DEVELOPMENT OF A TEST CYCLE FOR THE INVESTIGATION OF BRAKE WEAR PARTICLES

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OUTLINE

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INTRODUCTION – BACKGROUND

- ✓ **Different driving conditions in experimental investigation of BW emissions is one important reason for different results and conclusions**
- ✓ **The PMP introduced a WI with the aim of defining normal driving conditions in order to provide guidance for the harmonization of future BW studies**
- ✓ **Parameters relevant for BW such as speed, deceleration, number and duration of braking events were calculated from the WLTP database**
- ✓ **The final report became available in March 2016 and can be found at the dedicated PMP webpage**

https://www2.unece.org/wiki/pages/viewpage.action?pageId=2523173

INTRODUCTION – CURRENT STATUS

- ✓ **The new ToR (June 2016) include the selection (or development) of a test cycle appropriate for the investigation of Brake Wear Particles**

- ✓ **The steps defined by the PMP group during the last meeting were:**
  - **WLTP Database Analysis (Concluded)**
  - **Comparison with Existing Industrial Cycles (On-Going)**
  - **Development of a first version of the Braking Cycle (To be bone)**
  - **Testing and Validation of the New Cycle (To be bone)**

- ✓ **Real world data provided by industrial partners have been processed with the aim of being compared to those of the WLTP database**

BRAKE RELATED PARAMETERS

- ✓ **Deceleration Rate**
  - **WLTP Database**
  - **Industrial Cycles**
  - **Comparison**
- ✓ **Brake Phase Duration**
- ✓ **Initial Vehicle Speed**
- ✓ **Final Vehicle Speed**
- ✓ **Other Parameters**

DECELERATION RATE – WLTP DATABASE

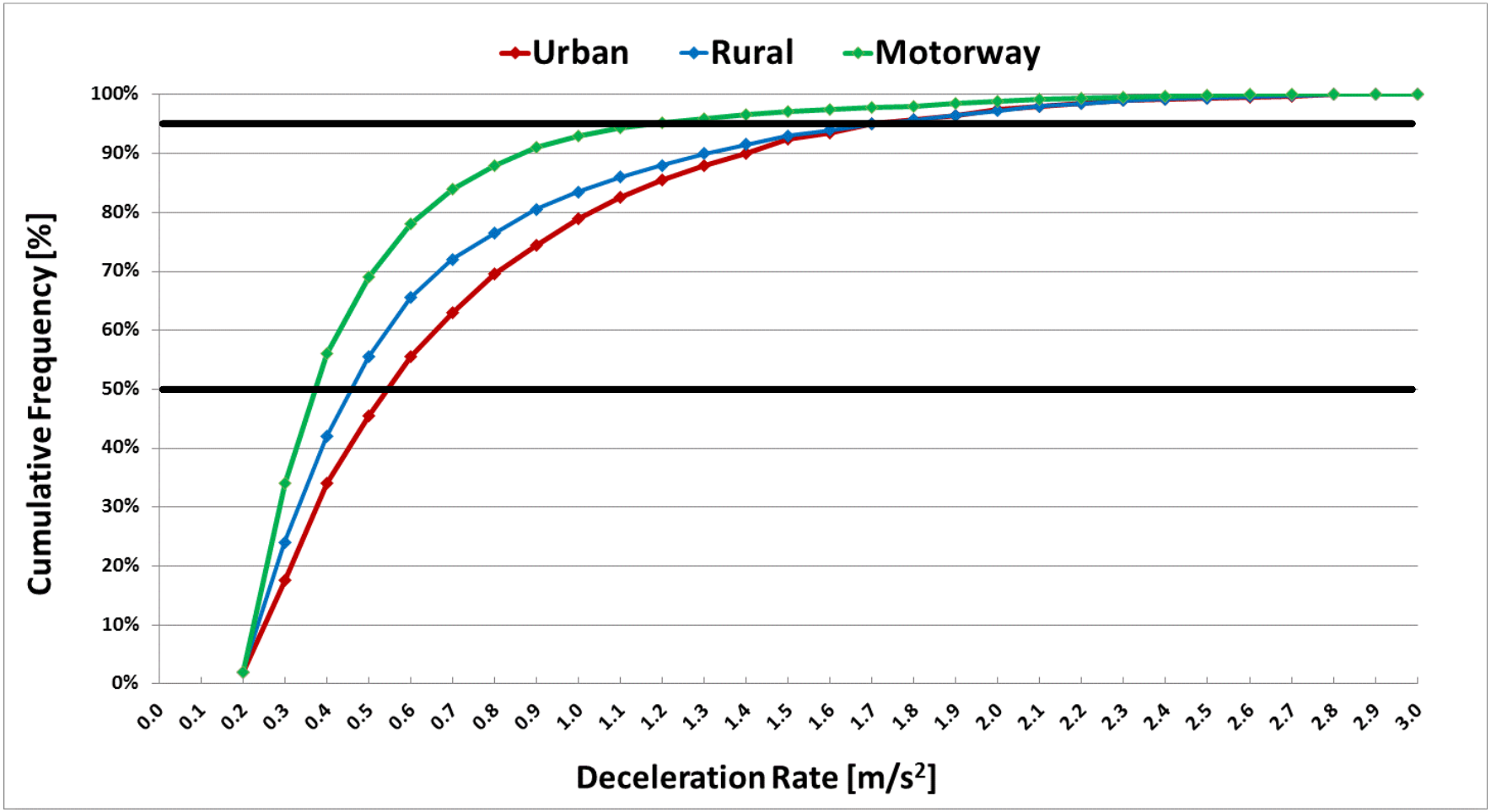
Region	Road Type	Deceleration Rate [m/s²]
Europe Median (50%)	Urban	0.6
	Rural	0.5
	Motorway	0.4

Region	Road Type	Deceleration Rate [m/s²]
Europe Extreme (95%)	Urban	1.7
	Rural	1.7
	Motorway	1.2

Median and extreme deceleration rates for different road categories in Europe

- ✓ A median deceleration rate of 0.6 m/s² is found in European urban areas probably also due to many events occurring within traffic jams
- ✓ Lower rates are found in rural areas and motorways
- ✓ Deceleration rates > 1.7 m/s² can be considered as extreme in all European areas. Generally more "soft" braking in motorways

DECELERATION RATE – WLTP DATABASE



Deceleration distributions for different road categories in Europe

DECELERATION RATE – INDUSTRIAL CYCLES

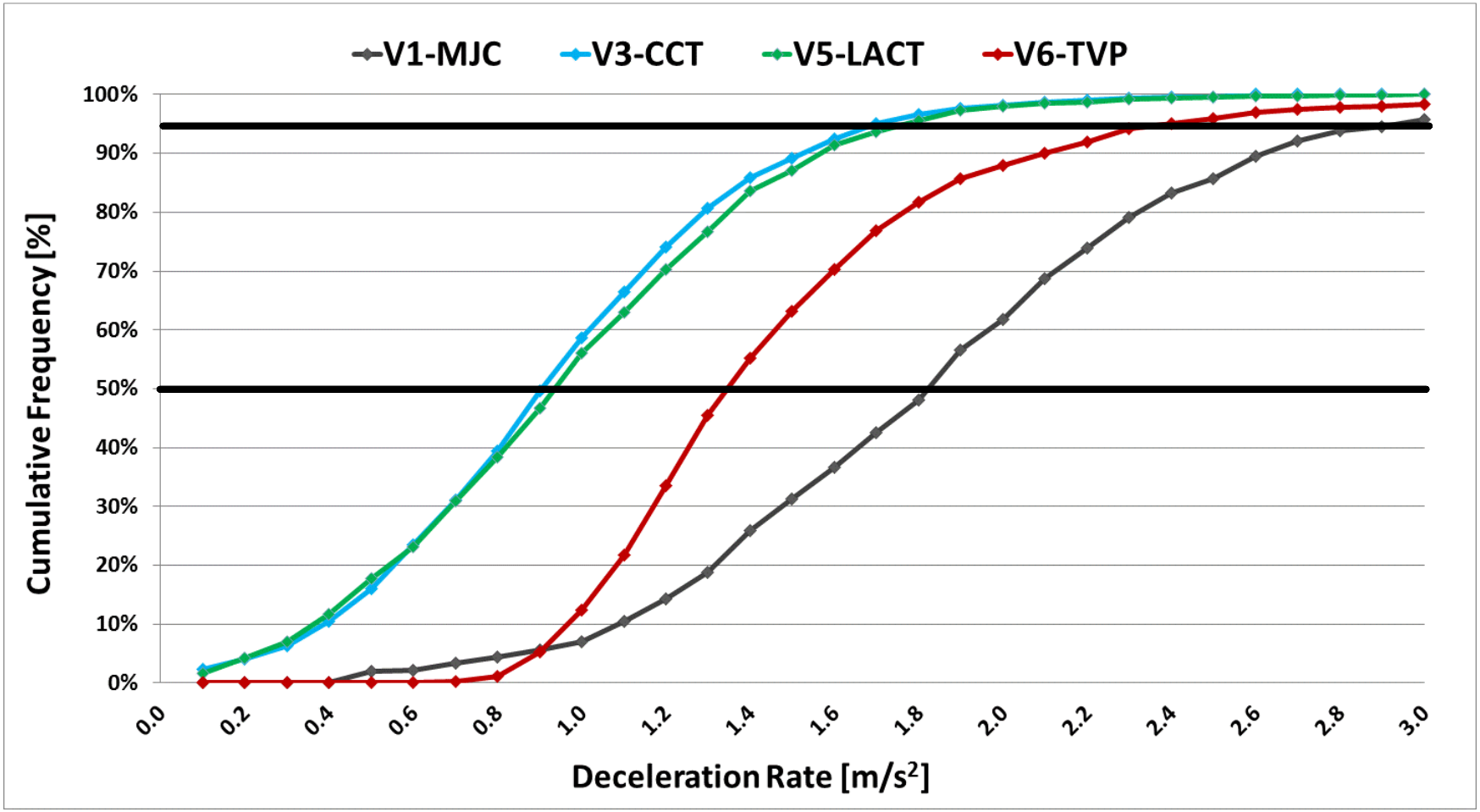
Cycle	Deceleration Rate [m/s²]
Los Angeles City Traffic	0.9
Cologne City & Suburban	0.9
Taxi Villa Paris	1.4
Mojacar	1.3-1.9
WLTP Europe Urban	0.6

Cycle	Deceleration Rate [m/s²]
Los Angeles City Traffic	1.8
Cologne City & Suburban	1.7
Taxi Villa Paris	2.4
Mojacar	2.9
WLTP Europe Urban	1.7

Median and extreme deceleration rates for different cycles

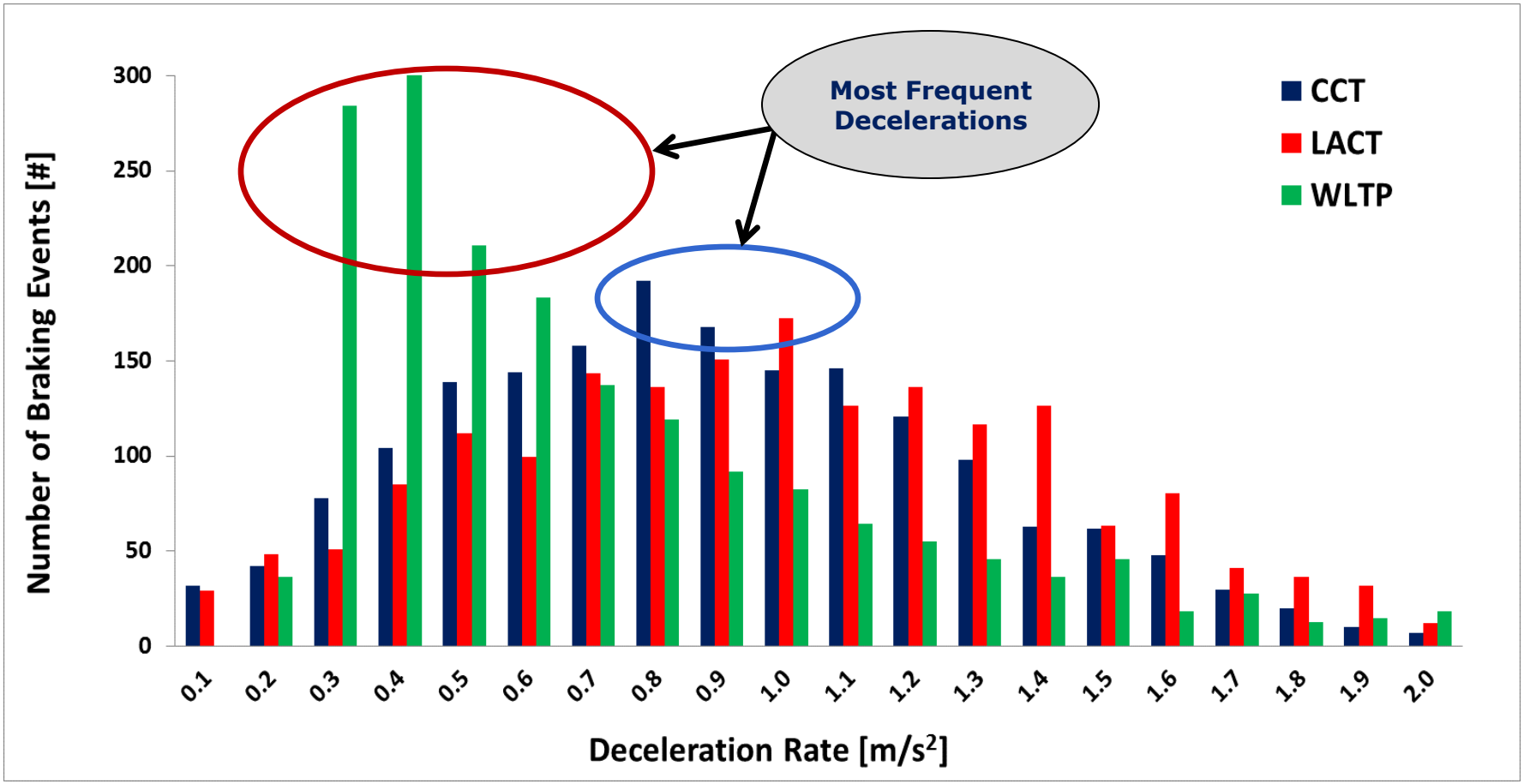
- ✓ **LACT and CCS showed median deceleration rates closer to the WLTP data compared to TVP and Mojacar**
- ✓ **Similarly to real world deceleration rates higher than 1.7 m/s² can be considered as extreme also in case of LACT and CCS**

DECELERATION RATE – INDUSTRIAL CYCLES



Deceleration rate distributions for different industrial cycles

DECELERATION RATE – COMPARISON



Distribution of deceleration rates normalized for the same amount of total brake events

BRAKE RELATED PARAMETERS

- ✓ Deceleration Rate
- ✓ **Brake Phase Duration**
  - **WLTP Database**
  - **Industrial Cycles**
  - **Comparison**
- ✓ Initial Vehicle Speed
- ✓ Final Vehicle Speed
- ✓ Other Parameters

BRAKE PHASE DURATION – WLTP DATABASE

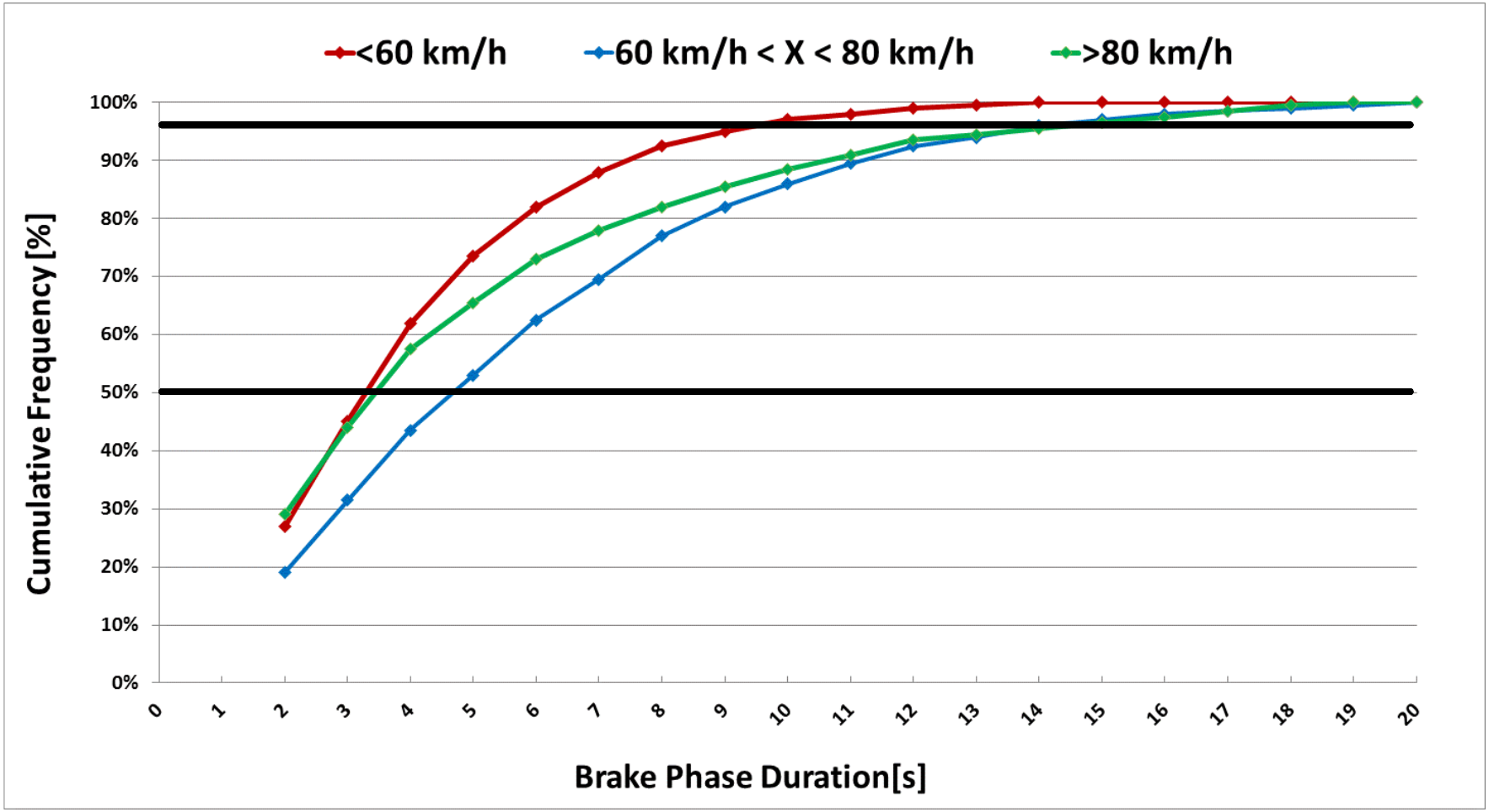
Region	Road Type	Brake Phase Duration [s]
Europe Median (50%)	Urban	3.3
	Rural	3.4
	Motorway	2.5

Region	Road Type	Brake Phase Duration [s]
Europe Extreme (95%)	Urban	9.0
	Rural	10.2
	Motorway	10.3

Median and extreme brake phase duration distributions for different road categories in Europe

- ✓ Median brake phase duration in European urban and rural areas is approximately 3.5 s
- ✓ Slightly shorter brake phase duration is found in motorways
- ✓ Brake phase duration longer than 9.0 s is considered extreme in urban areas while for rural areas and motorways the value is 10.0 s

BRAKE PHASE DURATION – WLTP DATABASE



Brake phase duration distributions for different road categories in Europe

BRAKE PHASE DURATION – INDUSTRIAL CYCLES

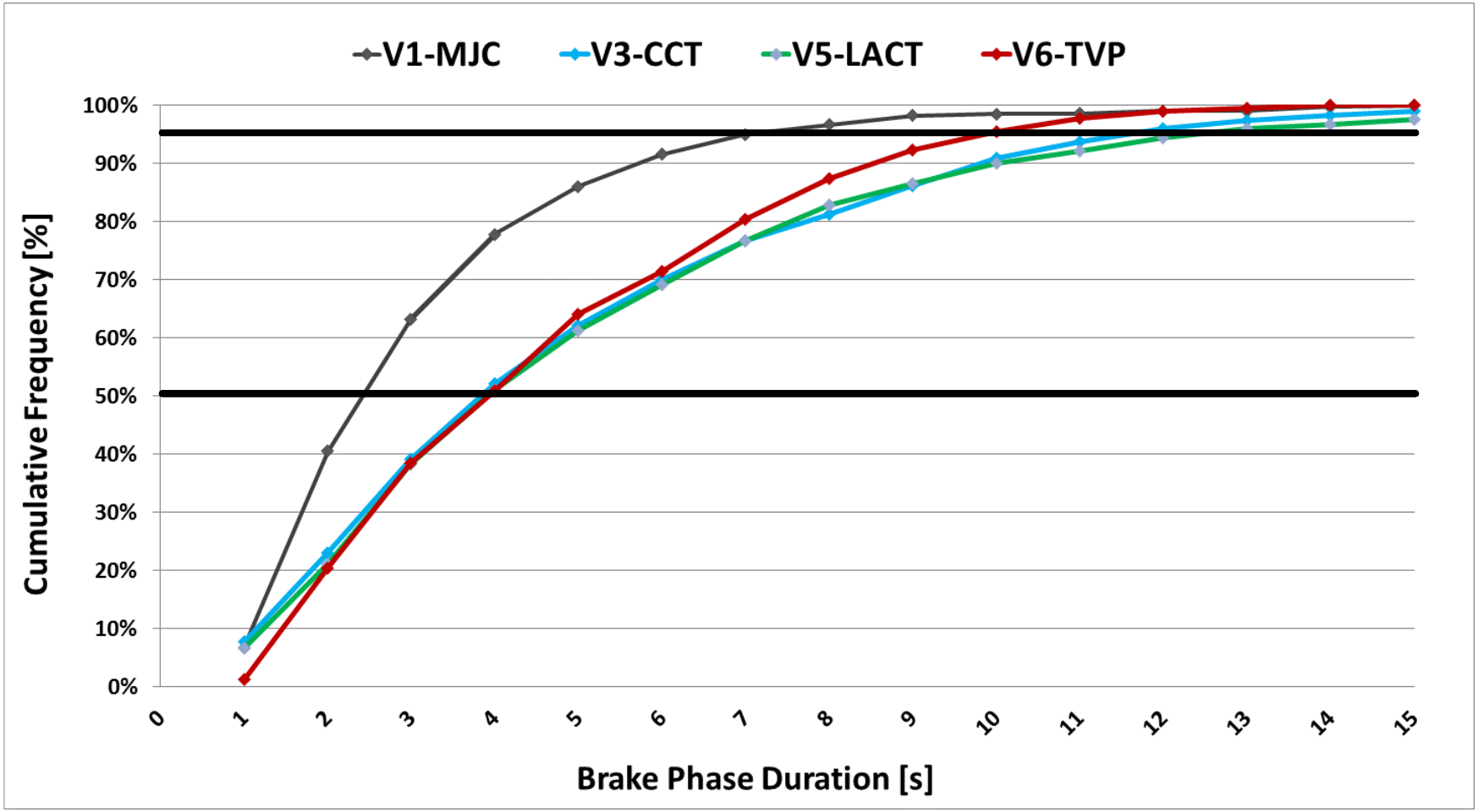
Cycle	Brake Phase Duration [s]
Los Angeles City Traffic	3.9
Cologne City & Suburban	3.9
Taxi Villa Paris	4.0
Mojacar	2.5
WLTP Europe Urban	3.3

Cycle	Brake Phase Duration [s]
Los Angeles City Traffic	12.5
Cologne City & Suburban	11.5
Taxi Villa Paris	10.0
Mojacar	7.0
WLTP Europe Urban	9.0

Median and extreme brake phase duration for different cycles

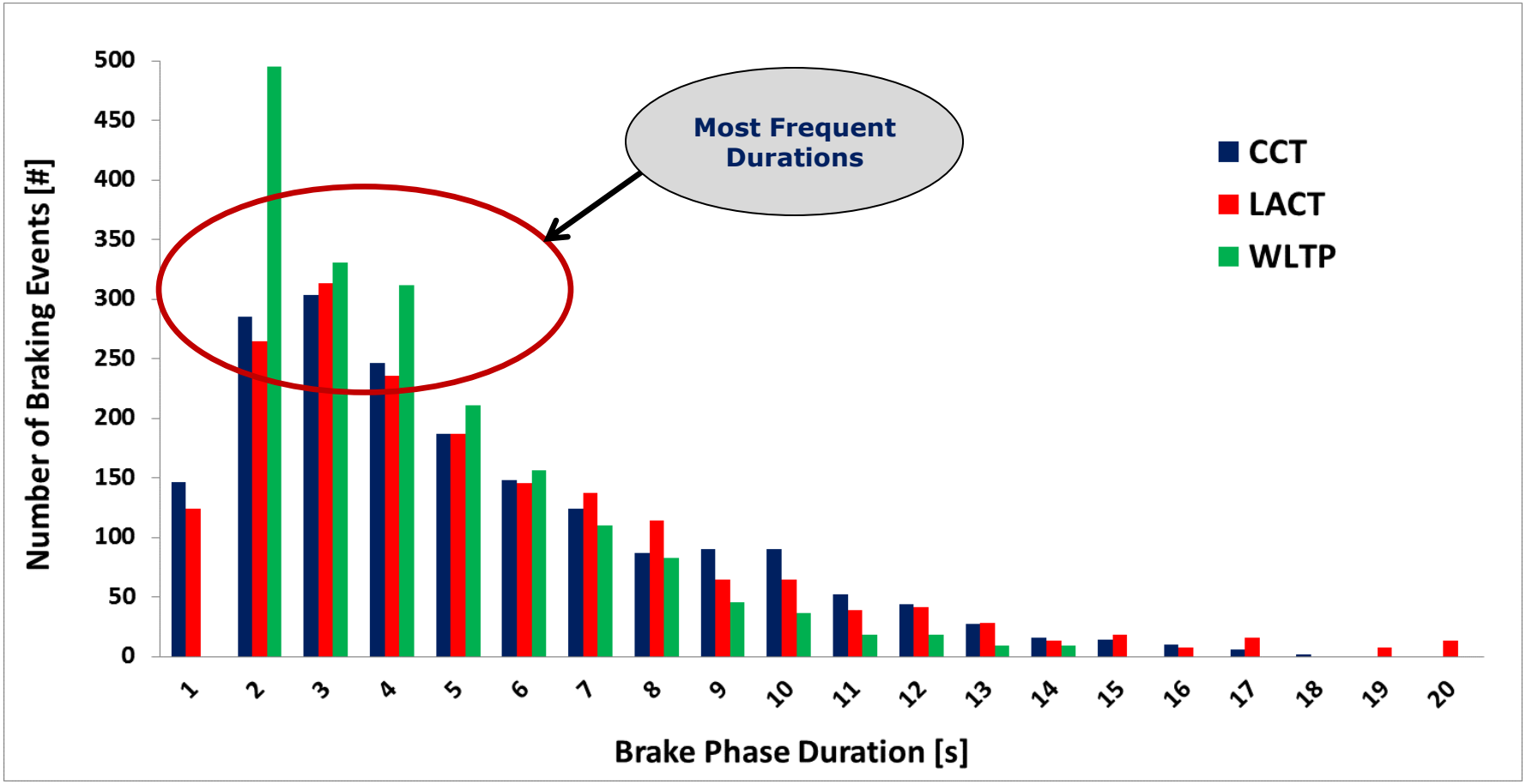
- ✓ **LACT, CCS and TVP showed median brake phase durations of ~4.0 s which is relatively close to the WLTP data for European Urban areas**
- ✓ **Brake Phase Durations longer than 10 s can be considered as extreme in almost all cases**

BRAKE PHASE DURATION – INDUSTRIAL CYCLES



Brake Phase duration distributions for different industrial cycles

BRAKE PHASE DURATION – COMPARISON



Distribution of brake phase duration normalized for the same amount of total brake events

BRAKE RELATED PARAMETERS

- ✓ Deceleration Rate
- ✓ Brake Phase Duration
- ✓ **Initial Vehicle Speed**
- ✓ **Final Vehicle Speed**
  - **WLTP Database**
  - **Industrial Cycles**
  - **Comparison**
- ✓ Other Parameters

VEHICLE SPEED – WLTP DATABASE

Region	Road Type	Vehicle Speed [km/h]
Europe Median (50%)	Urban	28.3
	Rural	64.7
	Motorway	114.8

Region	Road Type	Vehicle Speed [km/h]
Europe Extreme (95%)	Urban	60.2
	Rural	113.7
	Motorway	137.9

Median and extreme average vehicle speed distributions for different road categories in Europe

- ✓ Median average vehicle speed in European urban areas is 28 km/h. Speeds higher than 60 km/h are considered extreme
- ✓ Median average vehicle speed in European rural areas is 65 km/h. Speeds higher than 114 km/h are considered extreme. The values for motorways are 115 km/h and 138 km/h, respectively

VEHICLE SPEED – INDUSTRIAL CYCLES

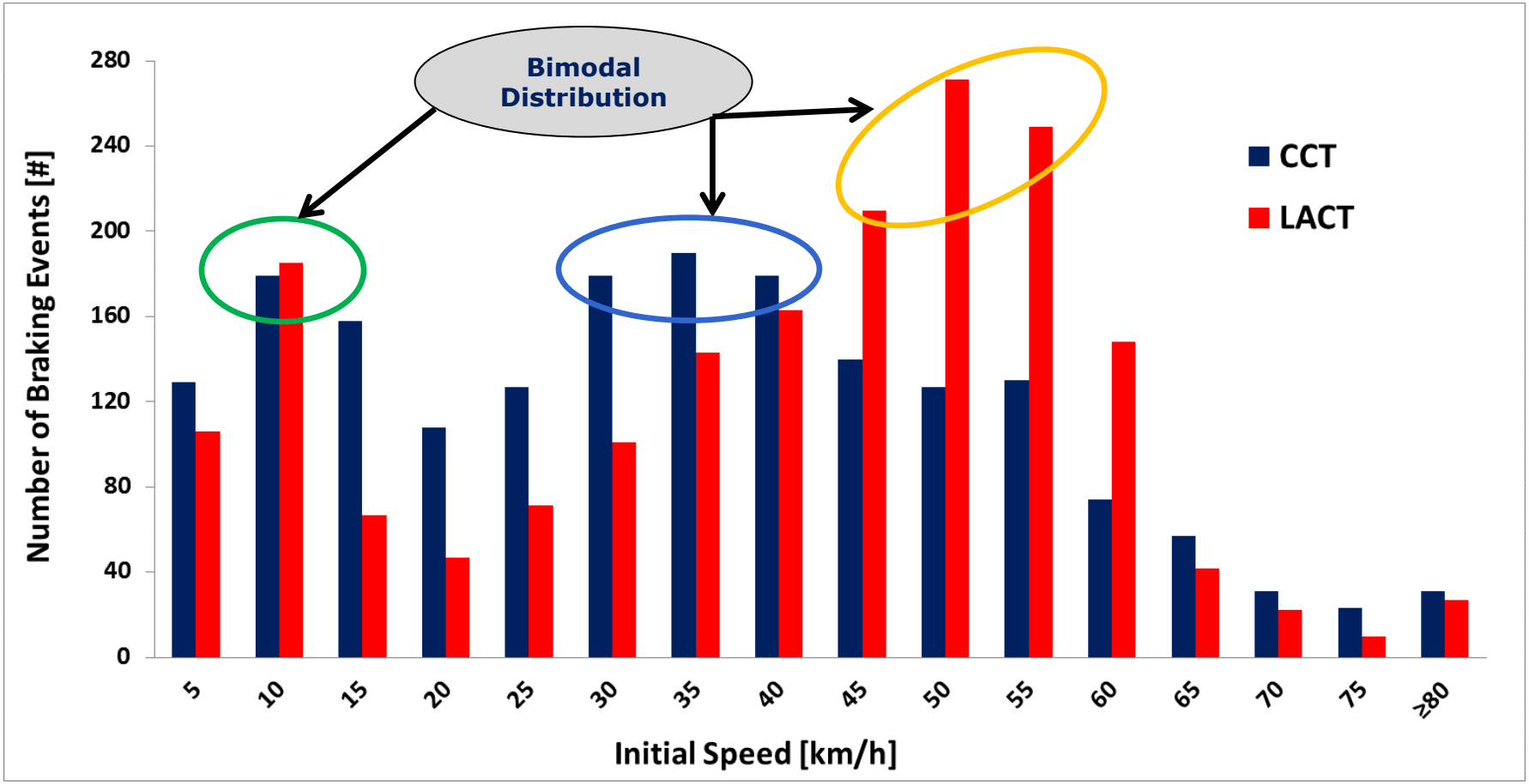
Cycle	Initial [km/h]	Final [km/h]
Los Angeles City Traffic	42	7
Cologne City & Suburban	32	7
Taxi Villa Paris	44	12
Mojacar	53	33
WLTP Europe Urban	>28*	<28*

Cycle	Initial [km/h]	Final [km/h]
Los Angeles City Traffic	61	52
Cologne City & Suburban	66	49
Taxi Villa Paris	74	54
Mojacar	95	81
WLTP Europe Urban	>62*	<62*

Median (50%) and extreme (95%) initial and final vehicle speed for different cycles

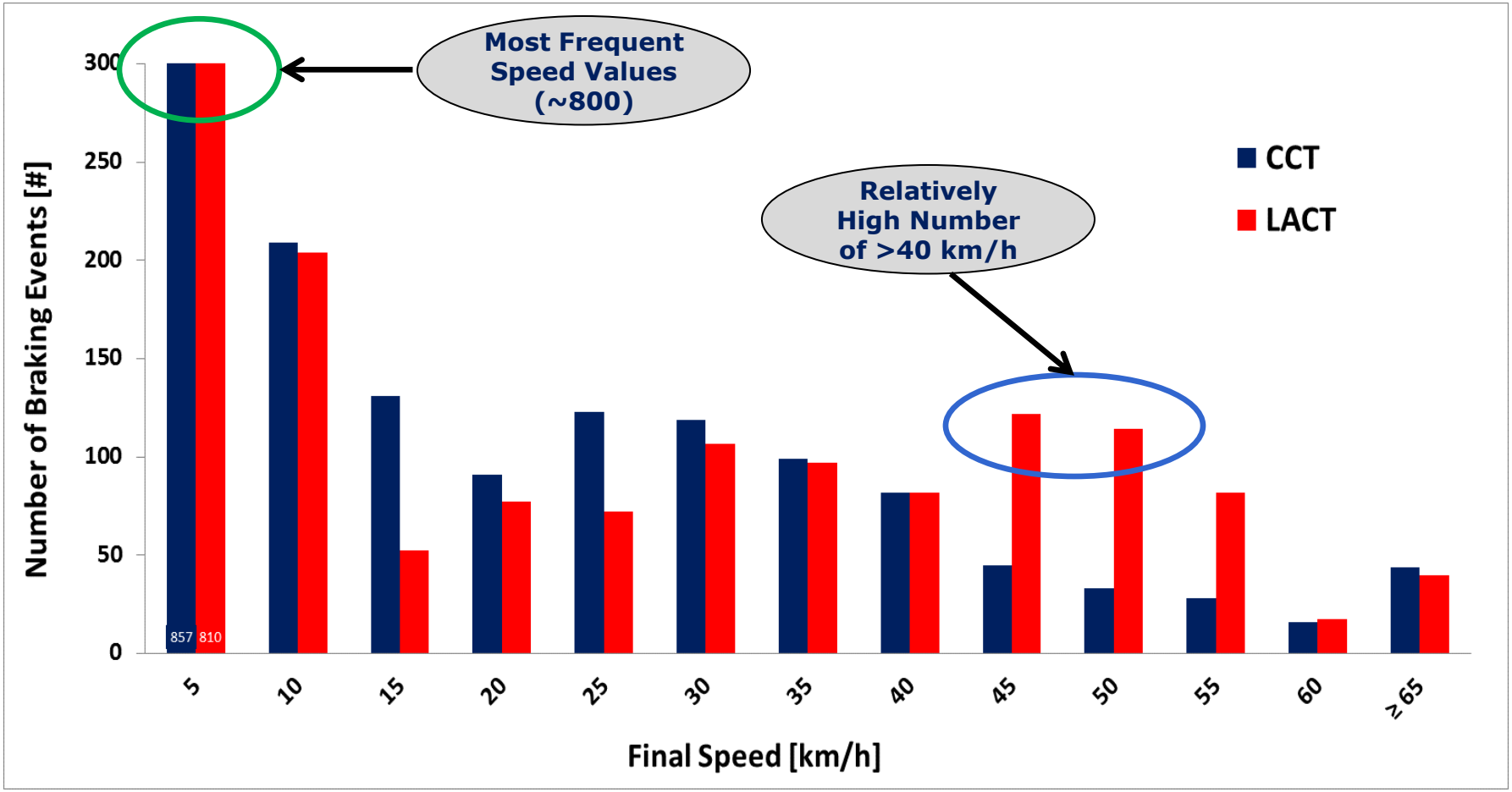
- ✓ Initial brake speeds > 65 km/h are considered extreme for both LACT and CCS in agreement with the extreme WLTP average speed
- ✓ LACT and CCS have a relatively higher amount of full stop brake events explaining thus the low final braking speed

INITIAL VEHICLE SPEED – COMPARISON



Distribution of initial vehicle speed normalized for the same amount of total brake events

FINAL VEHICLE SPEED – COMPARISON



Distribution of final vehicle speed normalized for the same amount of total brake events

BRAKE RELATED PARAMETERS

- ✓ Deceleration Rate
- ✓ Brake Phase Duration
- ✓ Initial Vehicle Speed
- ✓ Final Vehicle Speed
- ✓ **Other Parameters**
  - **Number of events and full stop braking**
  - **Initial Disc Temperature**

NUMBER & FULL STOP EVENTS – COMPARISON

Cycle	Average [#/km]	Full Stop [%]
Los Angeles City Traffic	2.3	20.3
Cologne City & Suburban	2.3	31.6
Taxi Villa Paris	4.6	22.4*
Mojacar	1.9	13.0
WLTP – Europe Total	1.6	15-30
WLTP – Europe Urban	3.8	31.8

- ✓ **2.3** braking events per km occur over LACT and CCS, while the value for normal urban driving is higher
- ✓ CCS demonstrate similar proportion of full stop events to normal urban driving while LACT has less full stop events

Number of brake phases per km (#) and percentage (%) of brake phases down to a stop phase (i.e. < 1km/h) with respect to the total number of braking events for different cycles

INITIAL DISC TEMPERATURE – COMPARISON

Cycle	Median Initial Disc Temperature [°C]	Applications with T_{ini} >100°C [%]
Los Angeles City Traffic	84.5	~20
Cologne City & Suburban	61.5	<10
Taxi Villa Paris	192.6	>90
WLTP – Europe	???	???

- ✓ LACT and CCS show very high percentage of brake applications below 100°C
- ✓ TVP has a completely different temperature profile with many applications higher than 100°C

CONCLUSIONS

- ✓ **Mojacar can not be used to reproduce real world urban driving conditions due to steeper braking events (i.e. higher deceleration rates and lower duration)**
- ✓ **Similarly TVP exhibit significantly higher deceleration rates as well as relatively higher number of events per km**
- ✓ **On the other hand, CCS and LACT data could be used to reproduce real world urban driving conditions with maybe some adjustment at the deceleration rates**
- ✓ **LACT is already an established procedure used by most industrial parties while CCS is not yet an established procedure**

European Commission

Thank you very much - Stay in touch

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