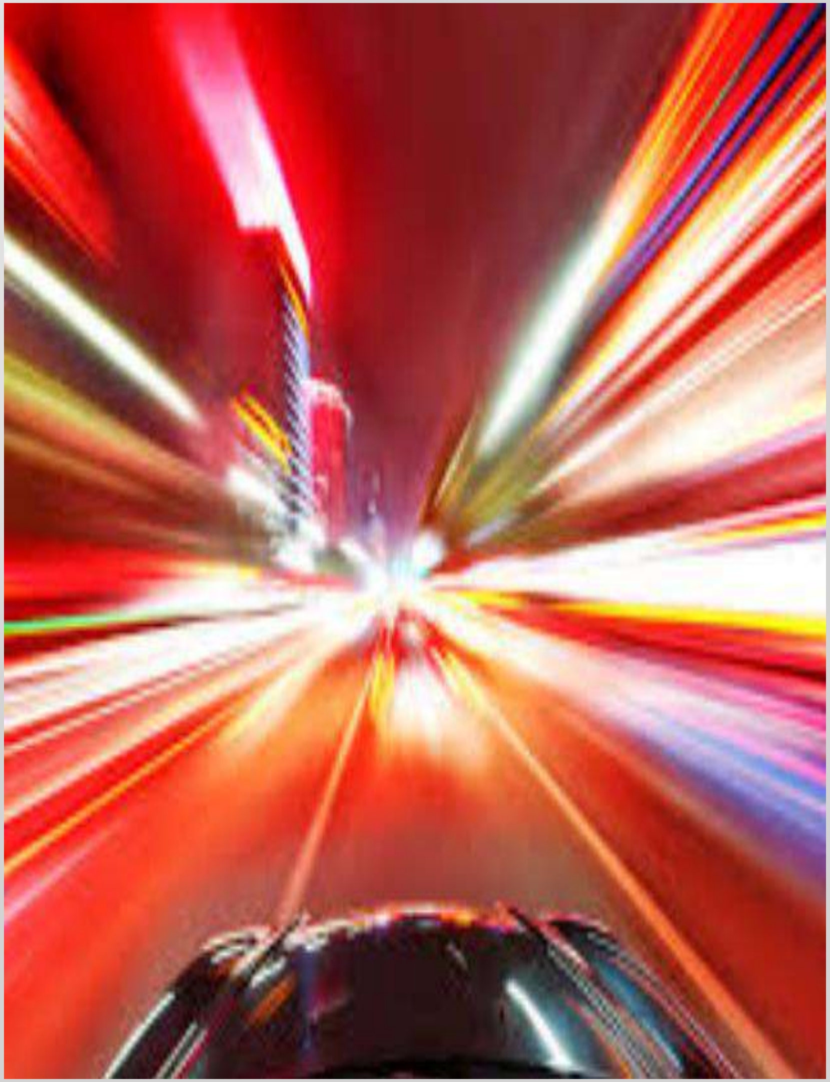
- 3D vs 2D road design stages
  - actual road alignment consists of a 3D line designed in 3 different, independent and uncorrelated 2D stages:
    - ✓ horizontal alignment
      - tangents, circular arcs and transition curves
    - ✓ vertical alignment
      - constant grades and vertical curves
    - ✓ superelevation
      - cross – slopes



Although specific rules apply between design elements, existing guidelines fail to offer concrete 3D guidance design

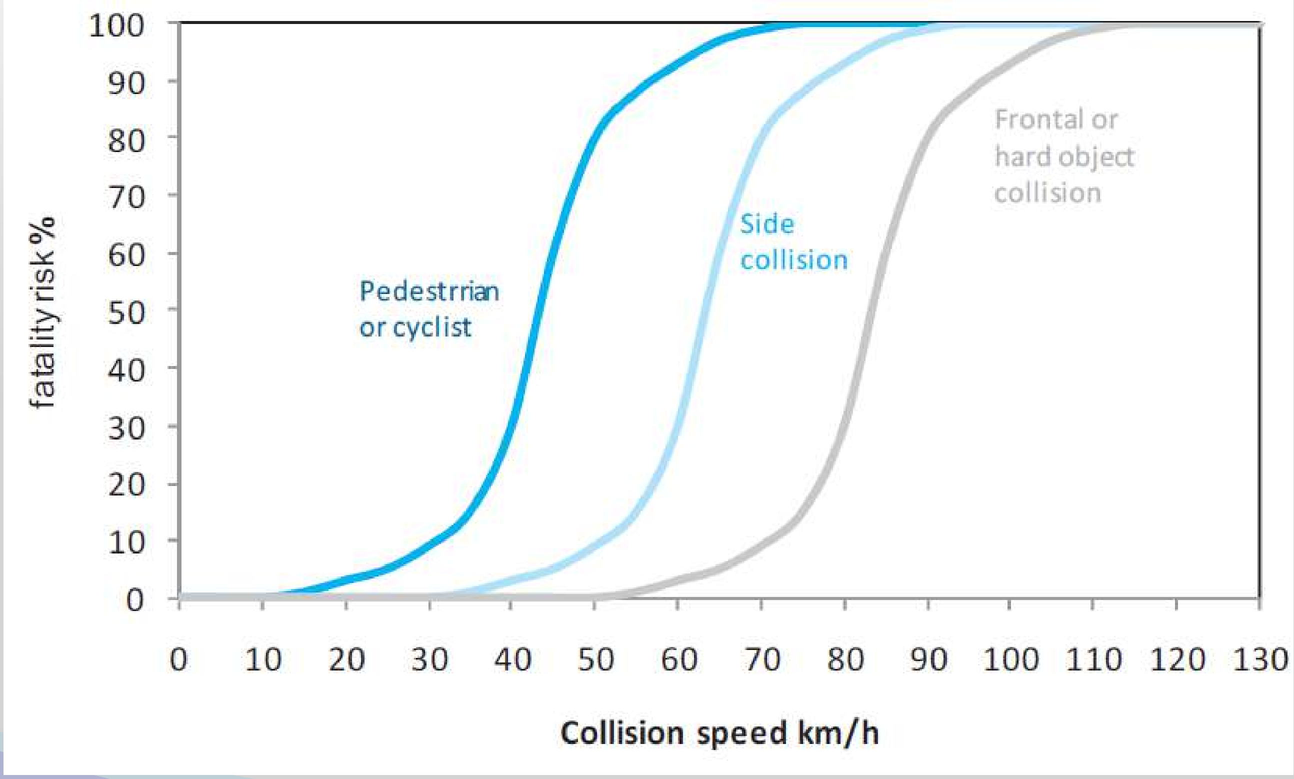
Basic Considerations

- Speed impact
  - dominant parameter in road safety
  - important factor to be considered by travelers in selecting alternative routes
  - reduces the visual field
  - restricts peripheral vision
  - limits time for drivers to receive and process information
  - imposes restrictions in critical design parameters



Basic Considerations

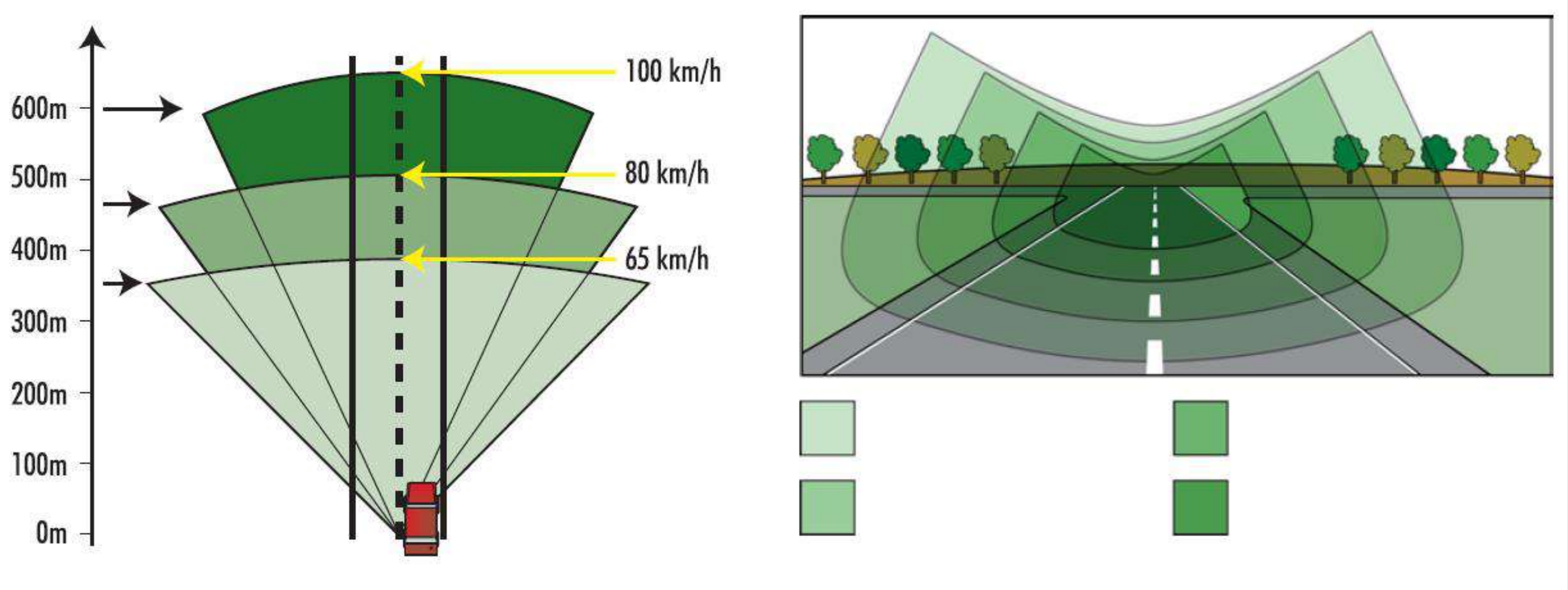
- **Speed impact**
  - **fatality risk for 3 major crash types at different impact speeds**



Wramborg, P. “A New Approach to a Safe and Sustainable Road Structure”, (2005)

Basic Considerations

- Speed impact



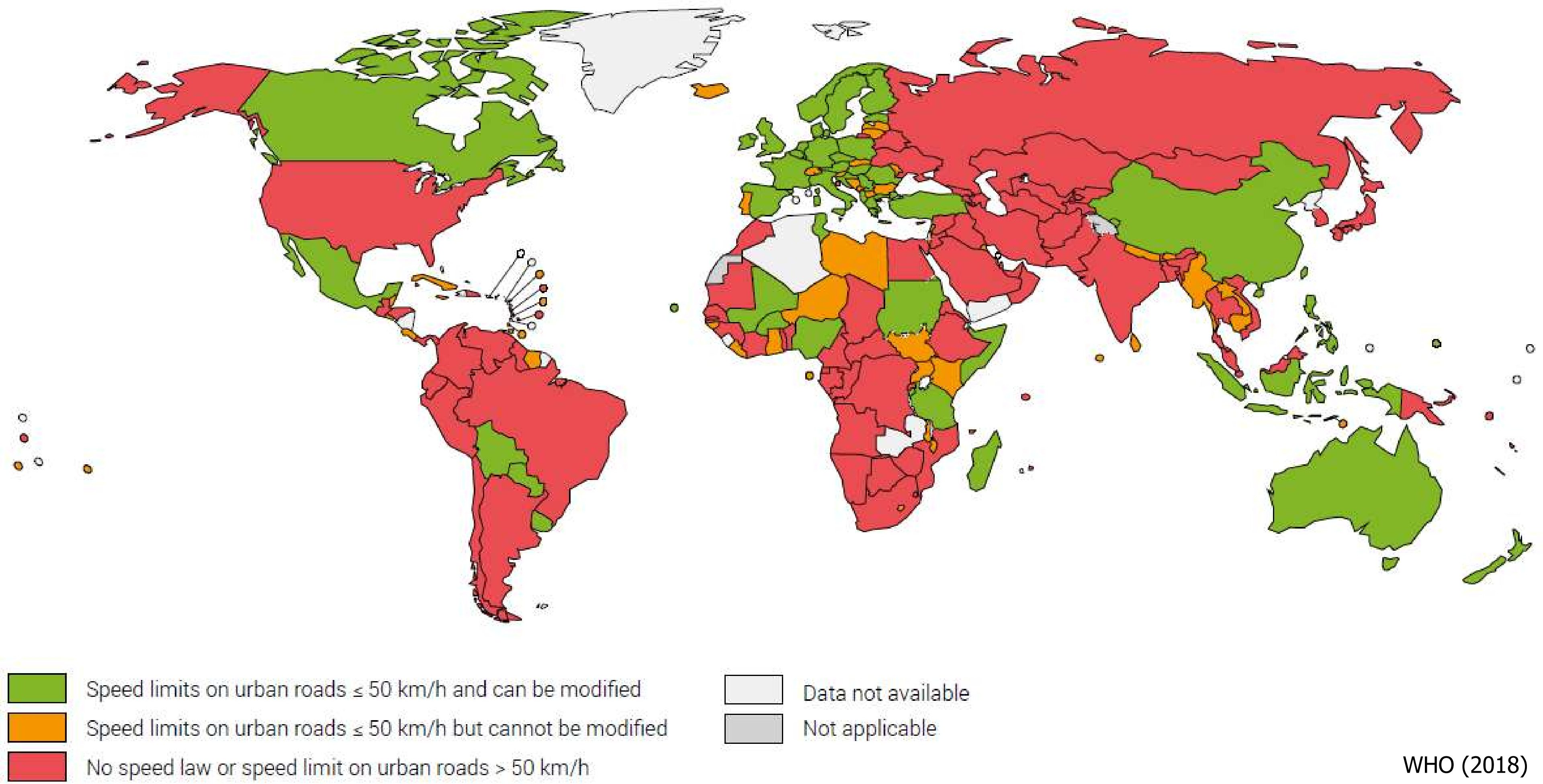
PIARC, Road Safety Manual (2003)

Basic Considerations

- **Types of speed**
  - **operating speed**
    - vehicles speed under free flow conditions
    - extracted from 85th% of the distribution of observed speeds and associated to road geometry
  - **running speed**
    - road section length divided by running time of travel
    - most appropriate for evaluating level of service
  - **design speed**
    - determines various geometric design parameters
    - selected based on anticipated operating speed, topography, adjacent land use and functional classification of the road
    - safety, mobility and efficiency combined with constraints of environmental quality, economics, aesthetics and social – political impacts
    - ranging from 20km/h – 130km/h

Basic Considerations

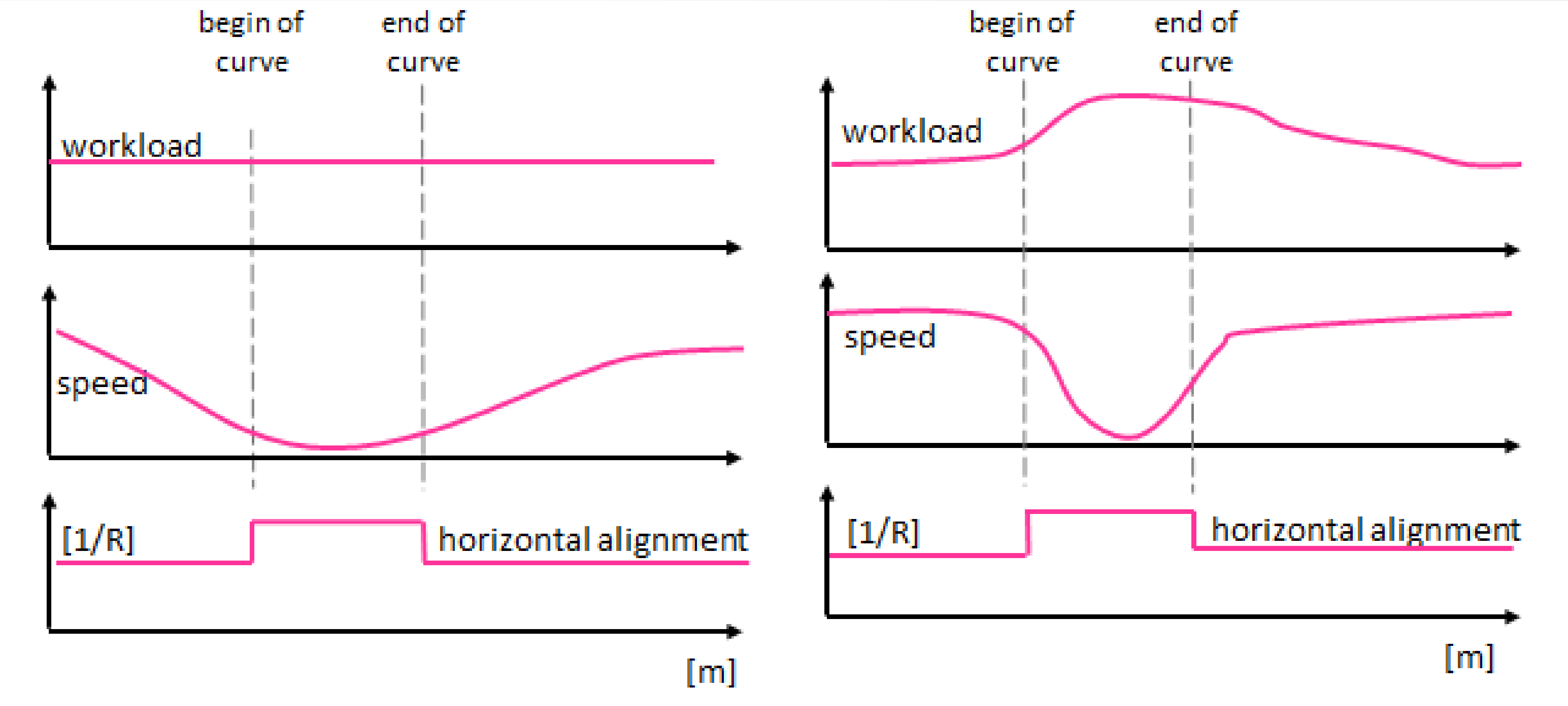
- Countries with speed laws meeting Best Practice (2017)



WHO (2018)

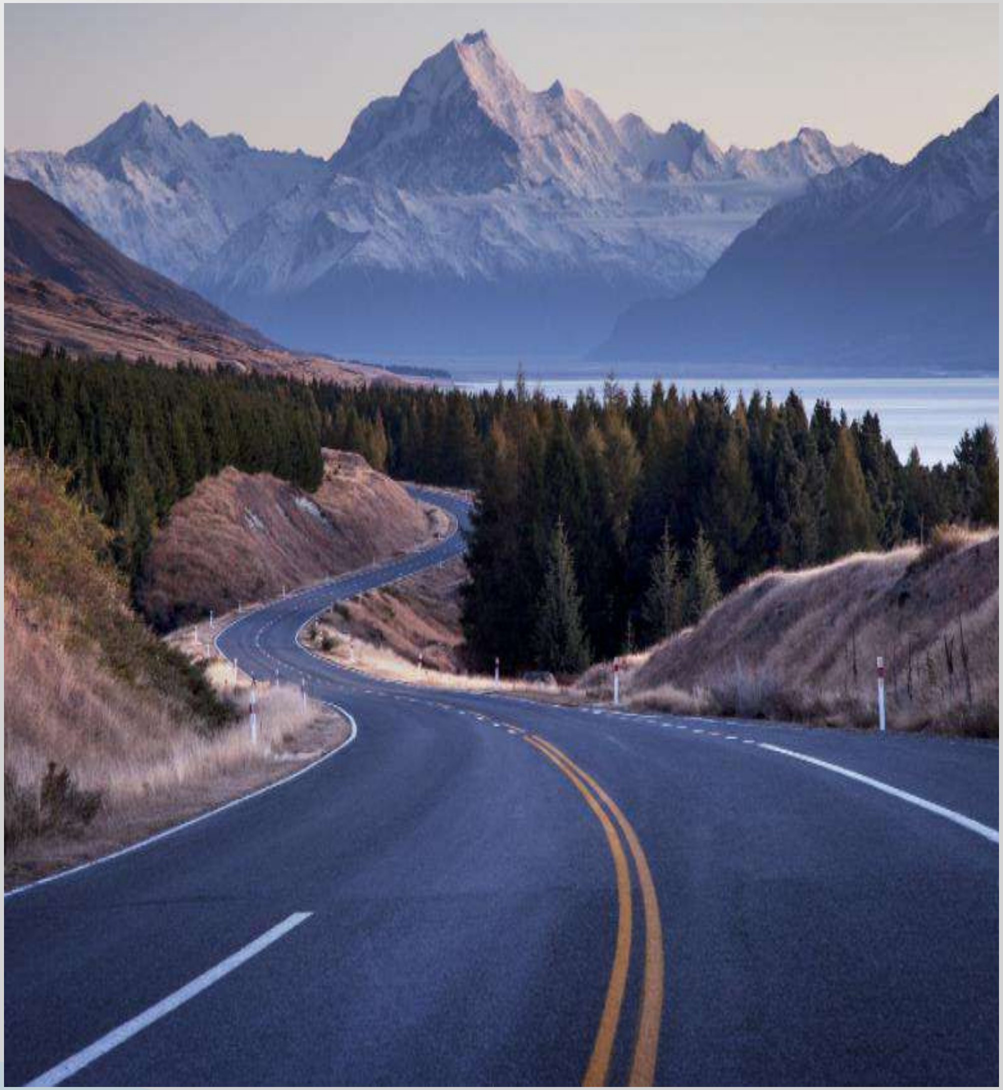
Basic Considerations

- **Infrastructure adaption to human capacity**
  - **workload in curves with good and inappropriate design**



Basic Considerations

- **Infrastructure adaption to human capacity**
  - self explaining roads
    - traffic environment which elicits safe behavior simply by it's design
    - advocates the use of set road categories to ensure drivers are not confused by different types with varying speed limit

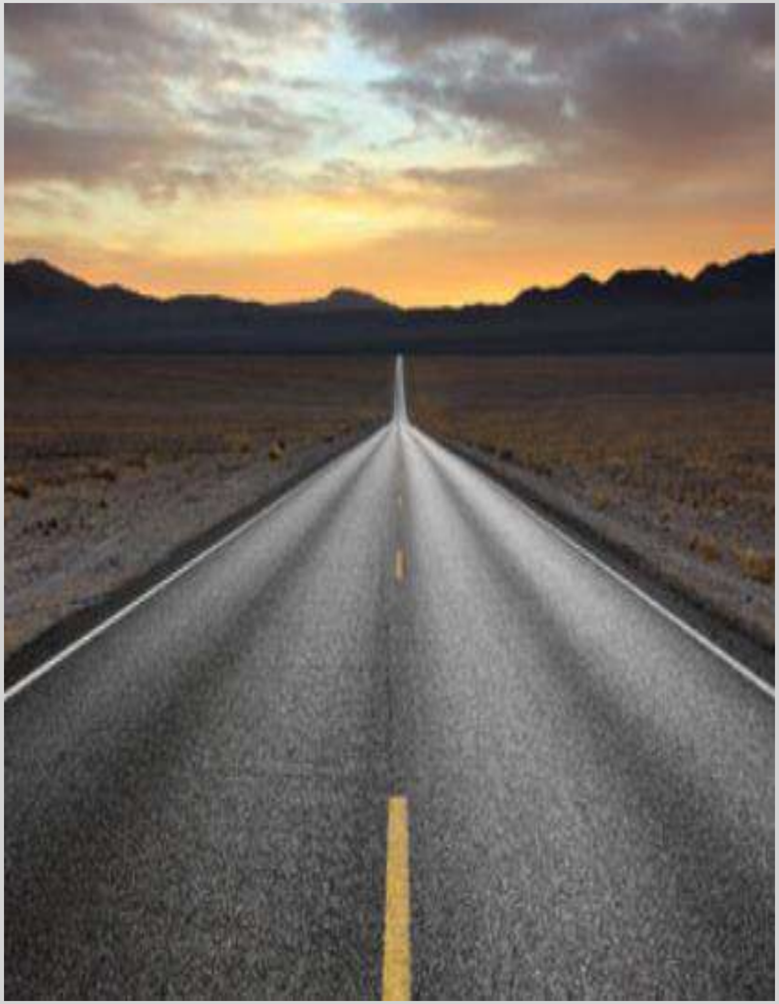


Basic Considerations

- Infrastructure adaption to human capacity
  - self explaining roads

Speed limit = 70km/h

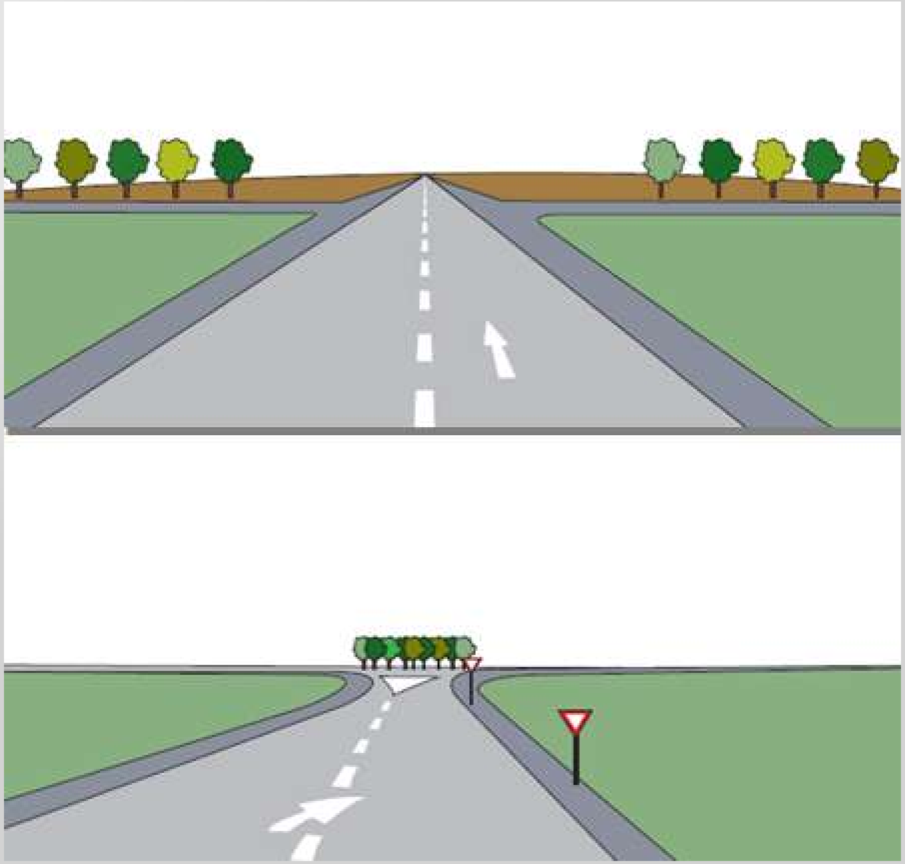
NOT a Self Explaining Road



Basic Considerations

- Infrastructure adaption to human capacity
  - self explaining roads

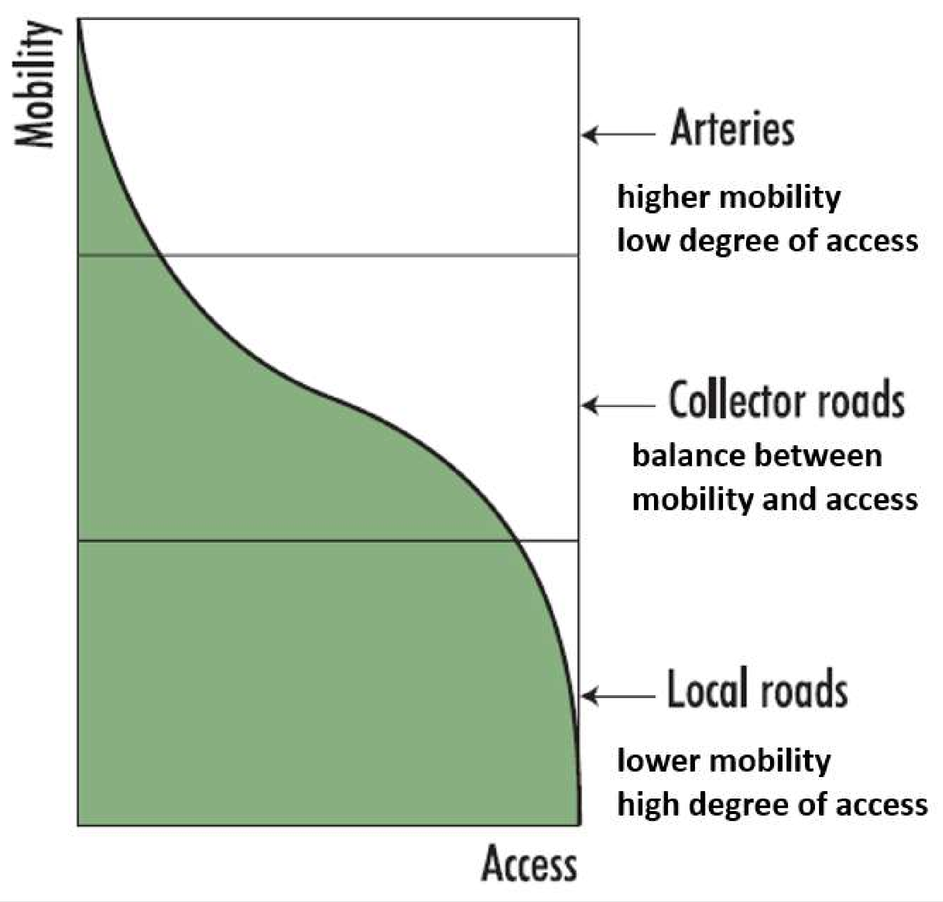
Self Explaining Roads
through landscaping



PIARC, Road Safety Manual (2003)

Basic Considerations

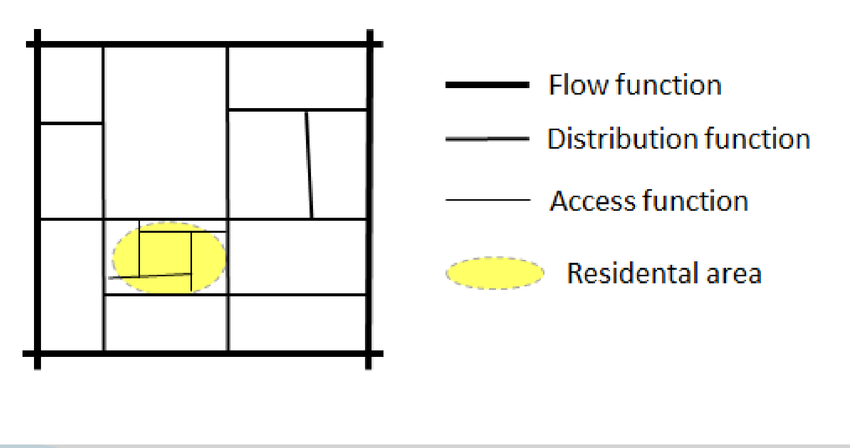
- Road categorization
  - functional classification



PIARC, Road Safety Manual (2003)

Basic Considerations

- **Road categorization**
  - **network**
    - ✓ **flow function: vehicle movement rapid and uninterrupted**
      - through roads (national, international roads)
    - ✓ **distributor function: distribution and collection of traffic to and from different districts and residential areas**
      - distributor roads (regional roads)
    - ✓ **access function: provide entrance - vehicle reach and depart from an individual dwelling, shop, etc.**
      - access roads (local roads)



Basic Considerations

- **Road types**
  - **motorway**

Basic Considerations

- Road types
  - regional road

Basic Considerations

- **Road types**
  - **local road**

Basic Considerations

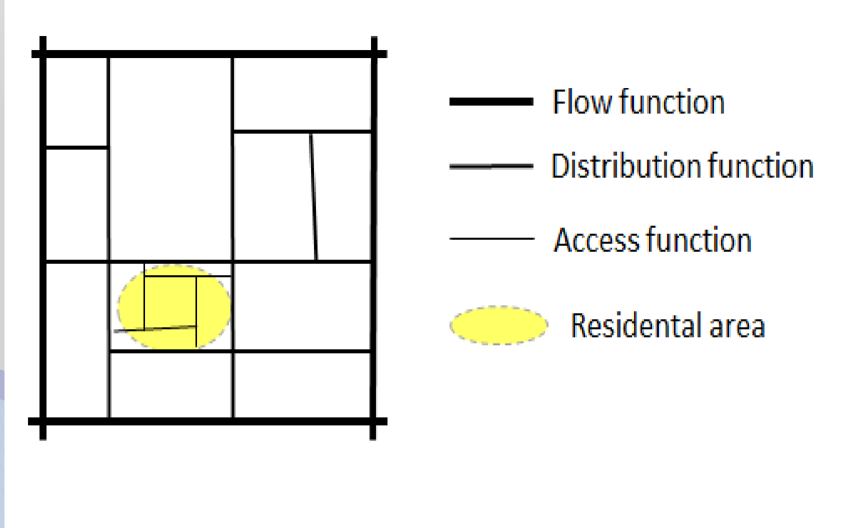
- **Road types**
  - **map example**

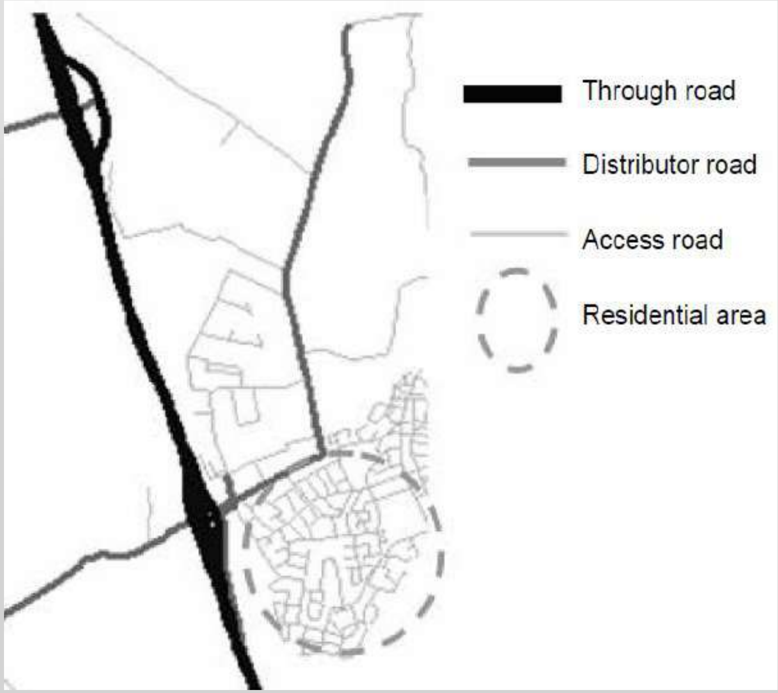
Road Design Parameters Interaction

- Sustainable safety
  - functionality
  - homogeneity
  - predictability

Road Design Parameters Interaction

- **Functionality**
  - speed values compatible with the operation of the road
  - clear hierarchy of road network functions





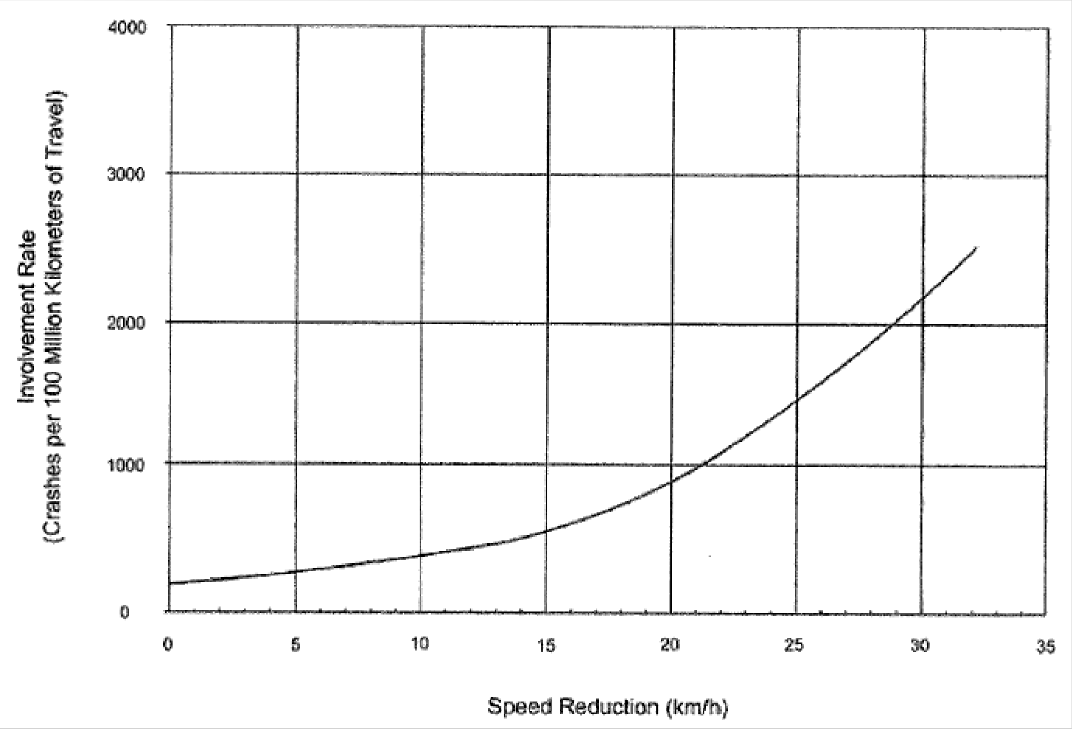
Road Design Parameters Interaction

- **Homogeneity**
  - uniformity in the mass and speed of vehicles using a road element otherwise adequately separated
  - incompatible road users should not share the same road parts
  - physical separation not always acceptable in mixed use environments where more interaction between different road users is desirable

Road Design Parameters Interaction

- **Homogeneity**
  - areas with steep grades and increased trucks presence

Crash involvement rate of trucks for which running speeds are reduced below average running speed of all traffic



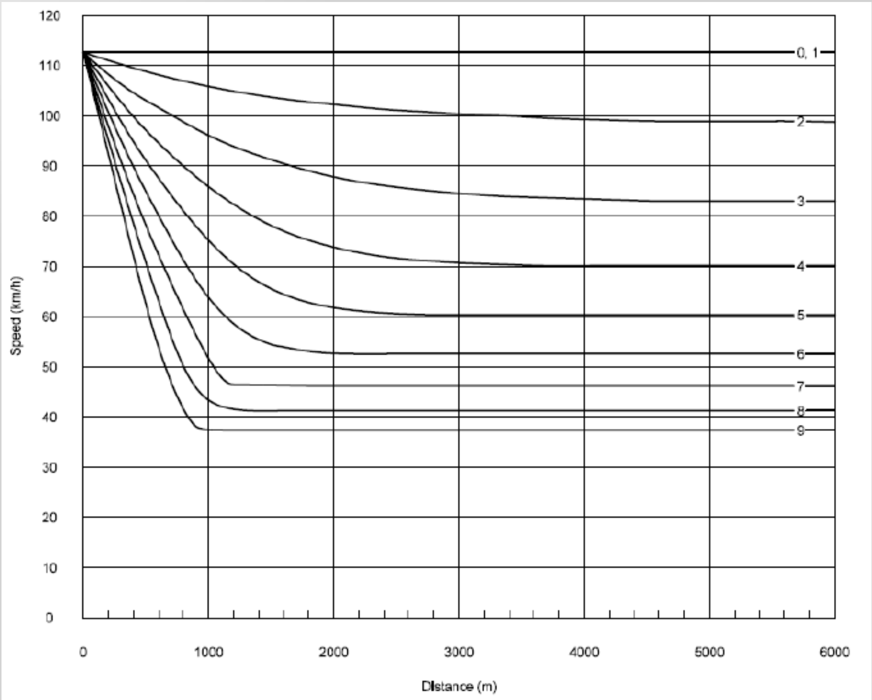
AASHTO (2018)

Road Design Parameters Interaction

- **Homogeneity**
  - **areas with steep grades and increased trucks presence**
    - ✓ **climbing lanes benefits**
      - separation between fast and slow moving vehicles
      - traffic quality improvement
      - accident reduction

Design Vehicle: W/hp = 85kg/KW

AASHTO (2018)



Road Design Parameters Interaction

- **Homogeneity**
  - areas with steep grades

    and increased trucks presence
    - climbing lanes

Road Design Parameters Interaction

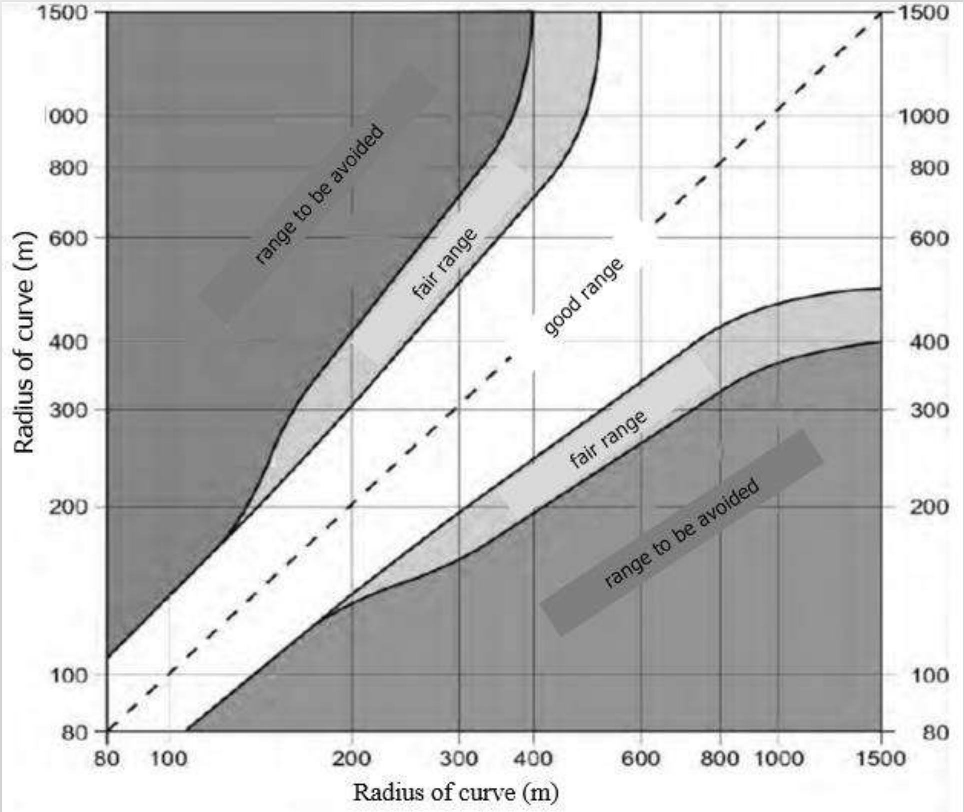
- **Predictability**
  - design of roads should direct drivers to select the appropriate speeds
  - road environment that satisfies drivers' needs and expectations in terms of safety with a fairly constant, low mental workload
  - road environment without violating the drivers' expectancy is the basis of the "self-explaining" road approach

Road Design Parameters Interaction

- **Predictability**
  - **achieved by**
    - ✓ **design consistency**
      - avoidance of abrupt changes
        of successive alignment elements
      - assessed by correlating successive elements between operational speeds or between design and operational speeds
    - ✓ **continuity**
      - ability of road geometry
        to conform to driver's expectations
      - closely related to
        psychological sight distance
        (depth of driving space, of which the driver supposes to have it completely registered)

Road Design Parameters Interaction

- **Predictability**
  - achieved by
    - ✓ design consistency

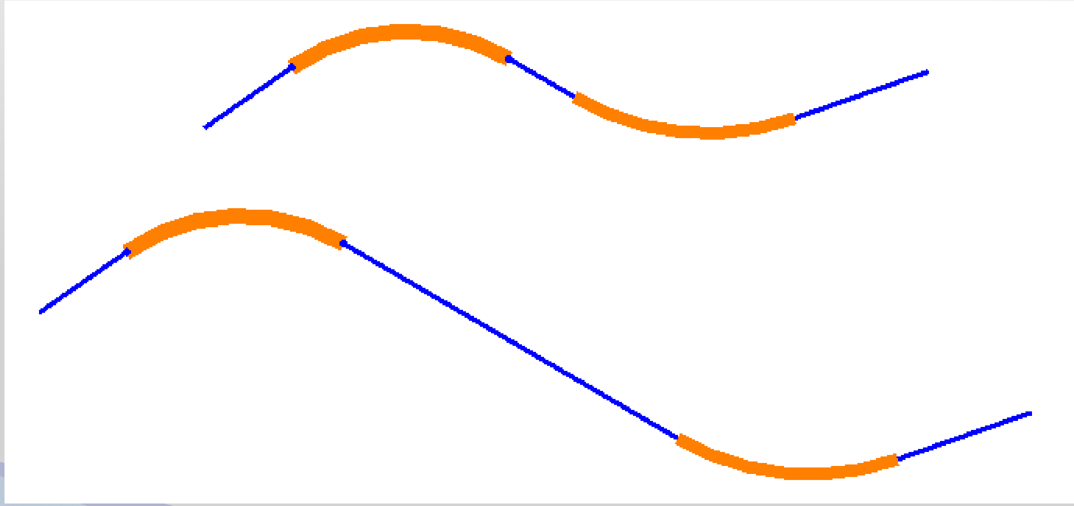


What about tangents between curves?

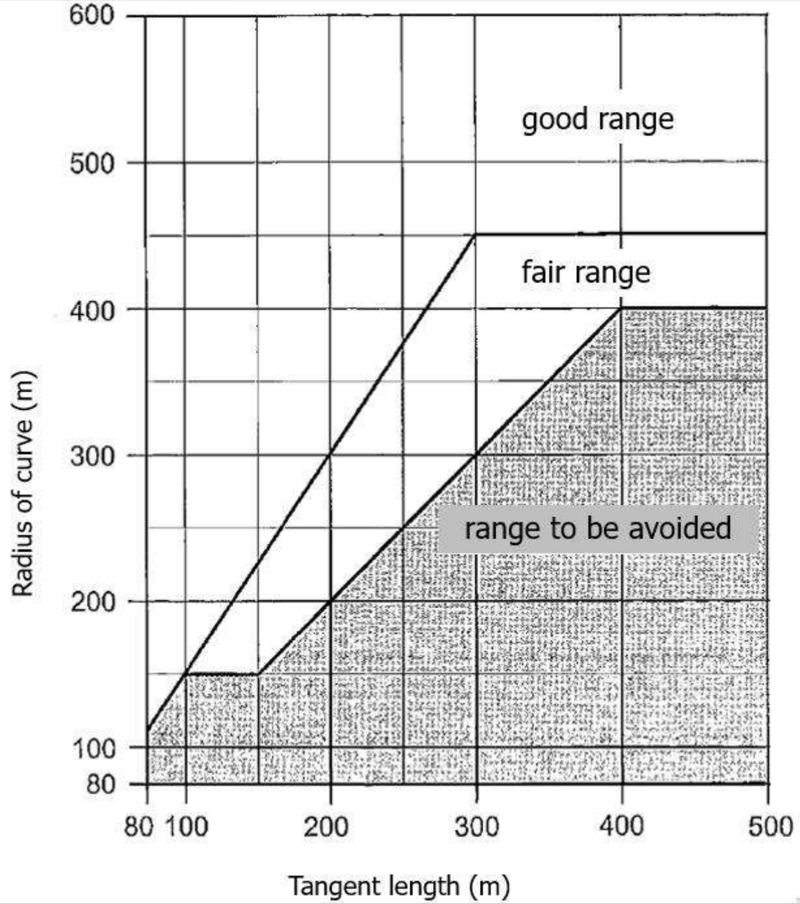
RAL (2012)

Road Design Parameters Interaction

- **Predictability**
  - achieved by
    - ✓ design consistency



What about tangents between curves?



RAL (2012)

Road Design Parameters Interaction

- **Predictability**
  - **achieved by**
    - ✓ **continuity**

- not visible crossing in 150 m

- concealed vision in 50 m

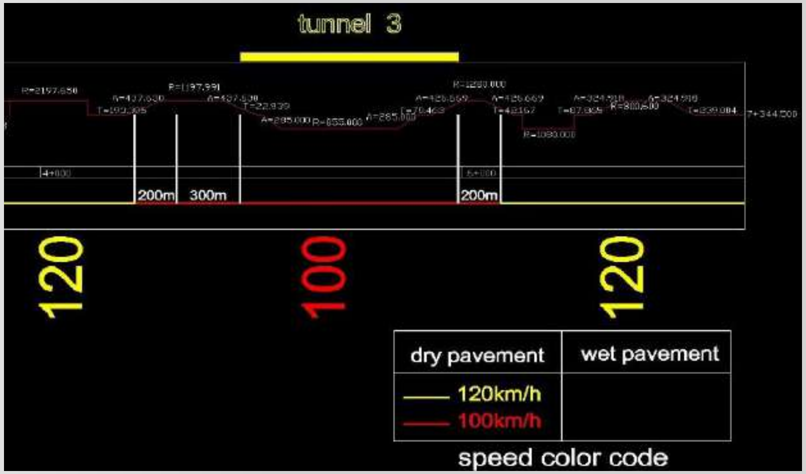
Road Design Parameters Interaction

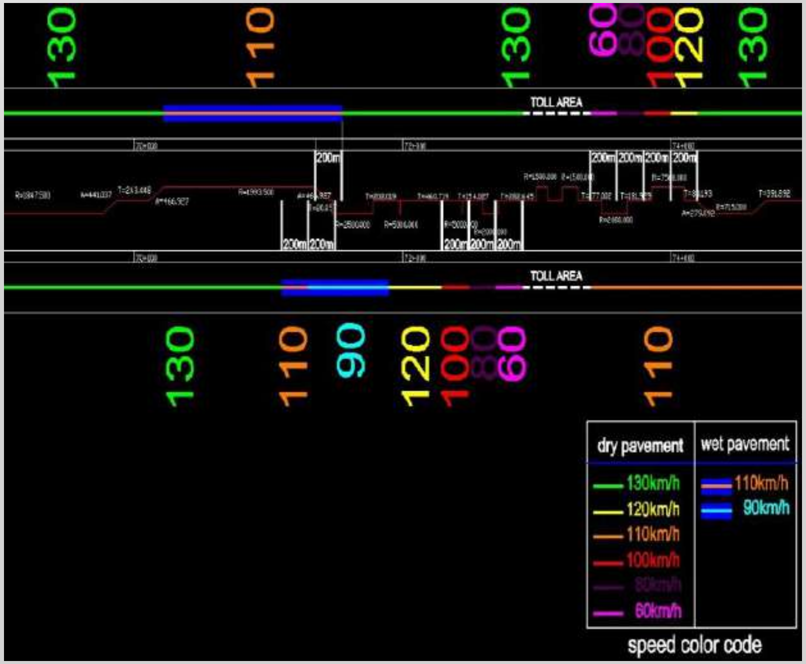
- **Predictability**
  - achieved by
    - ✓ continuity

PIARC, Road Safety Manual (2003)

Setting Speed Limits

- **Speed zone design as to eliminate excessive driving conditions based on:**
  - road functional classification
  - alignment consistency and continuity
  - skidding on curves provision
  - stopping sight distance provision
  - intersection and interchange areas
  - accident data



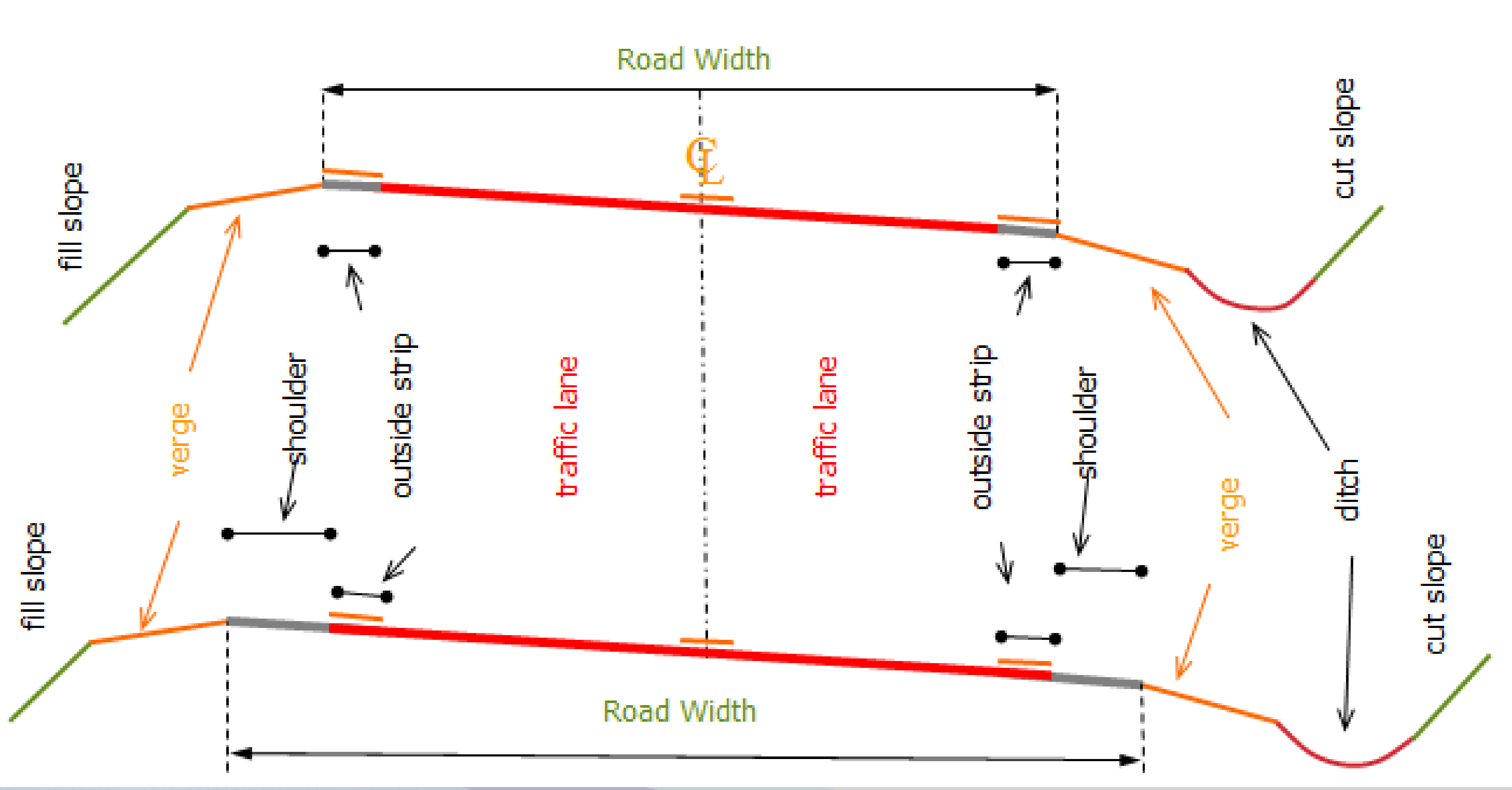


Traffic Calming and Speed Reduction Engineering Measures

- Roundabouts
- Design of transitional zones between rural and urban environment
  - visual impression of portal areas
- Speedometers combined with variable message signs
- Rumble strips
- Speed bumps and raised crossing platforms
  - urban areas

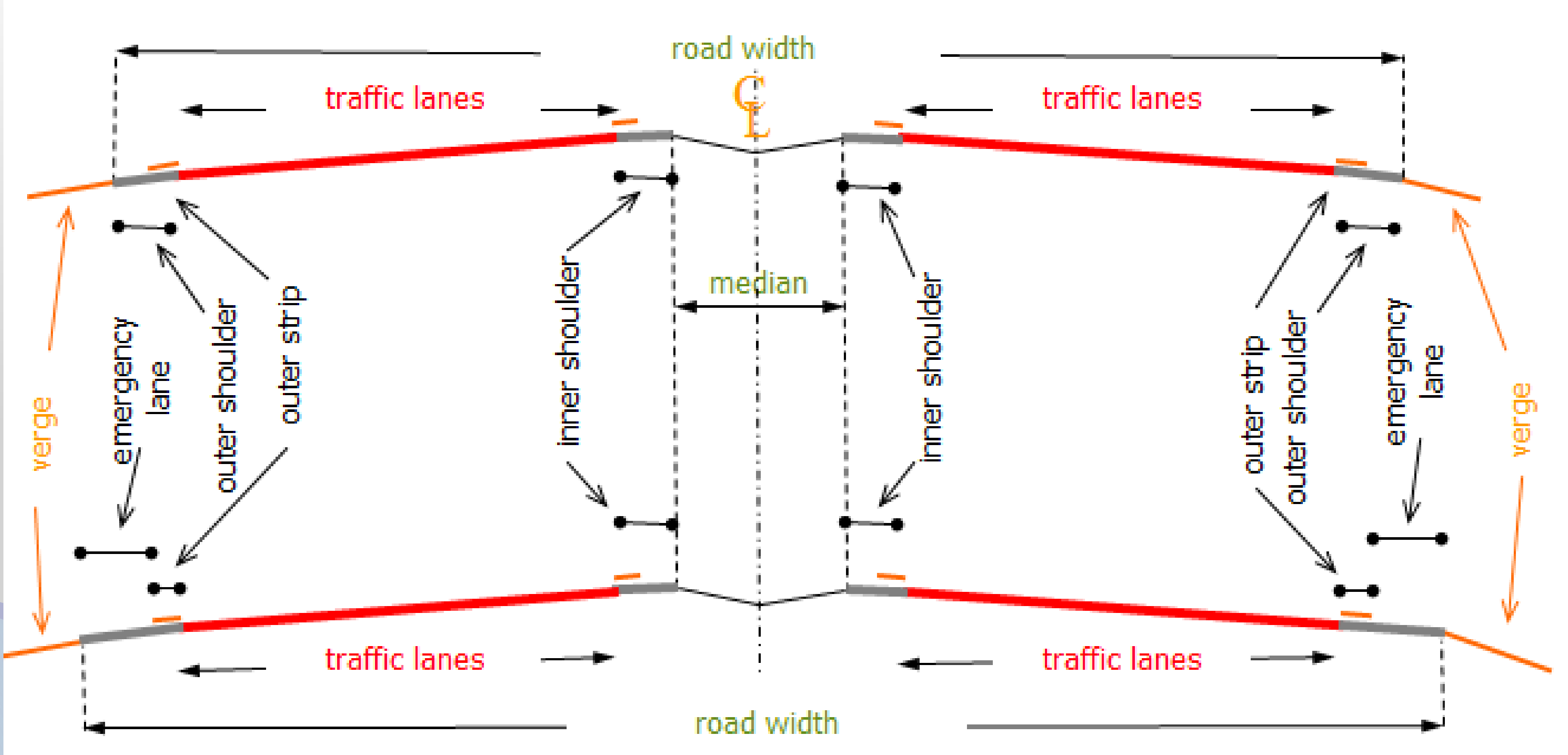
Cross Section Design

- **Main elements**
  - **undivided road**



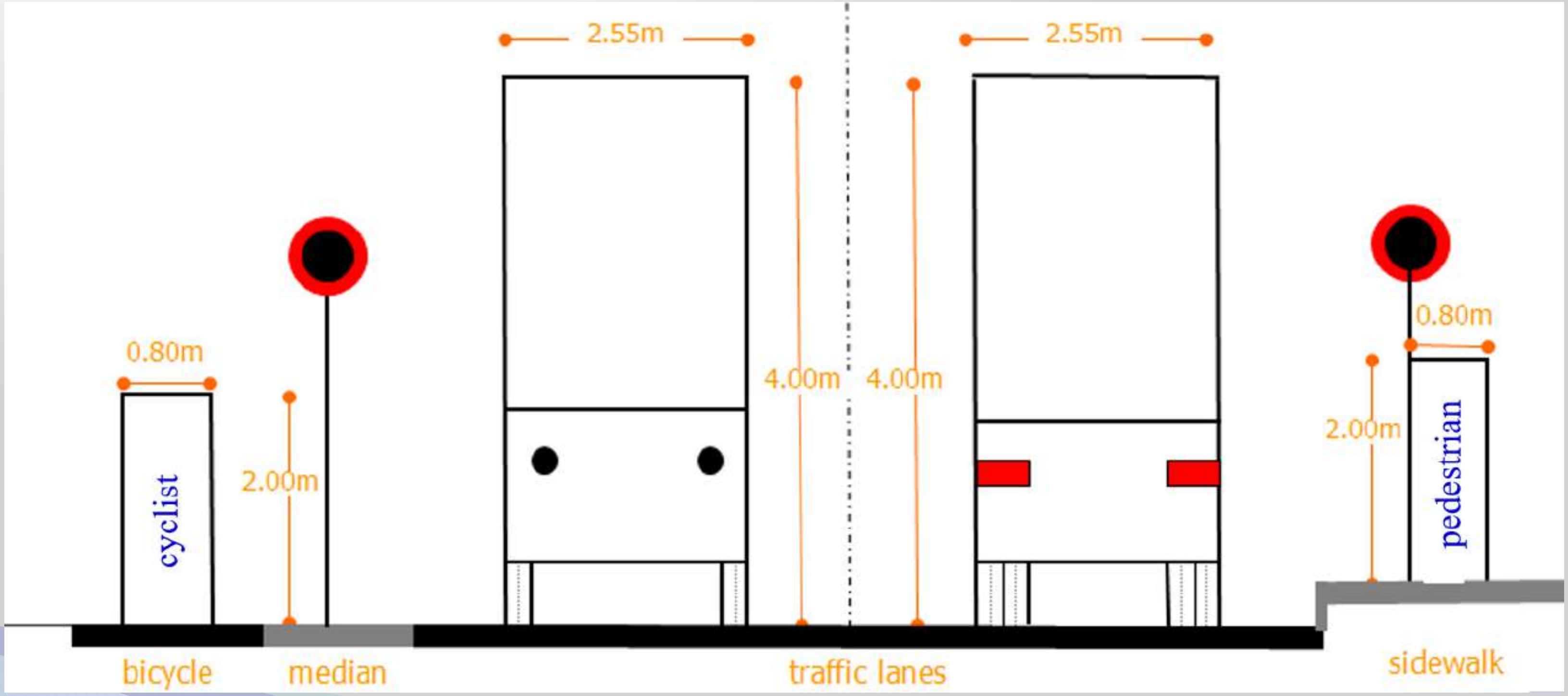
Cross Section Design

- **Main elements**
  - **divided road**



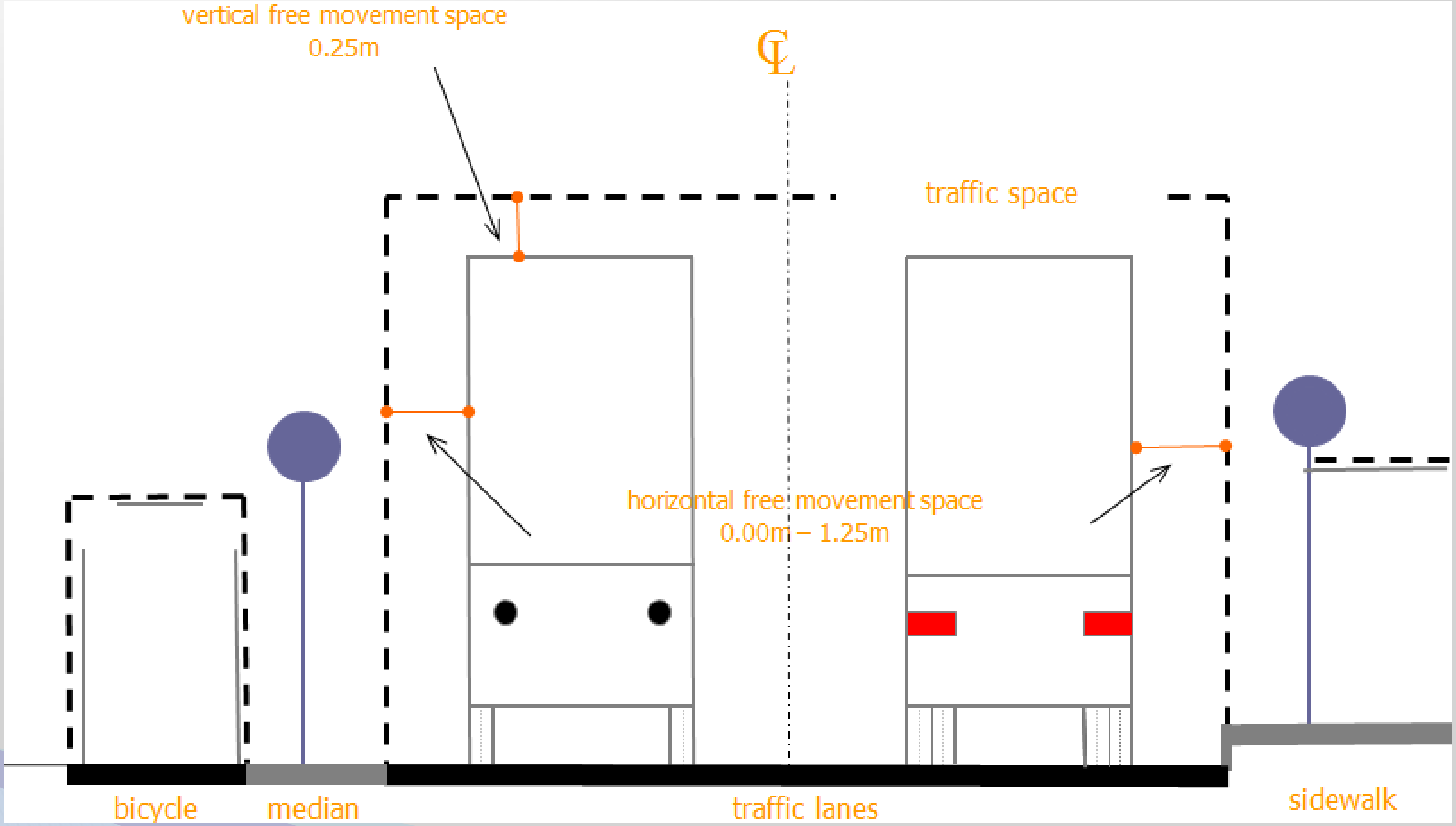
Cross Section Design

- **Main elements**
  - **design vehicle**



Cross Section Design

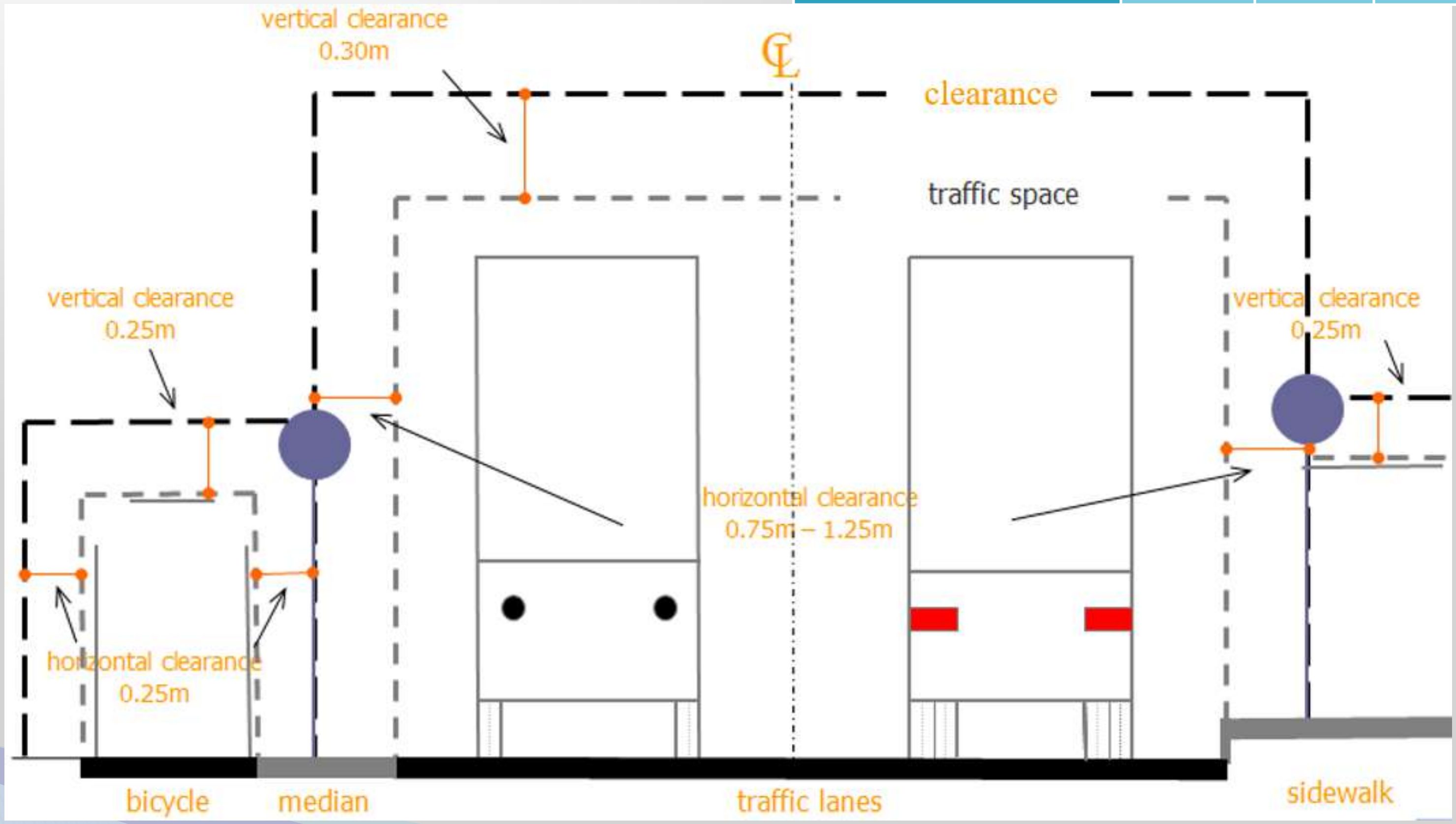
- Main elements
  - traffic space



Cross Section Design

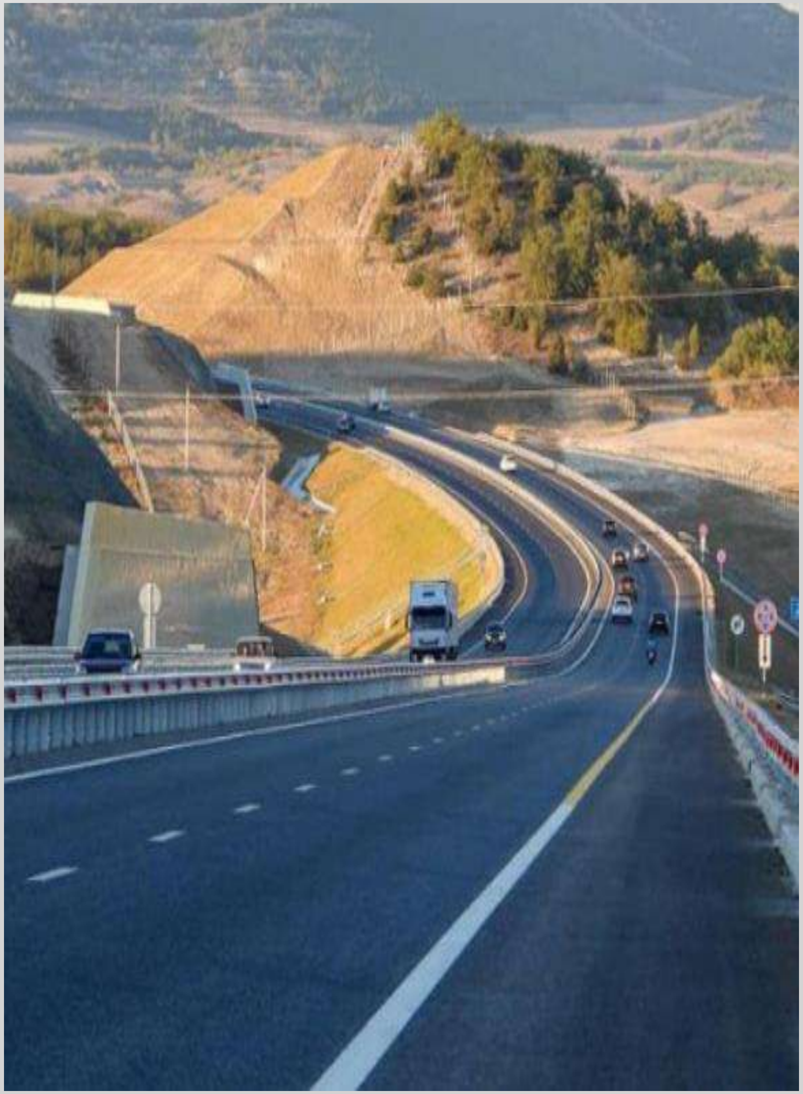
- **Main elements**
  - **clearance**

V_{limit} (km/h)	≤ 50	≤ 70	≤ 70
Horiz. Clearance (m)	≥ 0.75	≥ 1.00	≥ 1.25



Cross Section Design

- **Lane width typical dimensions**
  - motorways
    - ✓ 130 km/h: 3.75 m [passing (inner) lane 3.50m]
  - expressways
    - ✓ 100-110 km/h: 3.50m - 3.75m
  - two lane roads
    - ✓ 90-100 km/h : 3.00m - 3.25m
    - ✓ 50-80 km/h: 2.75m - 3.00m



Cross Section Design

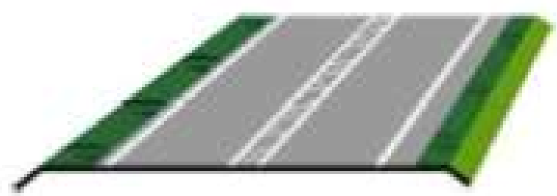
- **Unsafe cross sections**
  - on 4 (and more) lane roads
    of opposing traffic without a medium,
    the number of head on accidents
    and side accidents
    from left turning is extremely high

Cross Section Design

- **Unsafe cross sections**
  - 2-lane roads with wide lanes
    or wide hard shoulders,
    are regularly used as
    very narrow 4-lane roads
    and the number
    of heavy accidents is even higher
  - however,
    they can be transformed
    to 2+1 cross section
    with regulated overtaking possibilities
    on the middle lane

Cross Section Design

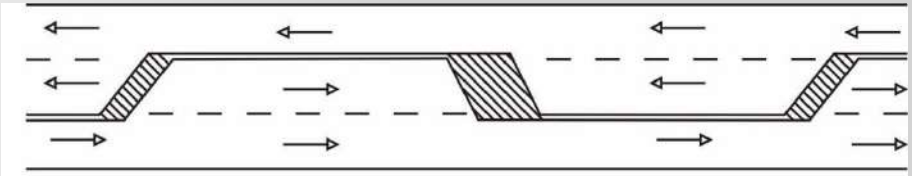
- 2+1 cross sections

2+1 roads / with 2-lane stretches	
Cross-section dimension: 15.5m Carriageway with: 12.0-12.5m Lane width: 3.25-3.5 Width of emergency lanes: - Width of median: 0.5-1.0m*	
Cross-section dimension: 11.5-12.0m Carriageway with: 8.5-9.0m Lane width: 3.5m Width of emergency lanes: - Width of median: 0.5-1.0m*	
*Median marking either double solid line or with additional transverse rumble strips	

RAL (2012)

Cross Section Design

- 2+1 cross sections



Cross Section Design

- 2-1 cross sections

2-1 road	
Cross-section dimension:	7.5-9.0m
Carriageway with:	4.5-6.0m
Lane width:	3.0-4.5m*
Width of emergency lanes:	-
Width of median:	-

*There are no separate driving lanes for both directions, in case of a meeting between opposing traffic both motorists have to use the safety strip

RAL (2012)

Cross Section Design

- Road edge design

Safe Roadside Environment

- **Potential measures, in order of priority**
  - remove or relocate objects by placing them outside danger zone (avoidance of abrupt slopes on fills)
    - create obstacle free zone
  - replace the support of an obstacle with a collision-friendly support
    - breakable or slide construction
  - protect danger zones with vehicle restraint systems

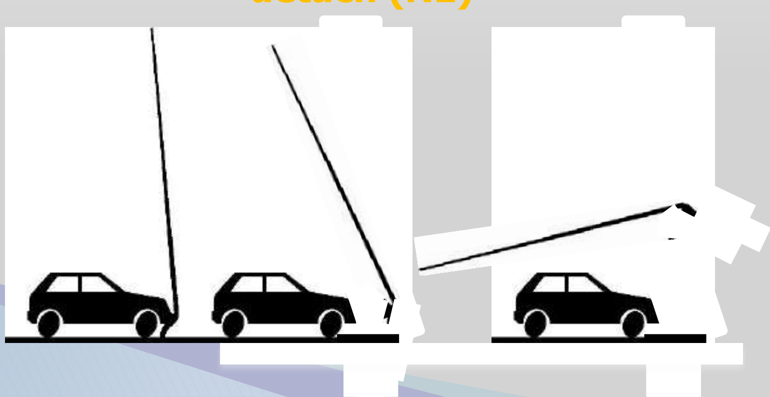
Safe Roadside Environment

- **Potential measures, in order of priority**
  - **remove or relocate objects by placing them outside danger zone [avoidance of abrupt slopes on fills (>2/3)]**
    - ✓ **create obstacle free zone**
      - certain criteria apply in accordance with speed

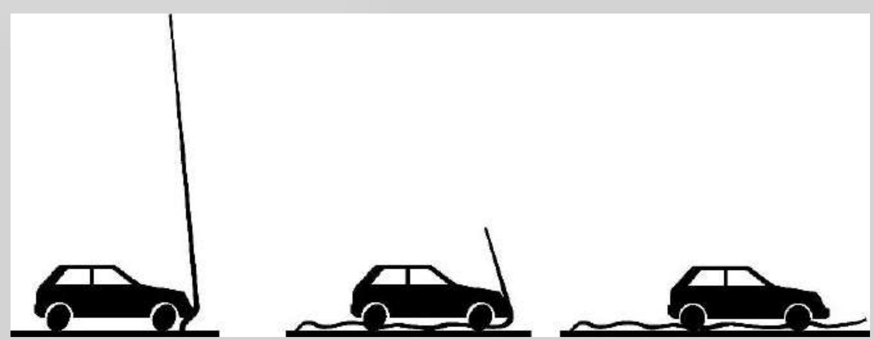
Safe Roadside Environment

- **Potential measures, in order of priority**
  - **replace the support of an obstacle with a collision-friendly support**
    - ✓ **EN12767, MASH**
    - ✓ **breakable or slide construction**
      - detach [neutral energy (NE)]
      - yield [high energy (HE), low energy (LE)]

detach (NE)



yield (HE, LE)



Willems, C. "Creating Forgiving Roadsides by Using Passive Safe System Road Equipment", (2015)

Safe Roadside Environment

- **Potential measures, in order of priority**
  - **protect danger zones with vehicle restraint systems (VRS)**
    - EN1317, MASH, GOST R52289, JTG

safety barriers

removable barrier sections

crash cushions

transitions

terminals

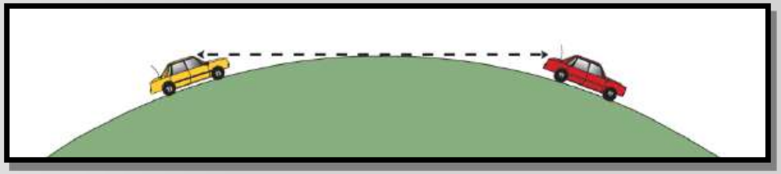
Visibility

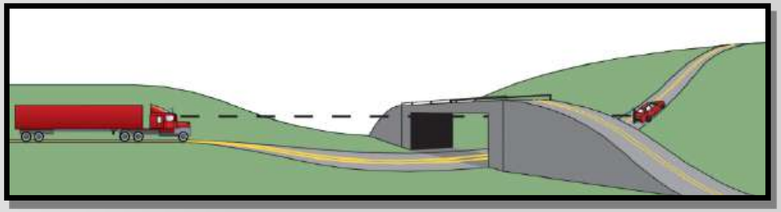
Visibility

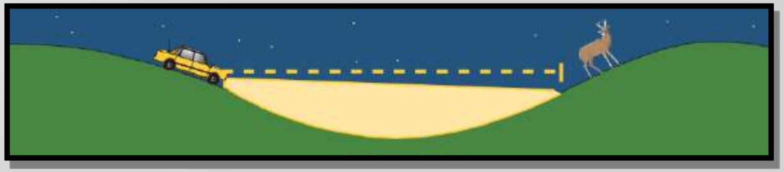
- Stopping sight distance
- Passing sight distance
- Decision sight distance
- Intersection sight distance
- Interchange sight distance

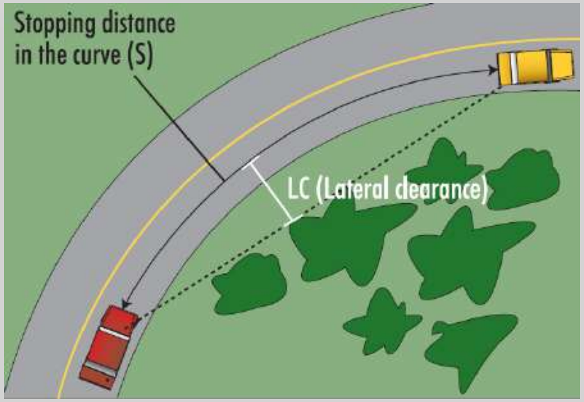
Stopping Sight Distance

- Highway geometric design element of fundamental importance
  - must be provided at every point along the road surface
- Stopping sight distance
  - crest vertical curve radii
  - sag vertical curve radii
  - lateral clearance on right curves
  - inner shoulder width on left curves of divided highways









PIARC, Road Safety Manual (2003)

Stopping Sight Distance

- Highway geometric design element of fundamental importance
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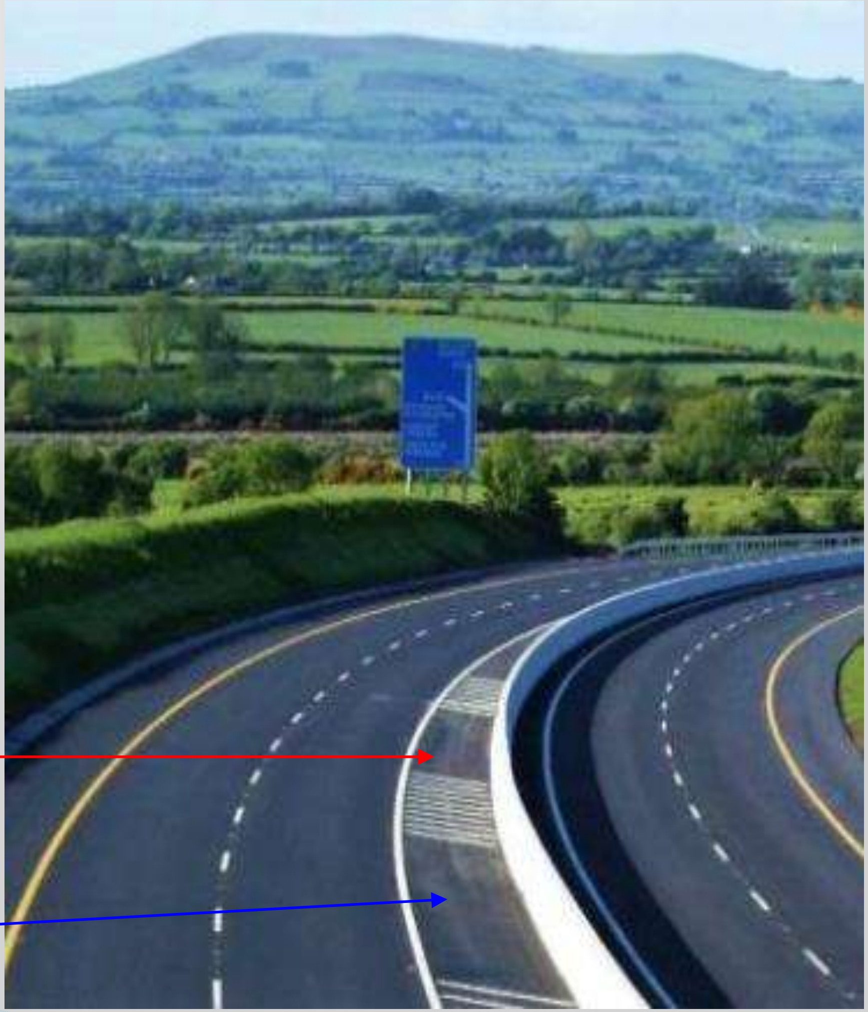


not to be considered as an additional lane
(in general <1.20m)

Stopping Sight Distance

- **SSD, under similar lighting conditions:**
  - $SSD_{DEMANDED}$ related with the ability of the vehicle to reach stop condition depending on
    - ✓ the road (geometry)
    - ✓ the driver (perception – reaction)
    - ✓ the vehicle (dynamic characteristics)
  - $SSD_{AVAILABLE}$ associated with the frontal sight field visible to the driver during daytime conditions and depends on
    - ✓ the road (geometry)
    - ✓ the roadside environment (roadside obstacles)

Stopping Sight Distance

- $SSD_{DEMANDED}$ calculation
  - distance traveled during driver's perception – reaction time, to the instant the brakes are applied
  - the distance while braking to stop the vehicle (pure braking distance)

$$SSD = V \times t + \frac{V^2}{2(\frac{a}{g} + s)}$$

V_o (m/sec) : vehicle initial speed
t (sec) : driver's perception – reaction time [2.5sec (AASHTO, 2018), 2.0sec (RAA 2008)]
g (m/sec^2) : gravitational constant
a (m/sec^2) : vehicle deceleration rate [3.4m/sec^2 (AASHTO, 2018), 3.7m/sec^2 (RAA 2008)]
s (%/100) : road grade [(+) upgrades, (-) downgrades]

Stopping Sight Distance

- **Collision speed calculation $V_{D'}$**
  - **for cases where**

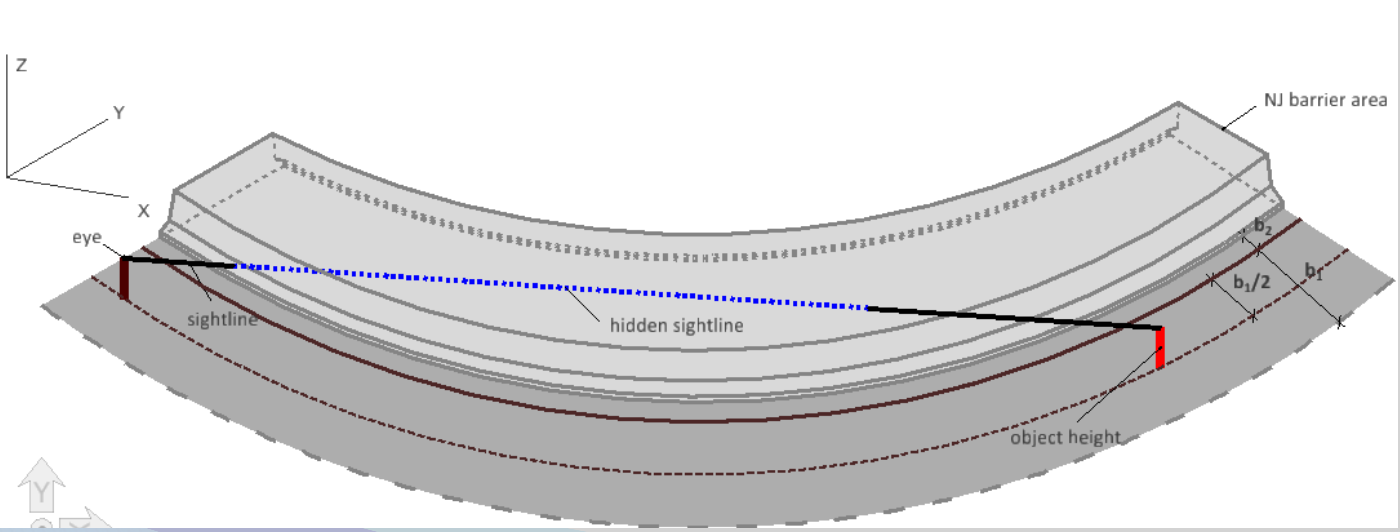
$$D' < SSD - \frac{V_o t}{3.6}$$

$$V_{D'} = 3.6\sqrt{\frac{V_o^2}{3.6^2} - 2\left(a + g\frac{s}{100}\right)D'}$$

D' (m): distance along pure braking distance
V_o (km/h) : vehicle initial speed
t (sec) : driver's perception – reaction time [2.5sec (AASHTO, 2018), 2.0sec (RAA 2008)]
g (m/sec^2) : gravitational constant
a (m/sec^2) : vehicle deceleration rate [3.4m/sec^2 (AASHTO, 2018), 3.7m/sec^2 (RAA 2008)]
s (%/100) : road grade [(+) upgrades, (-) downgrades]

Stopping Sight Distance

- $SSD_{AVAILABLE}$
  - uninterrupted line of sight between the driver's eye and the obstacle
    - typical height of the driver's eye
      - 1.00m for passenger cars
      - 2.00m regarding trucks
    - typical obstacle height
      - 0.50m - 1.00m

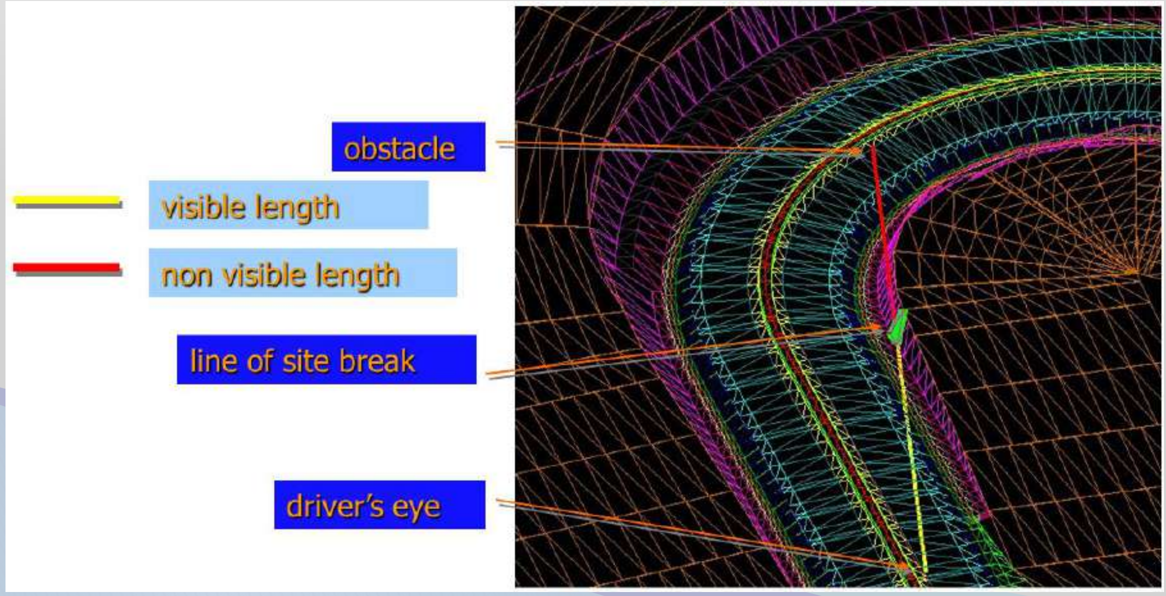


Stopping Sight Distance

- **SSD adequacy breakpoint (3D perspective)**

  $SSD_{DEMANDED} \le SSD_{AVAILABLE}$

  - options
    - ✓ determine the examined curve's inferred safe speed
    - ✓ define the inner shoulder width for a desired speed

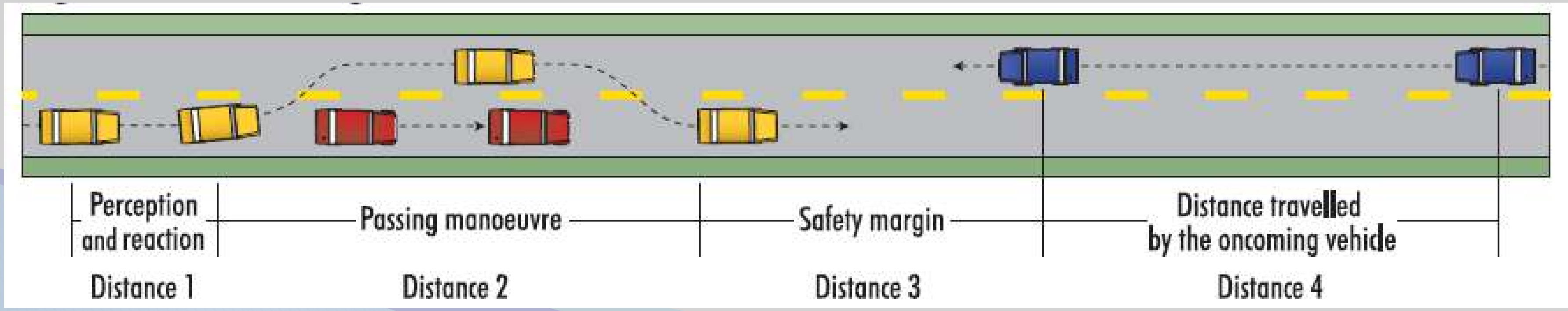


Passing Sight Distance

- Length allocated to process safe passing of vehicle ahead
- Provided on bidirectional - two lane roads
- Depends on vehicles' operating speed
- Minimum PSD to be provided for 20% - 25% of the road's length

$D_1+D_2+D_3+D_4$ = Passing Sight Distance

$t_{maneuver}(D_1+D_2) = t_{maneuver}(D_4)$



PIARC, Road Safety Manual (2003)

Passing Sight Distance

- **Impact Parameters**
  - road geometry
    (in general permissible in broad horizontal and vertical curves)
  - $PSD_{AVAILABLE} \geq PSD_{DEMANDED}$
  - allocated PSD areas
    - ✓ high traffic →
      high overtaking demand →
      reduced passing areas →
      possible provision 2 +1 roads

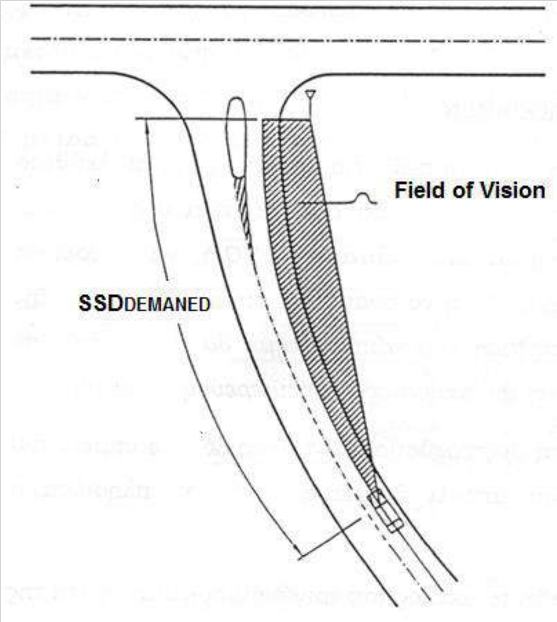
Decision Sight Distance

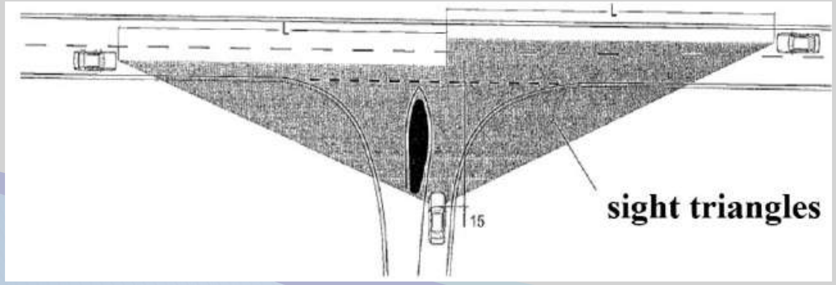
- Length of roadway where the driver
  - detects optically
    an unexpected information
  - adjusts effectively his speed
  - completes efficiently and safely
    the required maneuvers

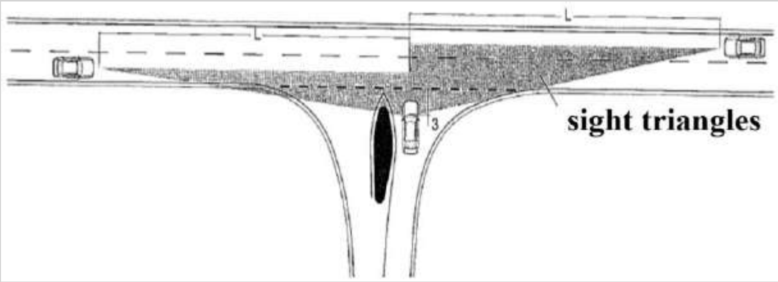
- Examples
  - complex intersections
    or interchanges
  - locations requiring unusual
    or unexpected maneuvers
  - major cross – section changes
  - work – zone areas

Intersection Sight Distance

- $SSD_{AVAILABLE} \geq SSD_{DEMANDED}$
- Yield Crossing (15m from edge line)
  - L=110m (V≤70km/h)
- Controlled Crossing (3m from edgeline)
  - L=110m (V=70km/h)
  - L=200m (V>70km/h)



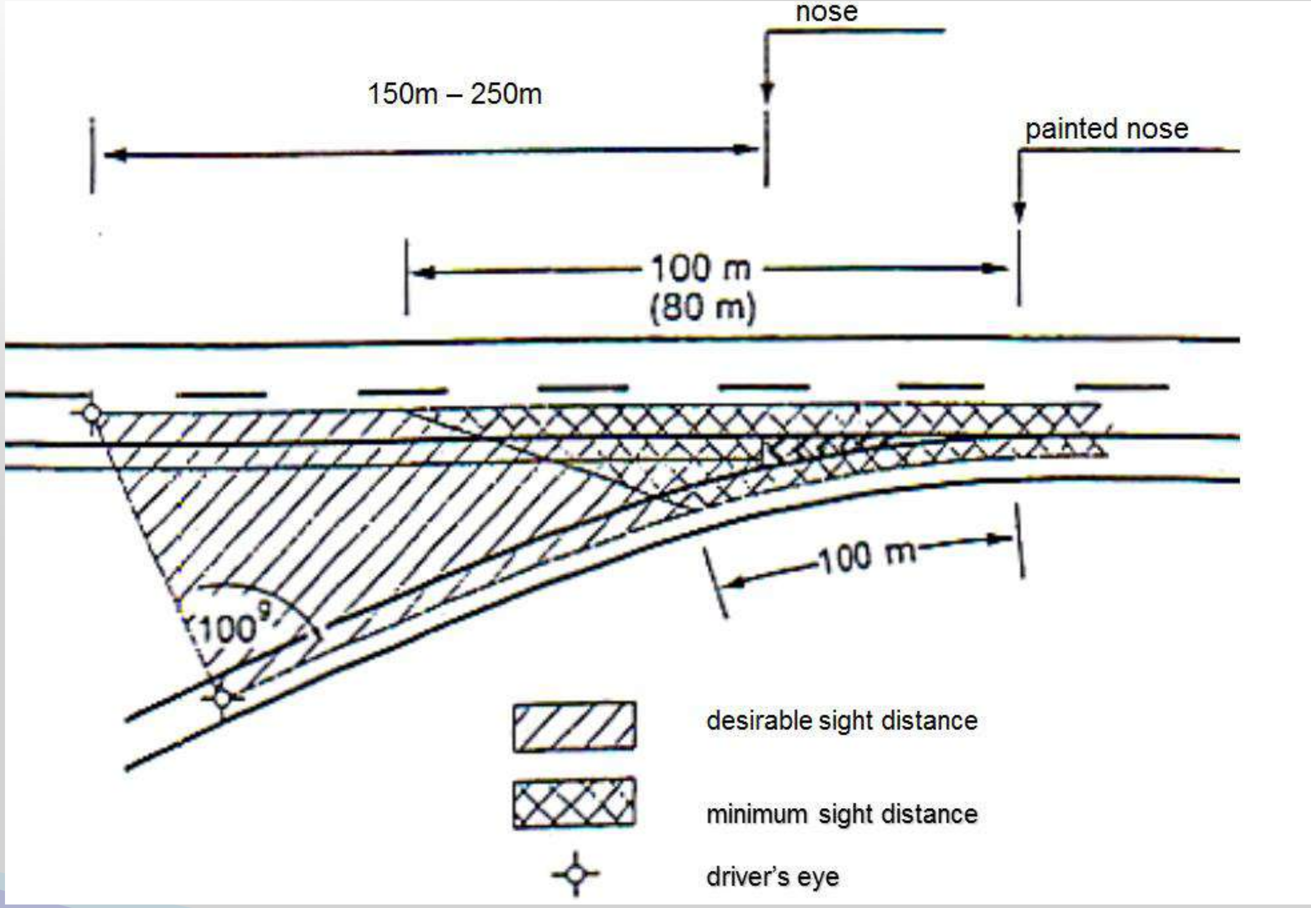




RAL (2012)

Interchange Sight Distance

- Entrance ramp



RAA (2008)

ROLE OF INFRASTRUCTURE DESIGN IN ACHIEVING SUSTAINABLE ROAD SAFETY

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