CARNET
FUTURE MOBILITY RESEARCH HUB

IV Symposium
Challenges for Urban Mobility
"MaaS, data and xG in our cities"

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CENTRO DE INNOVACIÓN Y TECNOLOGÍA
UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Critical Lane Width for Semi-autonomous vehicles



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- Objectives
- Hypotheses
- Methodology
- Analysis
- Discussion
- Conclusions
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Introduction

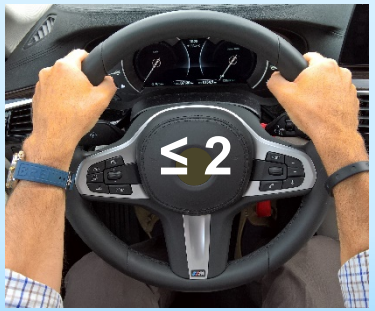
Urban Road Infrastructure

- Geometric design:
  - Curve radius; lane width; sight distance
- Signing, road marking and signals:
  - Continuity and consistency
- Pavement
- Operating speeds
- Capacity and traffic operation
- VRUs

???

Automated Vehicles

- Automated Driving Levels
- Autonomous Vehicle Operational Models
- Long-term deployment:
  - Technological challenge
  - Large-scale CAVs testing:
    - Benefits, costs, operating conditions,…





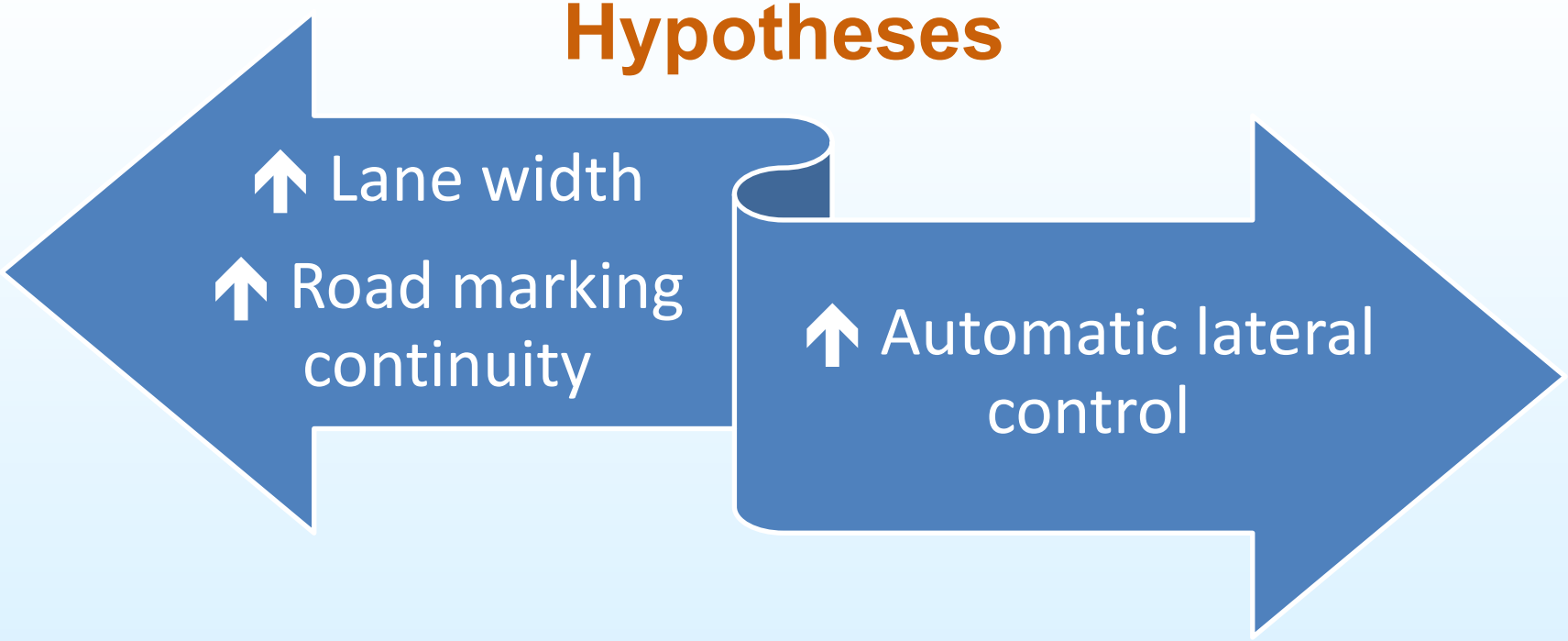


Critical issue: degree of potential benefits when only a portion of vehicle is CAVs with diverse ADLevels

Objectives

- **Experimental approach to the capacity of the urban road infrastructure to accommodate semi-autonomous driving systems:**
  - Study the impact of **lane width** and **road marking layout** on semi-autonomous vehicle automatic lateral control (**LKA**)
  - Carry out **observations** of automatic lateral control performance along urban streets, with different:
    - Lane width
    - Road marking

Hypotheses



- There is a minimum lane width that allows automatic lateral control to maintain the control: **automatic lane width**
- There is a maximum lane width that always requires human lateral control: **manual lane width**
- There is a lane width with the same probability of automatic and human lateral control: **critical lane width**

Methodology

- **Study site:**
  - Urban arterial ring road, 5.4 km long, with diverse lane widths
- **Method:**
  - Multiple round trips with a semi-autonomous vehicle:
    - BMW 520d (2017) + “Driving Assistant Plus” (Level 2)
    - Registration for every lane and trip with/without automatic lateral control:
      - Minimum number of trips for every lane: 10
- **Instrumentation:**
  - Video camera HD Garmin VIRB Elite

Methodology



Methodology



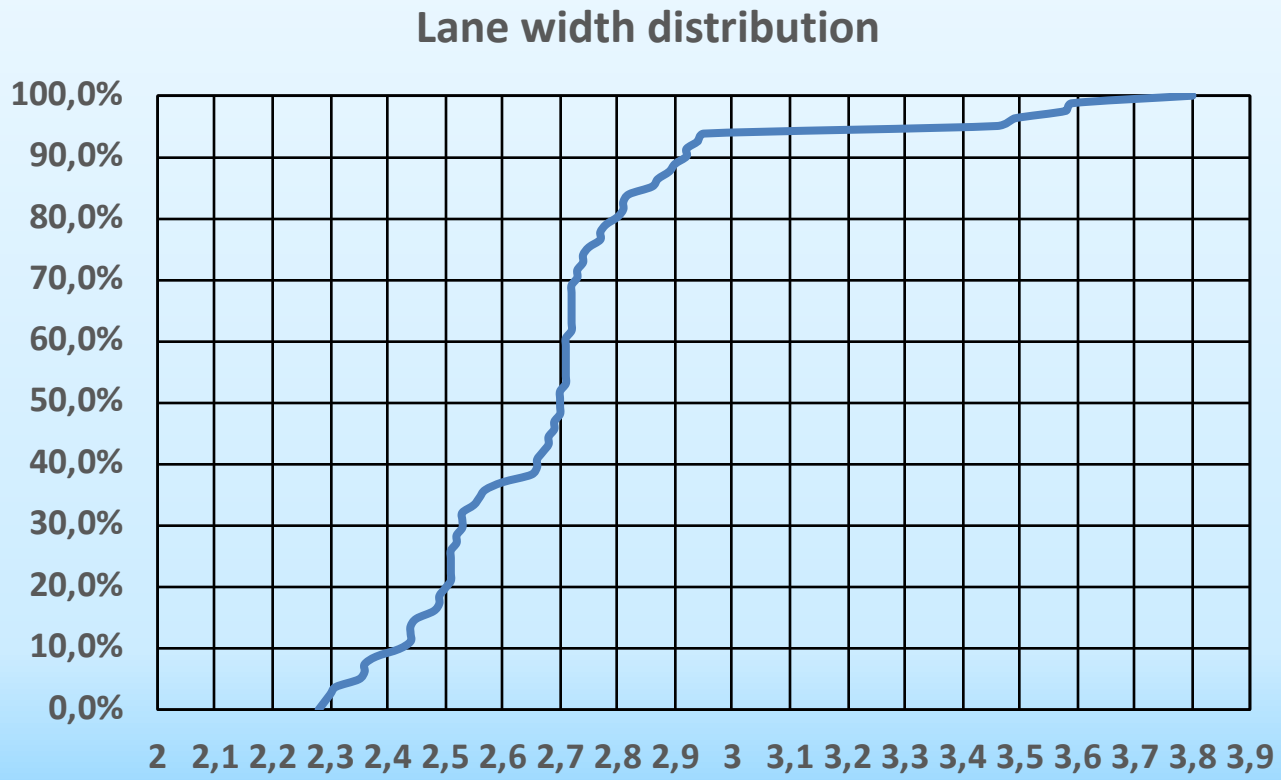






Methodology

- Number of lanes = 81 (on tangents)
- Lane width ⊂ [2.28 ; 3.80] m

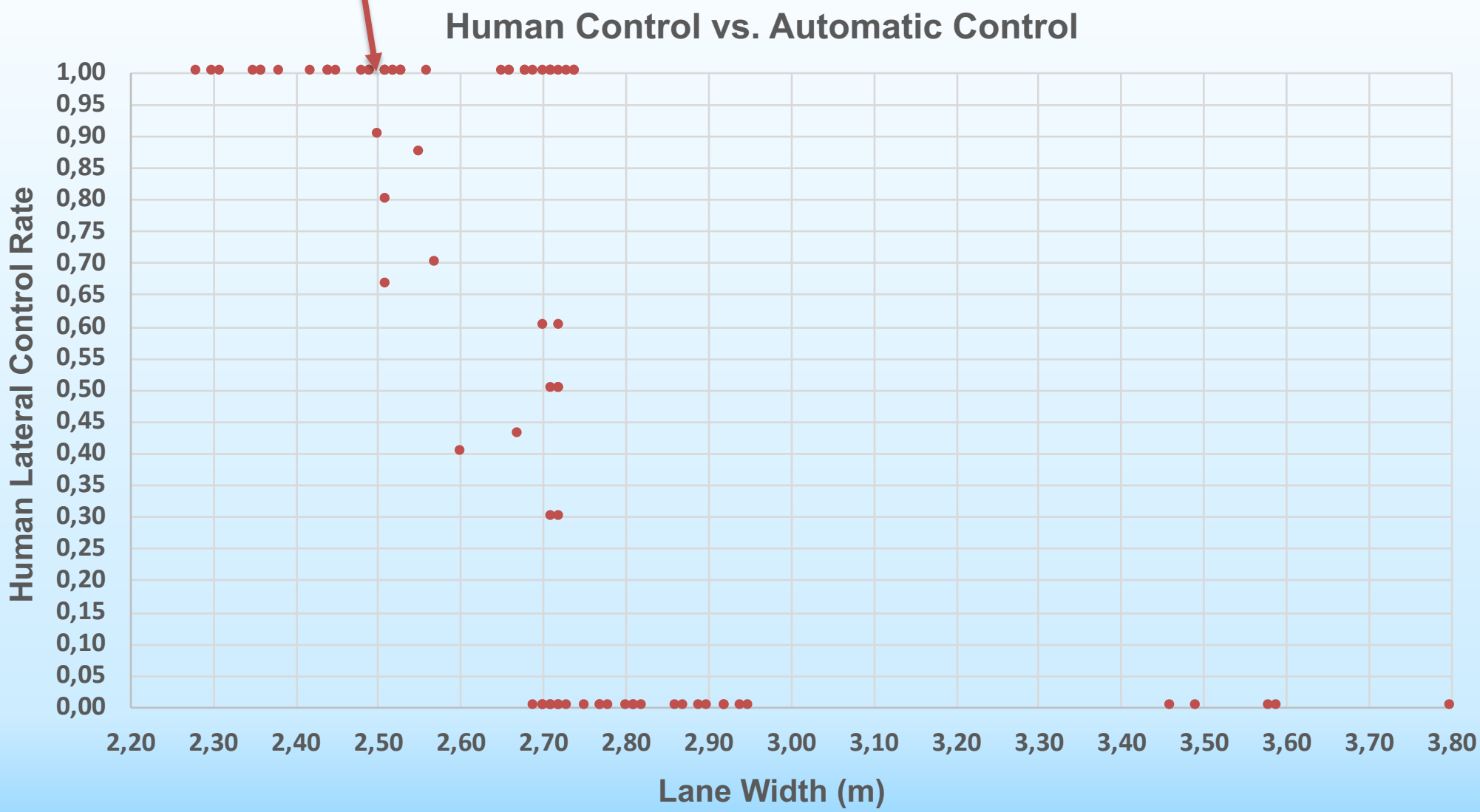


Methodology

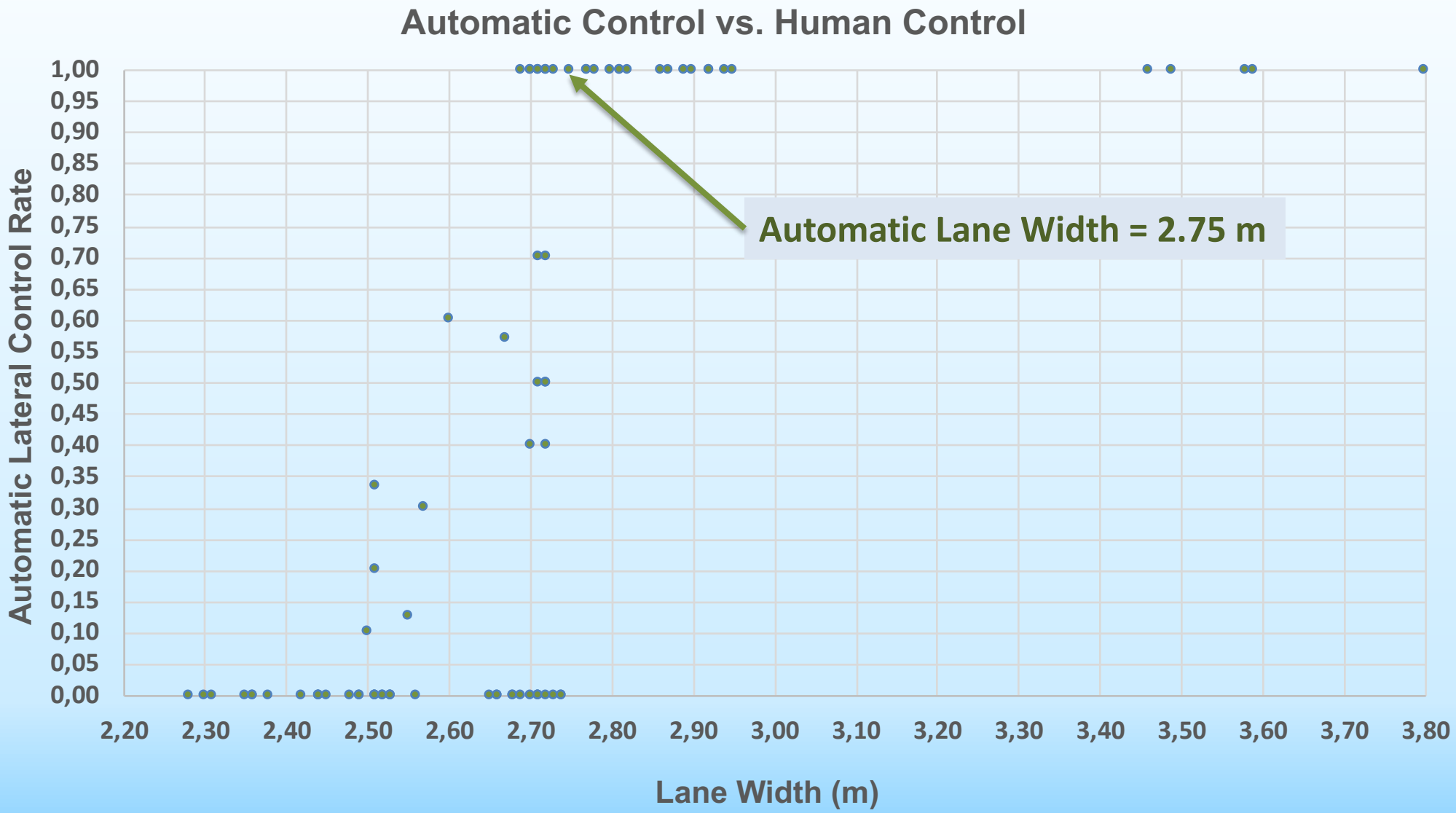
SECTION	CARRIAGEWAY (E/W)	LANE (Left=1;2;3;4;5)	WIDTH (m)	LKC RATE (Y=1; N=0)	TRIP									
					1	2	3	4	5	6	7	8	9	10
A2	W	3	2.94	1.0	1	1	1	1	1	1	1	1	1	1
A2	W	2	2.89	1.0	1	1	1	1	1	1	1	1	1	1
A2	W	1	2.60	0.6	0	1	1	1	1	1	1	0	0	0
A2	E	1	2.50	0.1	1	0	0	0	0	0	0	0	0	0
A2	E	2	2.90	1.0	1	1	1	1	1	1	1	1	1	1
A2	E	3	2.92	1.0	1	1	1	1	1	1	1	1	1	1

Analysis

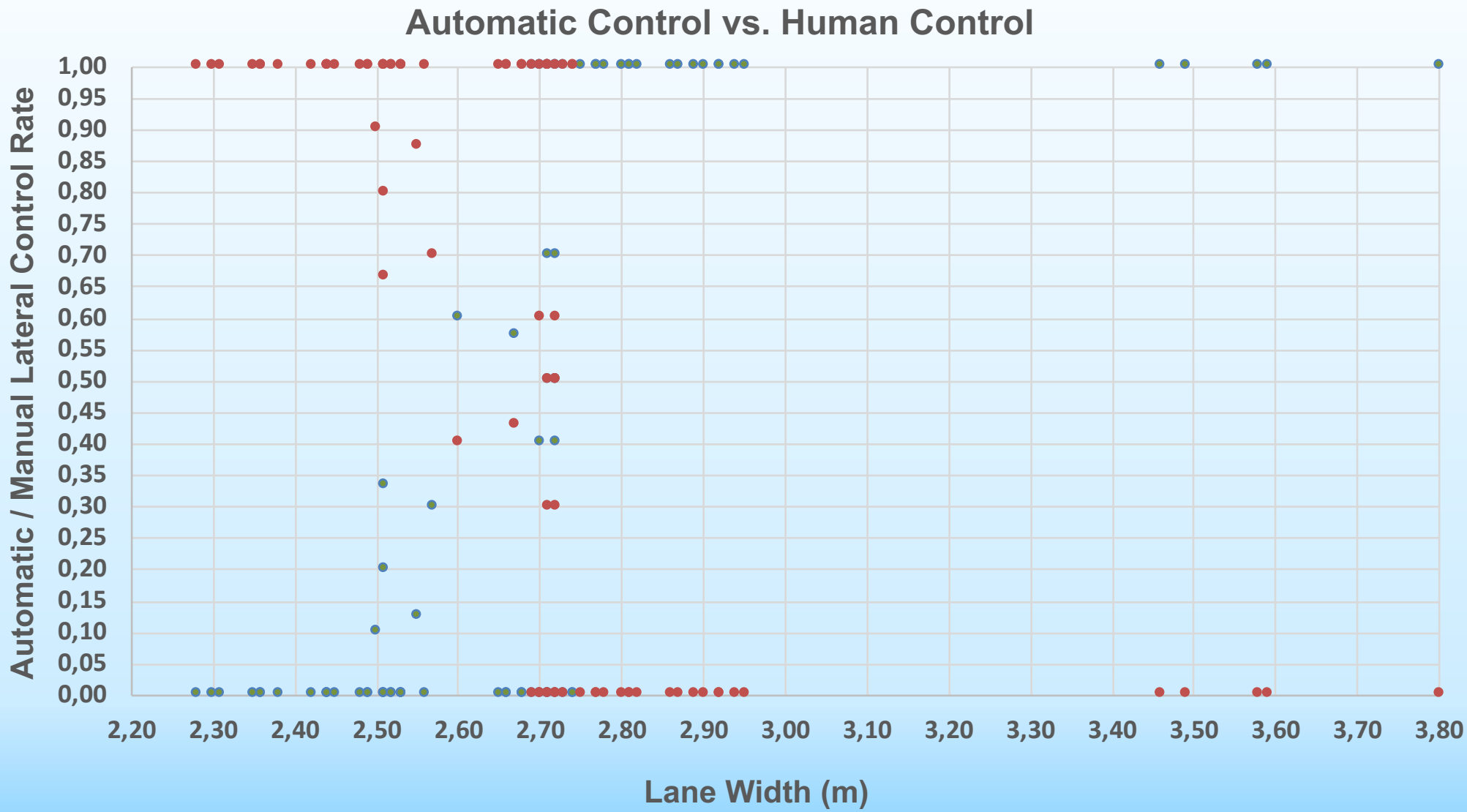
Manual Lane Width = 2.5 m



Analysis


Automatic Control vs. Human Control
Automatic Lateral Control Rate
1,00
0,95
0,90
0,85
0,80
0,75
0,70
0,65
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
Automatic Lane Width = 2.75 m
2,20
2,30
2,40
2,50
2,60
2,70
2,80
2,90
3,00
3,10
3,20
3,30
3,40
3,50
3,60
3,70
3,80
Lane Width (m)

Analysis


Automatic Control vs. Human Control
Automatic / Manual Lateral Control Rate
1,00
0,95
0,90
0,85
0,80
0,75
0,70
0,65
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
2,20
2,30
2,40
2,50
2,60
2,70
2,80
2,90
3,00
3,10
3,20
3,30
3,40
3,50
3,60
3,70
3,80
Lane Width (m)

Analysis


Critical Width (CW)
Automatic / Manual Lateral Control Rate
1
0,95
0,9
0,85
0,8
0,75
0,7
0,65
0,6
0,55
0,5
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
2,2
2,25
2,3
2,35
2,4
2,45
2,5
2,55
2,6
2,65
2,7
2,75
2,8
2,85
2,9
2,95
3
Lane Width (m)
CW = 2.72 m

Discussion

- **Automatic lane width = 2.75 m**
- **Experimental vehicle widths:**
  - Between external part of wheels = 1.85 m
  - Total width = 1.87 m (2.13 m w/rear-view mirrors)

- **Lateral space = 0.45 m (0.31 m)**

- **Automatic lane width for heavy vehicles = 3.45 (3.17) m:**
  - 2.55 m + 2*0.45 m = 3.45 m

Discussion

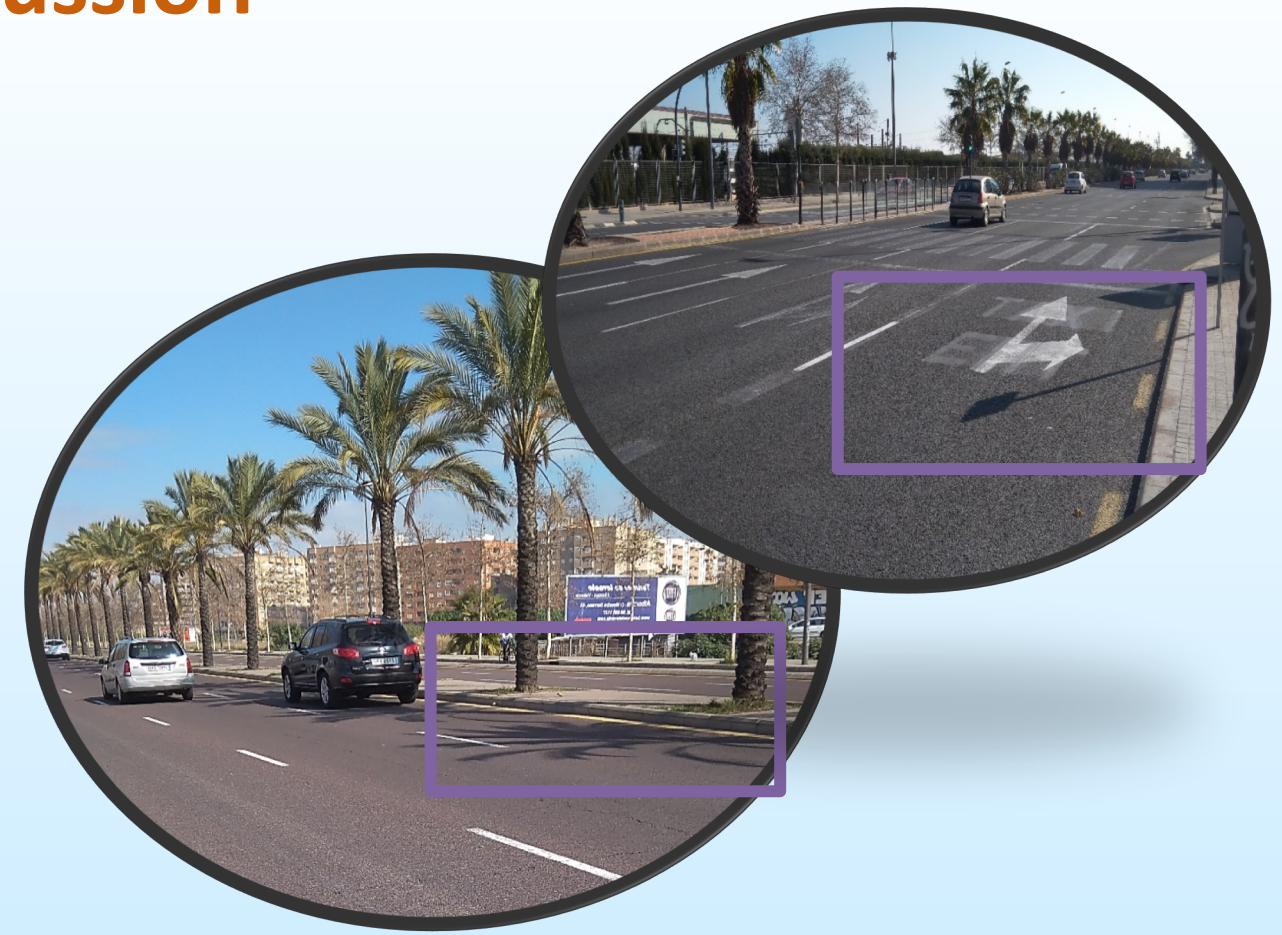
- **What may happen along curves?**
  - Wider lateral space for heavy vehicles
  - Shorter available sight distance when truck platooning travels on right lane along right turn curves



Source: Scania

Discussion

- **Experimental issues:**
  - Road marking:
    - Discontinuity
    - Color (w/y)
    - Visibility (paint/dust)
  - Shadows
  - Sun glare (E/W orientation)



Conclusion

- **New lane width concepts:**
  - Automatic lane width (≥ 2.75 m) for keeping the lateral control
  - Critical lane width (2.72 m) with the same probability of manual/automatic control
  - Manual lane width (≤ 2.50 m) for human control
- **A very short lane width range (0.25 m) to loosing the control**
- **LKA needs a lateral space = 0.45 m (0.31 m)**

- **Automatic lane width for heavy vehicles ≅ 3.45 (3.17) m**

Further Research

- **More observations:**
  - Other makes and car models
  - Heavy vehicles
- **Other road elements:**
  - Horizontal curves
  - Crest vertical curves
- **Other road marking layouts or patterns**
- **Other pavement issues:** cracking sealing
- **External circumstances:**
  - Adverse weather / Night driving / Sun glare









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Thanks for your attention



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