Submitted by the expert from WBIA

Informal document **GRVA-18-39**
18th GRVA, Geneva, 22-26 January 2024
Provisional agenda item 9(b)

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 $6.17 m/s^2$ (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 6.17m/s² 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

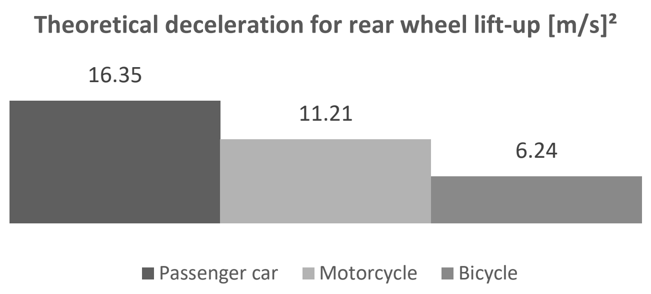

TABLE I
DRIVING DYNAMICS PARAMETERS BASED ON [4]

Symbol	Quantity	Vehicle	Motor Cycle	Electric Bicycle
m	vehicle mass in kg	1500	275	25
Δm	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 kgm²	1.14	0.65	0.16

Source: O. Maier, M. Pfeiffer, S. Scharpf and J. Wrede, "Conditions for nose-over and front wheel lockup of electric bicycles," doi: 10.1109/MECATRONICS.2016.7547145.

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 ≥ 6.17 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 ≥ 6.17 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 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

Source: UNECE 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 ≤ $0.0056V^2/P$
(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 ≥ 6.87 x 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, ≤ $0.0056V^2/P$
(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 ≥ 6.87 x P, in m/s^2;

Calculation example:

Calculation of PBC (from arbitrary measurement):

t = 0.76 s
P = 0.566/0.76 **= 0.75**

MFDD criteria = 6.87 x 0.75 **= 5.15 m/s^2**

Comparison with rider's best deceleration:**
rider's best value from same arbitrary measurement: 7.1 m/s^2

MFDD criteria / rider's best = 5.15 m/s^2 / 7.1 m/s^2 **= 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 s
P = 0.566/1.3 **= 0.43**

MFDD criteria = 6.87 x 0.43 **= 2.95 m/s^2**

Comparison with rider's best deceleration:**
rider's best value from same exemplary measurement: 4.0 m/s^2

MFDD criteria / rider's best = 2.95 m/s^2 / 4.0 m/s^2 **= 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