

Problems of the application of intelligent driver assistance systems on a single-track vehicles

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Abstract. This article considers some problems and features of the application of modern systems of driver assistance on single-track vehicles ("STV"). It is also mentioned the classification of intelligent driver assistance systems and design features of the "STV" that require an improvement for their successful application on such vehicle. There is also described perspective of systems' development that helps the "STV" driver. Also perspective the "STV" types with high safety construction are considered in this article.

Introduction

In January 2018 there were discussed essential improvement questions regarding the safety of motor transport in Europe during the regular conference of the European Association of motorcycle manufacturers (ACEM - European Association of Motorcycle Manufacturers). There were discussed problems regarding the environmental safety improvements, active and passive safety of motor vehicles, the development of intelligent driver helping systems ("IDHS") that were adapted for their installation on a single-track vehicles ("STV"). Also there were considered the interaction of the "STV" with other participants on public roads, the development and improvement of training systems for drivers of motor vehicles and other questions related to the safety of the "STV".

One of the conclusions made in ACEM conference resolution is a need of the intensive development of the "IDHS" for the "STV". This measure will significantly reduce risks of road accidents that occur with motor vehicles, and in case of getting the "STV" in an accident - it may reduce the severity of the consequences.

Dynamics of road accidents and number of the "STV" on roads of the EU and Russia.

According to the latest data of IRTAD (International Road Traffic and Accident Database - an international database of road traffic and accidents), accidents of two-wheeled vehicles decreased by 44 % from 2000 to 2014 years. In the period from 2010 to 2014 years, the number of deaths among motorcyclists decreased from 4304 to 3561 people (that is 17.3% less). In the same period the number of deaths among scooter drivers decreased from 975 to 622 people (that is 36.2% less). At the same time the number of the "STV" in the EU increased by 5.9% from 2000 to 2014 time period and amounted to 36.1 million by the end of 2014 year.

Research studies and works show us that the reduction of accidents and the severity of the consequences with the participation of the "STV" due to the increased number of the "STV" equipped



with driver assistance systems (anti - lock systems, etc.) is the beginning of its mass application during the period of 2008-2010 years.

According to Road Police data in Russia from 2012 to 2015 years number of deaths among all "L" vehicle categories decreased from 2033 to 1534 people (that is 24.6% less). But the number of the "STV" decreases each year at about 0.5-1 % in Russia. By the end of 2015 year there were officially registered 2.25 million L3 - L5, L7 categories of motor vehicles.

If we check figures of the reduction of death occasions in the EU and in Russia, it may seem that the situation in Russia even better than in Europe. Unfortunately it is not so. To be correct comparing the safety level of the "STV" in Russia and in the EU, it is important to consider not absolute figures, but relative ones. Let's count the number of deaths per 10,000 the "STV" units. In the EU it is 1,2 human per 10.000 the "STV" and in Russia - the number is 6,8 humans. Thus, driving motorcycle vehicles in Russia is 5,6 times more dangerous than in European Union.

The situation in Russia is even worse if we compare the number motorcyclists died during road accidents with the number of automobile drivers died in the same conditions.

The specific number of deaths per one registered motorcycle is twice more than the specific number of automobile drivers died during road accidents (3,2 per 10 thousand cars of the M1 vehicle's category).

If we compare death quantity of motorcyclists per one kilometer with the quantity of deaths of automobiles' drivers and passengers we'll find out that motorcyclists die 10 times more often!!!

The "STV" is the most dangerous type of vehicles in the world and especially in Russia!

Design features of single-track vehicles.

Advanced driver assistance systems (ADAS): adaptive cruise control (ACC), autonomous emergency brake systems (AEBS) and others, that were primarily designed for automobiles, cannot be installed on a motorcycle without necessary additional adaptation actions to its design features. Intelligent driver assistance systems require special methods and specific technical solutions to optimize their capacity to operate on the "STV" to improve road safety [1,2].

It is also very important to point out that these systems will require the development of appropriate human-machine interfaces (HMI). The "HMI" should minimize driver's distraction and should be specifically designed for the "STV". For example, messages should be prioritized to make general notices be replaced by security warning notifications.

The main design features of the "STV":

- insufficient stability during driving mode with low speed and unstable equilibrium while standing still; (Figure 1)
- due to the driver's and passenger's open sitting position on the "STV" they are directly exposed to negative external influences: snow, rain, wind, dust, etc.
- "STV" open construction requires the mandatory use of protective devices according to the regulations of all countries: a helmet, at least; "shells"; overalls; crags, etc.;
- motorcycle fit: driver's offset and inclination affect the vehicle's steerability, stability and fatigability of the driver during moving mode; (Figure 2)
- "STV" motion feature during its turn actions - with a large inclination, with the displacement position of the contact point; (Figure 3) [3].
- "STV" specific control units and control systems;
- "STV" are vehicles without bodies, therefore they have the worst passive safety during an accident.

For further consideration of perspectives and problems of the "IDHS" application for the "STV" we'll describe their simple classification.

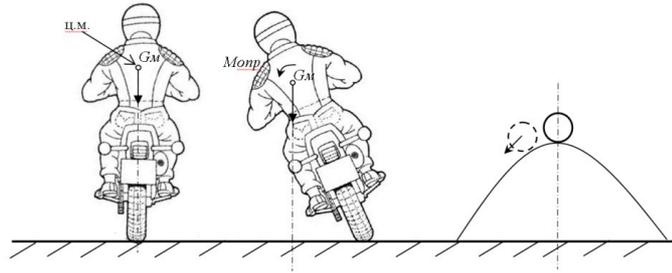


Figure 1. Unstable equilibrium position of the "STV" while standing still and driving with low speed.

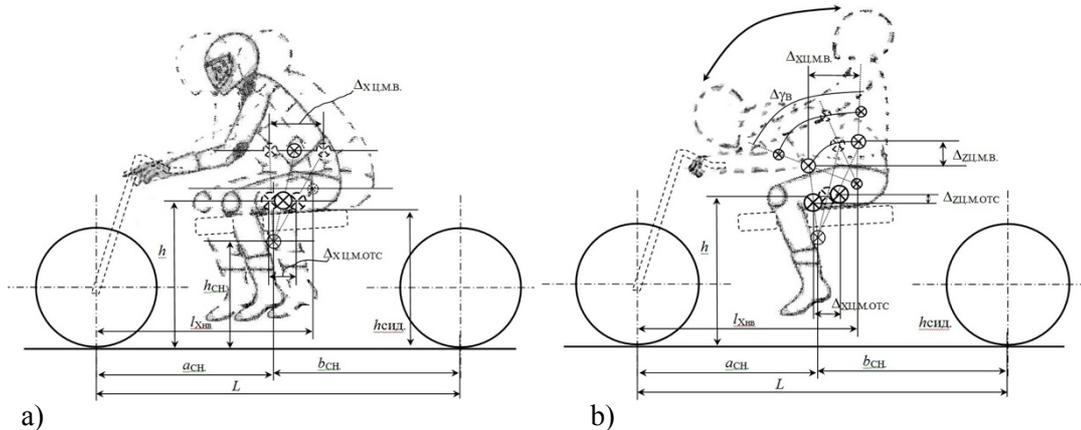


Figure 2. Types of driver's movements on the "STV" and displacement of general gravity center at the same time. a-longitudinal; b - inclination.

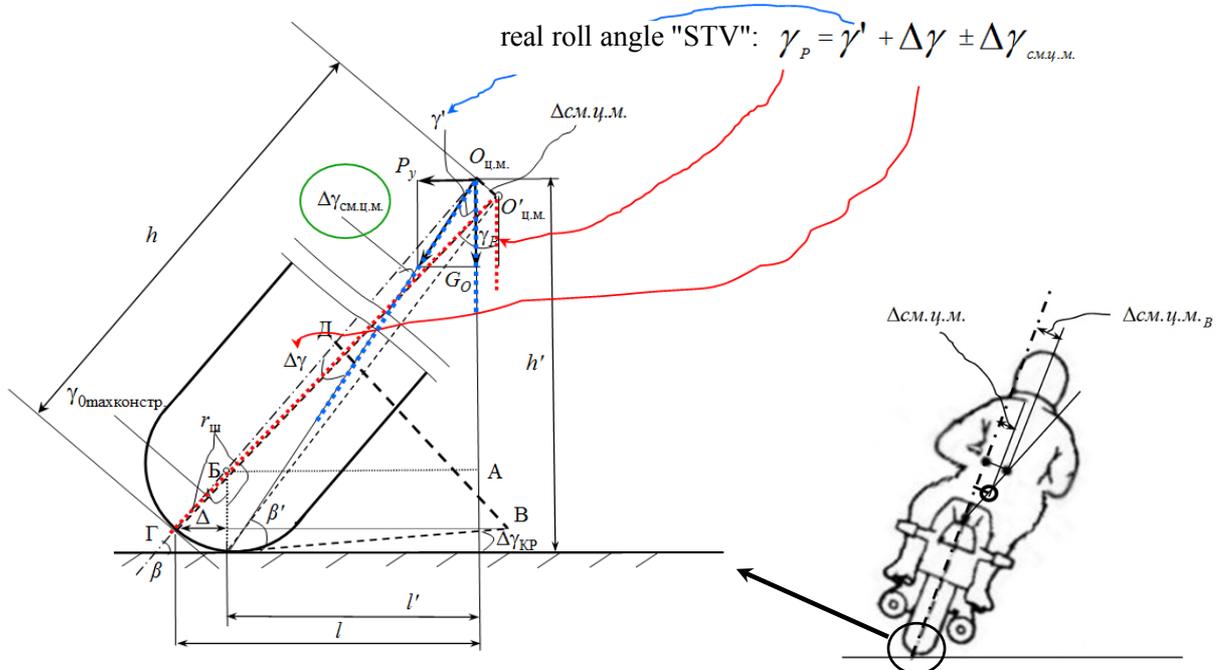


Figure 3. Motion during a turn mode using wide tires (taking into the consideration driver's displaced position).

Influence rate that affects the motion process of the vehicle:

- information, for example: marking recognition, navigator, information about "dead zones", adaptive lighting systems, etc. [4,5,6]

These systems only inform the driver without interfering in the motion process of the vehicle.

- executive and information, for example: AEBS;

At first, such systems warn the driver about the occurrence of a dangerous situation and necessity to take all important measures. If the driver (for any reason) does not react to warning signals, the system itself interferes into the moving process of the vehicle (in this case it slows down).

- automatically actuated, such as: ABS, ESP, rain sensor, etc.

These systems always work in automatic mode without the driver's participation. But they begin to influence actively vehicle's driving mode only after the occurrence of a dangerous ("ABS") or complicated (rain sensor) road situation.

- Autonomous and robotic, switched on by the driver itself (partial or complete replacement of the driver), for example: adaptive cruise control, lane keeping system, robot.

The purpose of these systems is partly (adaptive cruise control) or fully (robot driver) operation of driver's functions during vehicle's driving mode.

By purpose (scope):

- during braking mode: ABS, DSC, ASC, HDC, EBD, CBC, EBA, BAS, PBA, EPB, AEBS;

Systems of this group help the vehicle to brake safely during different road situations.

- during turn mode: ESP, DAS, AFS;

This "IDHS" group affects the vehicle's steering system to keep safe driving direction.

- during acceleration mode: ETS, ASR, EDS;

They provide a reliable and safe acceleration of the vehicle.

- universal: LKSS, SA, ACC, PDS, IPAS, etc.;

These "IDHS" affect several control units and can influence all vehicle's driving modes: acceleration, braking, changes of direction etc.

- during parking mode: PTS, AVM, TPMS;

Specialized systems that assist the driver during vehicle's parking mode in narrow space, completely or partially replace the driver's functions.

- comfort improvement: rain sensor, climate control, etc.;

These systems improve the comfort of vehicle control. They also improve traffic safety. As research studies have shown that the accumulation of driver's fatigue increases the probability of getting into an accident.

- after an accident: eCall (emergency warning system), seat belts, active head restraints, airbags.

Very important helping systems. These systems help to increase chances of human survival after an accident.

Due to the design features of the "STV" practically none of the above mentioned systems may be applied without its prior adaptation, and some systems can't still be used for the "STV" at all.

Intelligent driver assistance systems for automobiles that are not used on the "STV".

Some systems can't be applied for the "STV" and the reason is that there is simply no place for the installation. Some systems are not used because there is no need. And some systems can't yet be used on the "STV" due to control units action problems. For example: what happens to a motorcycle if the system that prevents the hitting a pedestrian suddenly jerks the steering wheel to avoid a crash in case of stop failure? Possibly the vehicle will fall on the side and during the sudden braking it will simply overturn.

The list of systems that are not still used during serial production of the "STV":

- alert system "dead zones";
- parking assistance systems (PTS, AVM, TPMS);
- Autonomous and robotic (partial or complete driver replacement system) - adaptive cruise control (ACC), lane keeping system (LCSS), robotic driver, etc.;
- help system after road accident: eCall (emergency alert system), safety belts, active head restraints, airbag;
- active steering systems: (DAS, AFS);
- body internal comfort systems (rain sensor, climate control, etc.).

Intelligent driver assistance systems installed during serial production of the "STV".

In present time the most popular "IDHS" that is applied for the "STV" is the "ABS" (Anti-lock braking system). The matter is that blocking of wheels during brake mode is the most dangerous action for single-track vehicle. The stable condition of the "STV" during high speed moving mode is provided by gyroscopic stabilizing moments of its wheels. If they are blocked (upon instant termination of the stabilizing moments) the stability of the "STV" becomes similar to its static mode (see Figure 1). As a consequence the "STV" instantly falls down. However, due to the "STV" design features it was not possible to apply the "ABS" from the automobile. It had to be improved significantly (Figure 4). The motorcycle has a separate brake drive on the front and rear wheels and two brake control units. Therefore, it has not one master brake cylinder, but two.

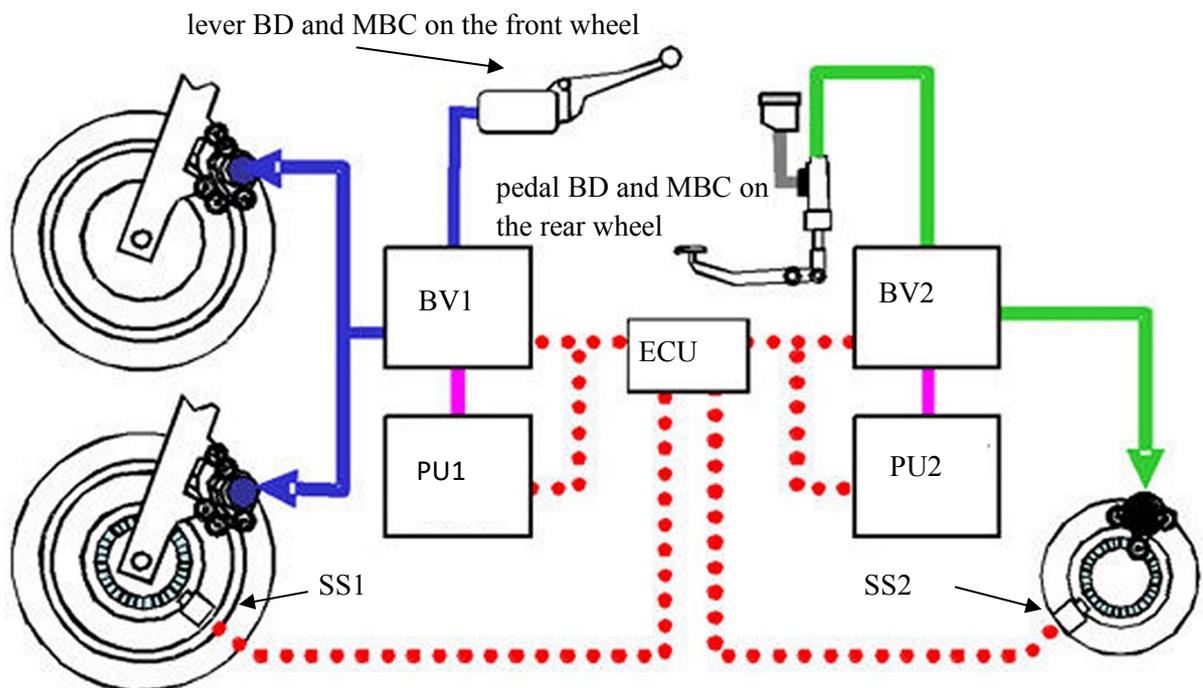


Figure 4. ABS schematic drawing for "STV".

BD - brake drive, MBC-the master brake cylinder, ECU- ABS electronic control unit, BV- block of valve, PU-power unit, SS-speed sensor, 1 - front wheel operating scheme, 2 - rear wheel operating scheme.

Separate brake drive on the front and rear wheels and two control units reduce efficiency of braking process of the "STV". Research works have shown that using a single brake control unit

improves accuracy and efficiency of the braking system. At present time many manufacturers began to install special systems on motorcycles that help the driver during braking mode. These systems include: CBS (Combined Brake Systems) a combined brake system and UBS (Unified Brake System) unified brake system. The feature of these systems is partial (CBS) or complete (UBS) substitution function of second brake control unit. When the driver operates only one brake control unit (e.g. a lever), the system starts to brake the second wheel itself. The main problem of such systems is that during the "STV" braking mode weight per front and rear wheels is redistributed in a complicated way (Figure 5).

Additional feature of the "STV" braking system is high probability of a complete distribution of weight per front wheel (possibility of rolling forward during braking mode). If the "STV" has lighter weight than the possibility of such braking process is much more probable to happen.

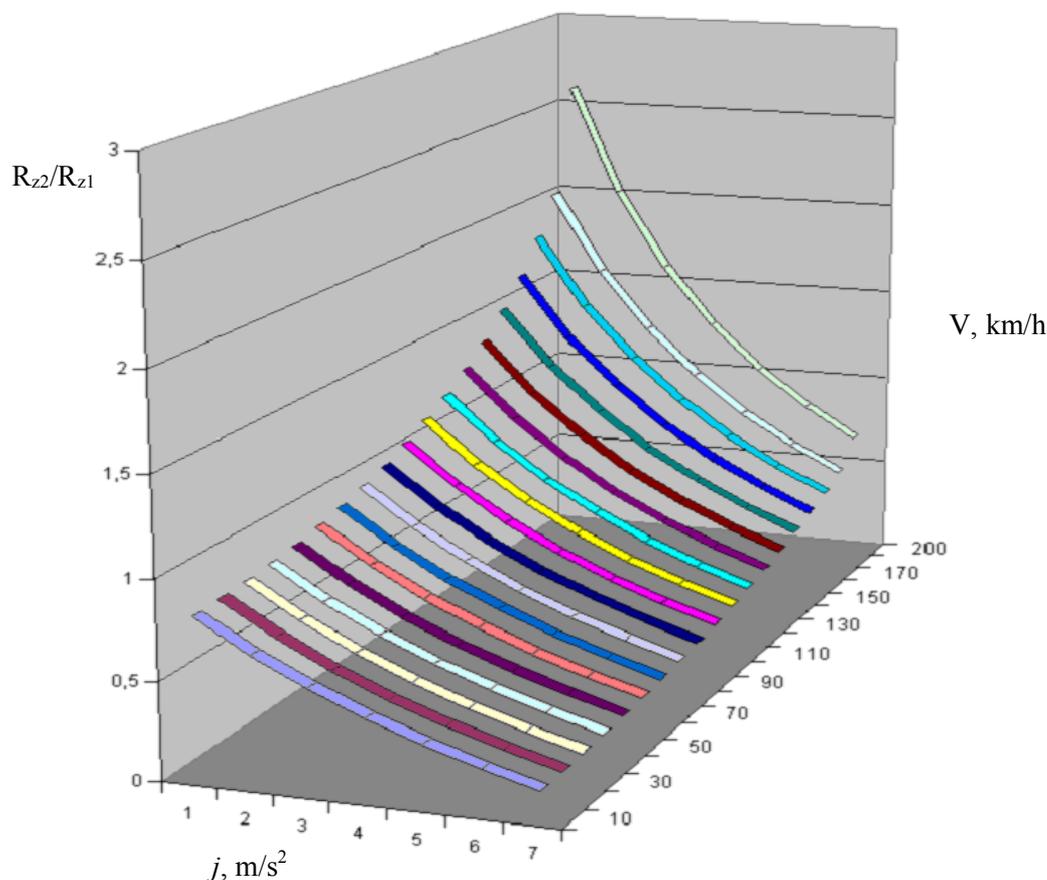


Figure 5. General diagram depicting vertical reactions on "STV" wheels depending on speed and deceleration.

While driving a motorcycle to shift gears, unlike the car, the driver has to use his feet. As in most cases due to the design features of the "STV" it is used a gear shift controlled by foot with a manual transmission. Some of motorcycle manufacturers began to install the QSS system (Quick shift system) - quick gear system to improve the driver's comfort. This is an analogue of robotic gearshift on automobile. The driver controls only the shift pedal, and the system itself determines the switching moment, squeezes the clutch and changes the fuel supply for smooth switching during reduced or increased transmission mode.

Another critical and very dangerous "STV" driving mode is sliding during the turn mode. Unlike the automobile for which the beginning of turnover during a turn mode is more dangerous, for the "STV" the most dangerous is the beginning of a sliding moment. The matter is that during a turn

mode the "STV" moves steadily only when the projection of the resulting gravity and centrifugal forces passes through the contact point of the wheel with the road (see Figure 3). If the lateral slip situation begins during the "STV" turn mode real turning radius increases suddenly, as a result centrifugal force reduces and the "STV" falls down. To prevent this situation, SCS (Slide control system) is used a sliding control system during the turn mode. It fixes the beginning of the slip and partially perform braking with the help of sensors, besides it reduces the fuel supply to engine cylinders [7].

Increasingly, the "IDHS" systems are used for modern motorcycles. They control the acceleration process and particularly prevent the occurrence of the rollover situation - front wheel shifting during acceleration. Unlike an ordinary automobile, the "STV" may easily roll over back with a shift acceleration, which is very dangerous. The feature of such systems (LIF (Lift control system) - front wheel lift control system; LCS (Launch control system) - start control system; TCS (Traction control systems) - traction control system) includes the determination of the beginning of the rollover and torque reduction on the drive wheel, to prevent this process. In addition, the TCS system determines the start of the motorcycle's driving wheel slip, reduces torque and ensures its acceleration with maximum efficiency and safety.

Another problem that may happen during driving a motorcycle at speeds from 40 to 80 km/h is the self-oscillation of the front controlled fork, so-called "wobbling" of the front part of a motorcycle. The EVD (Electronic vibration damper) system - electronic vibration damper handlebar is designed to eliminate such oscillation. Many of the motorcycles have much more simple system as a common damping (transverse damper) on the steering fork.

Recently BMW Company has announced the readiness to install the eCall system as an additional option on their motorcycles.

Perspective types of the "STV" and the intelligent driver assistance systems that are used for them.

Currently electric bicycles and small electric scooters are very popular among the customers as they are environmentally friendly transport. The advent of electrically driven "STV" gave a possibility to apply the "IDHS" to compact and light vehicles that previously could not be fitted: such as the ABS and the CBS.

In Europe the quantity of stable three wheeled "STV" increases. They are safer and more comfortable during the operation, but at the same time they have the advantages of a single-track transport: compact dimensions and good steering parameters (Figure 6). It is also possible to increase the stability of the "STV" at low speeds and during a stable mode, using retractable landing gear [8].



Figure 6. Example of sustainable and compact three-wheeled scooter.

However, we believe that the most promising and safe "STV" should be a new type of compact vehicle - Body single-track vehicle ("BSTV") (Figure 7). The presence of the body relates it into a class of safer vehicle, comparable to the automobile [9, 10]. Passive safety of the "BSTV"

becomes similar to the automobile. Besides it is possible to install the internal systems of driver assistance, such as seat belts, airbags, navigation systems, etc. Protection from the external negative factors increases the comfort and safety of operation and makes it possible to operate the "BSTV" all year, regardless of weather conditions.

On the "BSTV" it may be installed absolutely all the same "IDHS" systems, as on a conventional automobile. Besides the "BSTV" is more compact, economical and environmentally friendly compared to a conventional automobile, and therefore more perspective as a city vehicle.



Figure 7. Examples of "BSTV".

Summary.

Single-track vehicles, being the most dangerous in the world are least equipped with intelligent driver assistance systems. Due to the design features and traffic peculiarities, in order to install the "IDHS" systems on the "STV", the substantial adaptation actions of each system are required. Besides, some systems cannot be installed on single-track transport at all. On compact types of the "STV", such as bicycle and scooter, no driver assistance systems are installed at all.

Further improvement of the "STV" traffic safety is possible only with the introduction of the new types of the safe "STV" and new driver assistance systems, as well as the expansion of the application of existing "IDHS" on a larger number of the "STV".

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