

Submitted by the expert from WBIA



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# UN Regulations No. 78

## Limitations and Improvements for S-EPAC

# Limitations and Improvements for S-EPAC

- **Definition:**
  - EPAC is the acronym for Electrically Power Assisted Cycle, which are non-type approved e-bikes in EU.
  - S-EPAC is considered a pedal-driven vehicle of category L1 with auxiliary electric propulsion, which is a type-approved e-bike in EU
    - Specifically, it is a vehicle of subcategory L1e-B according to (EU) 168/2013)
- **Background:**
  - In certain conditions, ABS can offer benefit in terms of cycling safety as it optimizes the trade-off between bicycle stability and deceleration
  - ABS can work only within the physical limits of the bicycle (friction of tire & road, center of gravity of rider & bicycle, etc.)
  - ABS has, as all technical systems, a level of efficiency compared to rider's best performance (pro rider who knows when & how to brake)
- **Applicable standards:**
  - ABS is available for both EPAC and S-EPAC, hence UNECE R78 is mandatory for S-EPAC
  - Current design of the UNECE R78 targets ABS technology on powered two wheelers (PTWs) such as mopeds and motorcycles which have different physical limits (cf. slide 2)
- **Issue:**
  - The center of gravity (CoG) of S-EPACs combined with the level of efficiency of every ABS does not fit to the braking test "Stops on high friction surface" (chapter 9.3) which includes a vehicle independent deceleration threshold of  $6.17\text{m/s}^2$  (cf. slide 2)
- **Proposal:**
  - Changing the deceleration threshold definition from a vehicle independent one to a vehicle dependent one as in braking test "Stops on low friction surface" (chapter 9.4) enables a better fit of UNECE R78 to S-EPACs (cf. slide 3)

# A Standard made for Motorcycles and Mopeds

## Discussion points:

- The deceleration threshold of  $6.17\text{m/s}^2$  on high friction surface in UN R78 does not fit for bicycles physics (geometry, center of gravity, etc.)
- A brake efficiency of 100% is impossible in comparison to the rider's best values due to the working principle of ABS
- An ABS efficiency of 80-90% can be rated as very good and leads to a significant increase of stability and hence safety of the bike



Fig. 2. CG positions of motorized vehicle, motor cycle, electric bicycle  
Image sources: Daimler, Yamaha, Merida

### Theoretical deceleration for rear wheel lift-up [ $\text{m/s}^2$ ]

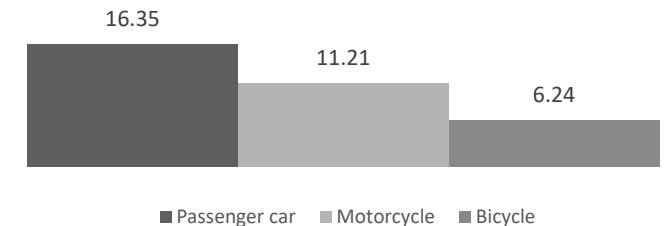


TABLE I  
DRIVING DYNAMICS PARAMETERS BASED ON [4]

Symbol	Quantity	Vehicle	Motor Cycle	Electric Bicycle
$m$	vehicle mass in kg	1500	275	25
$\Delta m$	additional load in %	+33	+45	+83
$l$	wheelbase in m	2.7	1.5	1.1
$l_F$	distance CG to front wheel in m (and %)	1 (37)	0.8 (54)	0.7 (61)
$l_R$	distance CG to rear wheel in m	1.7 (63)	0.7 (46)	0.4 (39)
$h$	height of CG to the road surface in m	0.6	0.7	1.1
$r$	wheel radius in m	0.29	0.28	0.35
$J_{yy}$	wheel moment of inertia in $\text{kgm}^2$	1.14	0.65	0.16

# Needed Change Points for S-EPAC

## Chapter

9.3. Stops on a high friction surface:

9.3.2. Performance requirements

### Current version

- a. The stopping distance (S) shall be  $\leq 0.0063V^2$   
(where V is the specified test speed in km/h and S is the required stopping distance in metres)  
or the MFDD shall be  $\geq 6.17 \text{ m/s}^2$ ; and
- b. There shall be no wheel lock and the vehicle wheels shall stay within the test lane.

### Proposal

The stopping distance (S) shall be...

- a.1 in general,  $\leq 0.0063V^2$   
(where V is the specified test speed in km/h and S is the required stopping distance in metres)  
or the MFDD shall be  $\geq 6.17 \text{ m/s}^2$ ; or
- a.2 in case of pedal-driven vehicles of category L1 with auxiliary electric propulsion,  $\leq 0.0056V^2/P$   
(where V is the specified test speed in km/h, P is the peak braking coefficient and S is the required stopping distance in metres)  
or the MFDD shall be  $\geq 6.87 \times P$ , in  $\text{m/s}^2$ ; and
- b. There shall be no wheel lock and the vehicle wheels shall stay within the test lane.

■ Current phrasing in UN R78

■ New additions to UN R78

# Exemplary Calculation for 9.3 and 9.4

## Current version of UNECE R78:

### 9.4.2 Performance requirements (Stops on low friction surface)

- a. The stopping distance (S) shall be  $\leq 0.0056V^2/P$   
(where V is the specified test speed in km/h, P is the peak braking coefficient\* and S is the required stopping distance in metres)  
 or the MFDD shall be  $\geq 6.87 \times P$ , in  $m/s^2$ ;

## Proposal:

### 9.3.2 Performance requirements (Stops on high friction surface)

The stopping distance (S) shall be...

- a.2 in case of pedal-driven vehicles of category L1 with auxiliary electric propulsion,  $\leq 0.0056V^2/P$   
(where V is the specified test speed in km/h, P is the peak braking coefficient and S is the required stopping distance in metres)  
 or the MFDD shall be  $\geq 6.87 \times P$ , in  $m/s^2$ ;

## Calculation example:

Calculation of PBC (from arbitrary measurement):

$$t = 0.76 \text{ s}$$

$$P = 0.566/0.76 = \mathbf{0.75}$$

$$\mathbf{MFDD \text{ criteria} = 6.87 \times 0.75 = 5.15 \text{ m/s}^2}$$

### Comparison with rider's best deceleration\*\*:

rider's best value from same arbitrary measurement:  $7.1 \text{ m/s}^2$

$$\mathbf{MFDD \text{ criteria} / \text{rider's best} = 5.15 \text{ m/s}^2 / 7.1 \text{ m/s}^2 = \mathbf{73\%}}$$

→ The pass criteria for ABS is 73% of rider's best value

## Calculation example:

Calculation of PBC (from another arbitrary measurement):

$$t = 1.3 \text{ s}$$

$$P = 0.566/1.3 = \mathbf{0.43}$$

$$\mathbf{MFDD \text{ criteria} = 6.87 \times 0.43 = 2.95 \text{ m/s}^2}$$

### Comparison with rider's best deceleration\*\*:

rider's best value from same exemplary measurement:  $4.0 \text{ m/s}^2$

$$\mathbf{MFDD \text{ criteria} / \text{rider's best} = 2.95 \text{ m/s}^2 / 4.0 \text{ m/s}^2 = \mathbf{74\%}}$$

→ The pass criteria for ABS is 74% of rider's best value

\* Calculation of PBC:

The Peak Braking Coefficient (PBC) is calculated from the test stop that generates the maximum vehicle deceleration rate, as follows:  $PBC = 0.566/t$ , where t = time taken, in seconds, for the speed of the vehicle to reduce from 0.8 Vmax to (0.8 Vmax – 20), where Vmax is measured in km/h

Source: UNECE R78

\*\* rider's best: mean deceleration from 0,8 Vmax to 0,1 Vmax, best out of 10 measurements without ABS to define a criteria close to the physical limit