Integrating Automated Vehicle Safety into Highway Geometric Design:

Novel Challenges and Criteria for Minimal Risk Conditions

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Introduction

TOR (ending ODD, failure - sensor, …)

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No answer for resuming control

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*MRM*s will start

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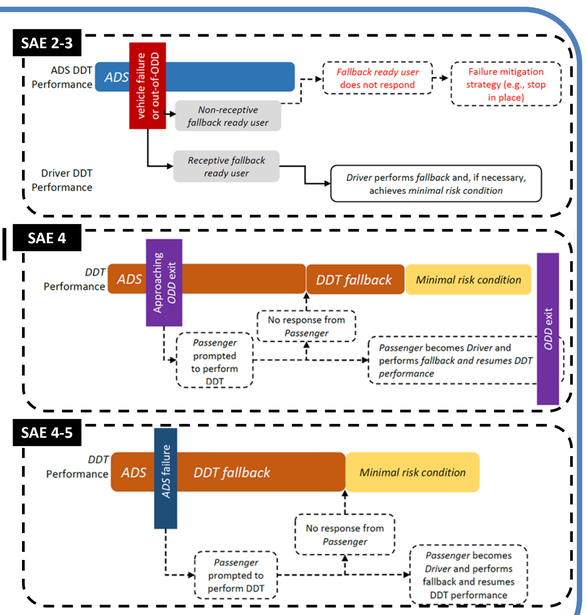
Looking for a *MRC*



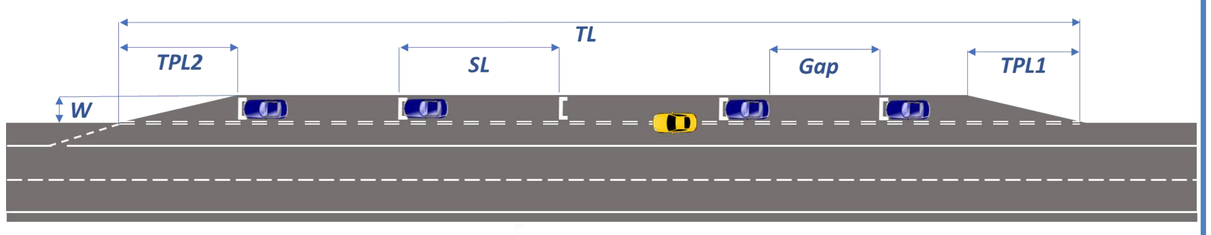
MRM: Minimal Risk Maneuvers – MRC: Minimal Risk Condition

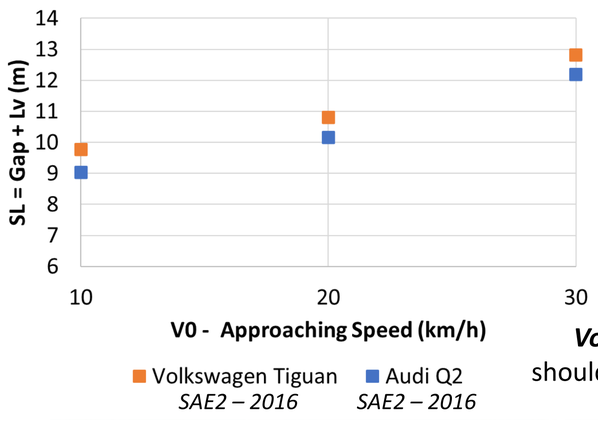
Objectives

- Some locations for MRCs should be allocated
  - Safe and accessible
- Geometric design criteria will be needed for:
  - Locations: <u>shoulders may not be safe enough</u>
  - Layout – safer typologies (more desirable)
    - **EERL – Extended Emergency Refuge Lane**
    - **SH – Safe Harbor**
  - Geometric design of elements

Extended Emergency Refuge Lane (EERL)

- Shoulder of the main carriageway must be full width and continuous to allow AVs to operate under MRMs
  - To reach a safe slot: deceleration/lane changing
  - To re-enter traffic lanes: lane changing/acceleration
- Slot length (*SL*): decel/lan.chang = *Gap* + veh.length
  - Experimental observations (Table/Figure)
- EERL total length: $TL = n \cdot SL + TPL1 + TPL2$
  - n: number of needed slots (demand models to be developed)
  - *TPL1* (Initial Taper Area Length) ≥ *Gap*
  - *TPL2* (Final Taper Area Length) ≥ *Gap*
- EERL width: *W* = 3 m (2.5 m minimum)

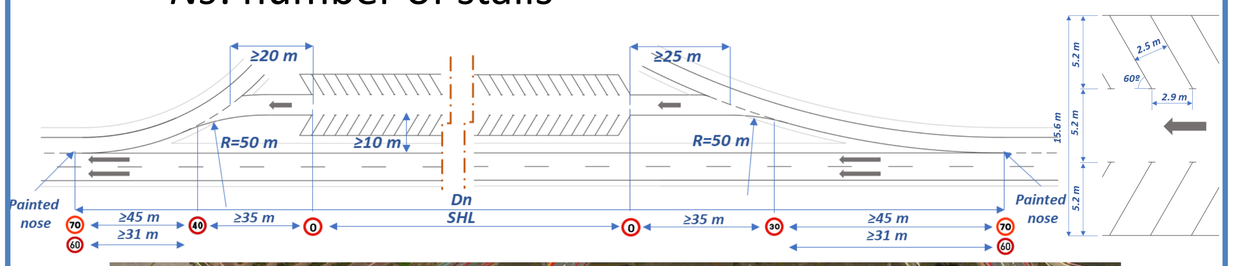
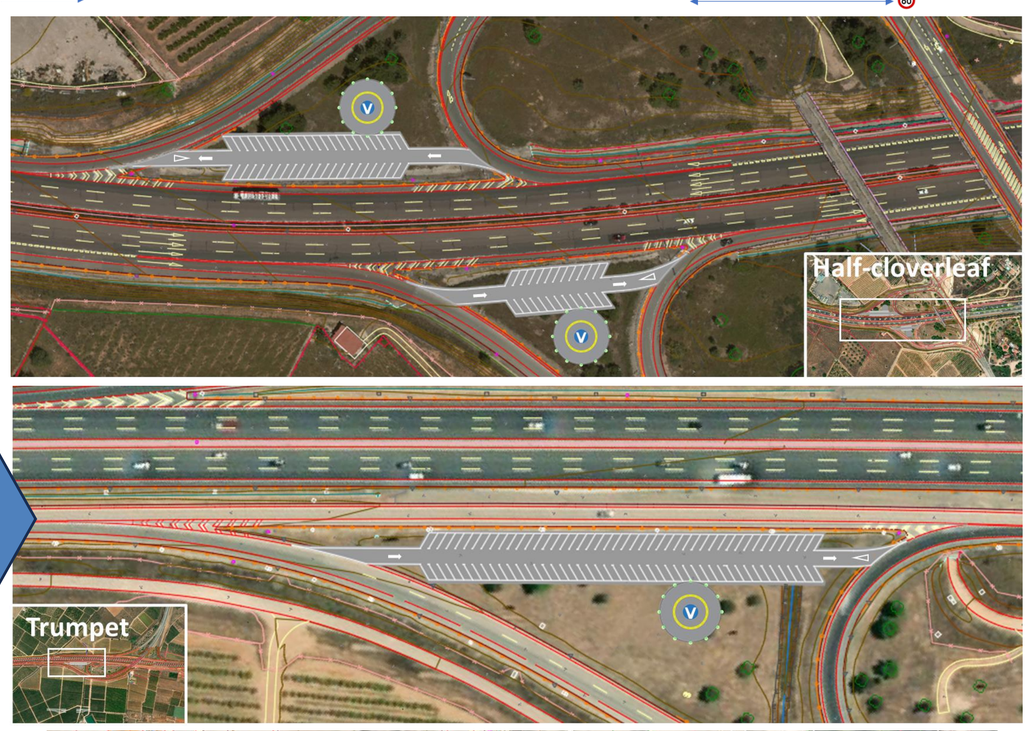




Design AV: L=4.5 m; Vo=30 km/h			
n	SL (m)	Gap=TPL1=TPL2 (m)	TL (m)
5	12.8	8.0	80
10	12.8	8.0	144
15	12.8	8.0	208
20	12.8	8.0	272

***Vo**: initial speed to start the lane change (from shoulder) and deceleration to stop at an available slot*

Safe Harbor (SH)

- Located in interchanges – inner areas
  - Areas between ramps with enough space
- Designed as one-way parking lot
  - Access from the beginning of an off-ramp
  - Exit to another on-ramp/secondary intersection/collector-distributor
    - Being able to re-enter to the main road
- Examples of possible types of interchanges
  - Trumpet / Diamond / Half-cloverleaf / Cloverleaf
- Main parameters:
  - *Dn*: distance between painted noses (off to on-ramp)
  - *SHL*: parking lot length
  - *Ns*: number of stalls

	Parking Lot Length - SHL (m)		Number of Stalls - Ns	
Dn (m)	V0 = 60 km/h	V0 = 70 km/h	V0 = 60 km/h	V0 = 70 km/h
150	23		14	
160	33	5	22	2
170	43	15	28	10
180	53	25	36	16
190	63	35	42	24
200	73	45	50	30
210	83	55	56	36
220	93	65	64	44
230	103	75	70	50
240	113	85	76	58
250	123	95	84	64