

# CONCEPT OF PREVENTIVE MOTION CONTROL APPLIED TO BUSES AND COMMERCIAL VEHICLES

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**Abstract:** *Despite numerous inventions have been introduced in the field of active safety during past two decades, insufficient safety of buses and commercial vehicles still remains an actual problem. Accidents involving urban and interurban buses, as well as heavy articulated trucks cause many more victims than those involving passenger vehicles. The aim of work has been to define functional compound of innovative complex active safety system based on method of preventive motion control in order to improve the road traffic safety level by avoiding accidents. The author has summarized new links in the driver - automobile - road - environment system conditioned by human factor influence, and fulfilled evolutionary analyze of active safety systems development, having applied method of scientific deduction. Principles of the human factor problem solution in the field of road traffic safety have been designated, a new classification of active safety systems has been charted, and functions of preventive motion control system have been enumerated.*

**Keywords:** *Road traffic safety, active safety systems, constructive safety, driver - automobile - road - environment system, method of preventive motion control, driver attention monitoring.*

## I. INTRODUCTION

The automobile construction has changed significantly in the past 50 years. It is hard to overestimate positive influence of different solutions in the active safety field on decrease of number of accidents and deaths on roads of the world, such as, for example, compulsory application of anti-lock braking system and electronic stability control in light passenger vehicles. Unfortunately, one has to face the facts that active safety systems, more and more widespread in passenger vehicles, are introduced in buses and cargo vehicles with considerable retardation. Meanwhile accidents involving those, as a rule, have more severe consequences, and drivers of those work in harder conditions. Amount of victims in an accident involving two light passenger vehicles can reach 8 or 10, whereas up to 80 persons risk their lives in a collision of two buses! While a commercial articulated vehicle driver loses control, chances of persons standing in his way vanish. Besides, in practice, modern road barriers that retain light vehicle successfully fail to resist impact of a heavy articulated vehicle. Therefore obligatory application of such systems should be legislated, first of all, in buses and commercial cargo vehicles (as it happened in Russia, for example, to ABS that was prescribed obligatory since 15.08.2004 exactly in buses).

Fixed - route buses and commercial articulated vehicles have their own specificity [1]. As a rule, drivers of those perform long rides of several hours with rigid timetable in hard conditions [2]. Work in such conditions, despite modern, partially automated control systems and high

usability of driver's workbench, leads to high rate of driver fatigue causing driver reaction time increase and high probability of distraction from road situation. Numerous cases of heart attacks, losses of consciousness, falling asleep that led to accidents have been fixed.

Besides, the global statistics of accidents show an interesting phenomena: in a few years after introducing of any active safety system happens an increase of accidents number. The thing is that every invention, after initial positive effect, over a period of time forces a **negative inverse effect**. Inverse effect from introduction of any active safety system has four directions:

1. Uncoordinated and restricted trend of inventions in the field of active safety.
2. Correcting character of active safety systems' action leads to drivers' intentions to find and exceed stability limit that is provided by the given system.
3. Effect from action of a corrective system is annihilated by drivers' intentions to exceed other stability limits of vehicle.
4. Application of active safety systems leads to decrease of drivers' attention concentration on the road and common level of drivers' abilities.

The task of the author's research is to find solutions for the problems mentioned above.

## II. FACTORS INFLUENCING ON ROAD TRAFFIC SAFETY

Consideration of the driver – automobile – road – environment system (DARES) in the last several decades has reached a new level in comparison to 1970's when Robert Rotenberg explored this question [3]. In order to improve road traffic safety the author offers to take new links into consideration, especially those involving influence of the human factor.

1. Factors influencing on the driver subsystem:
  - Law sphere, such as conflict situations in the traffic rules [4], responsibility for violation of the traffic rules, introduction of motor third-party liability (MTPL) insurance;
  - Quality of education in driving schools;
  - General level of individual behavior culture in the society.
2. Factors influencing on the automobile subsystem:
  - Quality of production and assemblage of vehicles;
  - Timeliness and quality of technical service and repair of vehicles;
  - Organization of technical revision of vehicles;
  - Active and passive safety level.
3. Factors influencing on the road subsystem:
  - Quality of road traffic organization, including lights regulation, drawing of road marking, road works designation;
  - Quality of roads building and repair;
  - Road infrastructure development level;
  - Introduction of intellectual transport systems (ITS);
  - Road cleaning and anti-icing meanings.

All the foresaid problems are hard-to-solve. Exist organizational and technical ways to solve those. Once the potentialities of the former ways are exhausted, the government swaps to the latter ones, and there are two principles of solving the DARES problems:

1) To help a driver to violate the traffic rules and speed limits safely if it is impossible to make him follow those;

2) To restrict engines' power (as it is done, for example, in Japan) and introduce different intellectual systems limiting vehicles' velocity.

There are not many countries ready to follow the second principle, and Russians with their mentality would be last in the list. Therefore most countries follow the first principle, inventing active safety systems that are designed to minimize the human factor influence on vehicle control process. However, anti-lock braking system, anti-spin regulation, electronic stability control, etc., all these systems increase maximal safe speed of vehicle, but not the safety itself [5]. On the contrary, introduction of those rather promotes obtusion of danger sense and decreases concentration of attention behind the wheel to most of the drivers. In this situation it is necessary to find a reasonable balance between restrictions and permits, or to introduce rigid limits without any possibility to switch those systems off. And if some "popular skilled craftsmen" unplug safety fuses, the engine simply should not start. The only hidden problem is in certification testing, but it can be easily solved by application of special set-ups for electronic control units that are known to nobody but manufacturer or automatic switching on after a certain period of time.

Also, drivers' attention is significantly distracted by mobile phones, multimedia devices in modern vehicles, application of navigators during motion (the route should be explored before a ride), and so on.

Automated vehicle control, nowadays already possible from the technical point of view, is considered a heal of any disease on the road, but it cannot become such a heal unless all the vehicles at once become automated. However, at first such technologies should get no more expensive than mobile phones, so that those could be introduced on all the vehicles without exception. Otherwise application of fully automated systems is unacceptable.

### **III. PREVENTIVE MOTION CONTROL METHOD**

In order to solve the problems formulated above, a modern active safety system should be based on the method of preventive motion control suggested by the author in 2009 [6], that is to imply:

- 1) Preventive character of action;
- 2) Unlimited adaptability to driver's actions;
- 3) Complex functional compound.

Basing on evolutionary analyze of vehicle control systems development, the author has derived four directions of active safety systems development that are conditioned by links in the DARES:

1. Behavioral micro level (wheel behavior). Includes anti-lock braking system, brake assist, electronic brake distribution, anti-spin regulation, hill assist, active front steering, active geometry control suspension.

2. Behavioral macro level (vehicle body behavior). Includes electronic control system, dynamic stability control, trailer assist, active suspension.

3. Internal level (driver and technical state of vehicle). Includes tire pressure regulation system, tire pressure monitoring system, onboard diagnostics, driver monitoring system.

4. External level (distance and side gap). Includes active cruise control, collision mitigation

system, engine start-stop system, blind spot assist, lane-keeping assist, cross-traffic assist, intellectual transport systems, traffic sign recognition.

Modern preventive motion control system (PMCS) should synthesize all those four levels, implying a complex of functions, presented on fig 1. Sensors and actuators can be divided into PMCS functions (fig 2). Functions interfere each with other, receive signals from needed sensors, and send control signals to needed actuators.

Functions linked directly to actuators are considered primary. Secondary functions connect actuators via other functions. For example, course stabilization function realizes control signal to brake mechanisms via adaptive braking function, to engine revolutions and active differentials via acceleration regulation function, and to steering gear via active steering function.

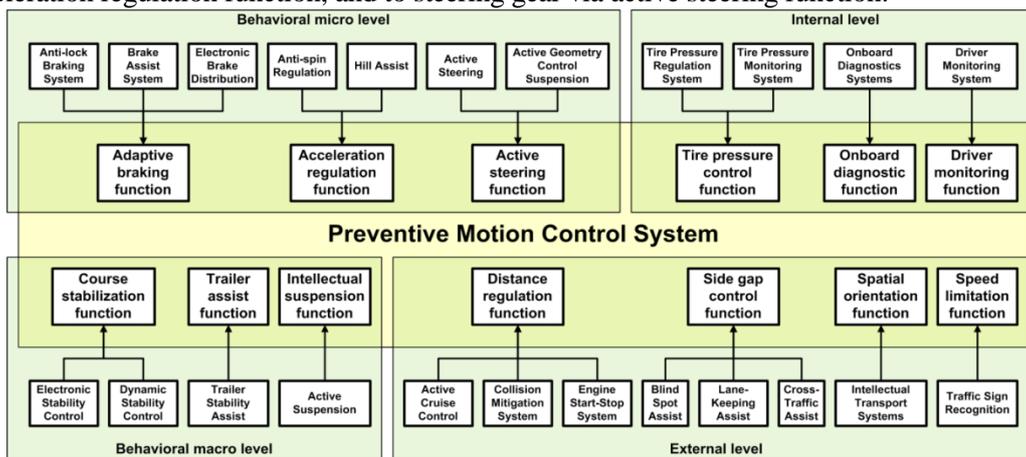


Fig 1. Classification of active safety systems by PMCS functions

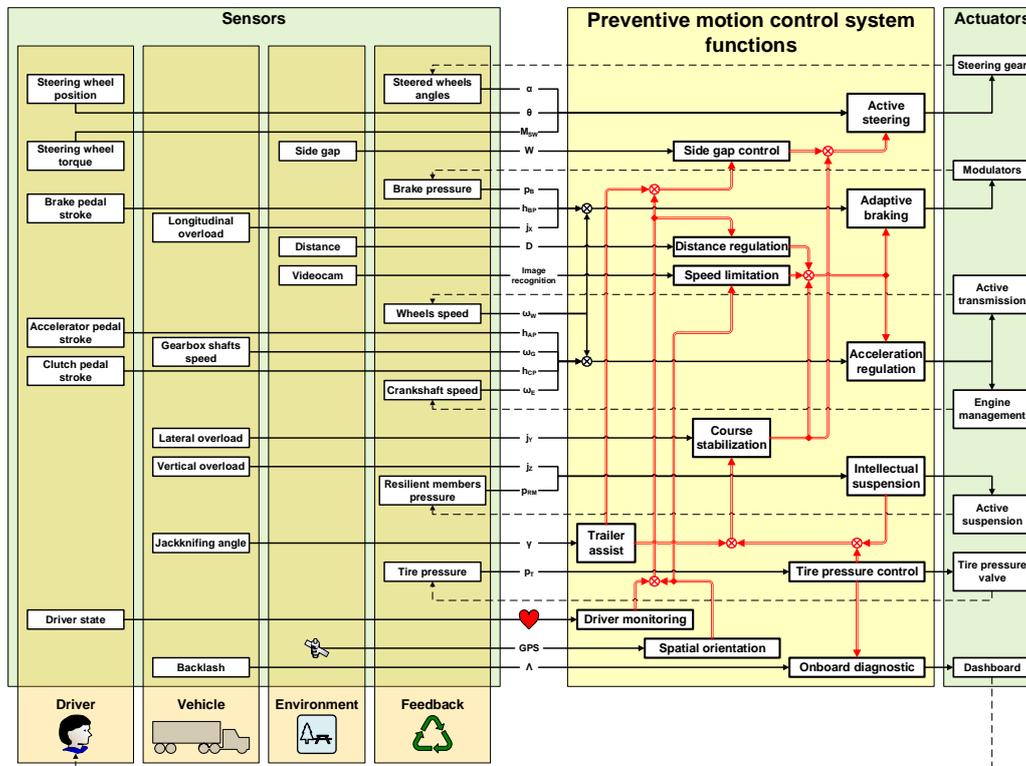


Fig 2. Interaction of PMCS functions with sensors and actuators

Sergei Buznikov mentions such destabilizing factors as loose wheel and suspension or steering destruction, and offers to use backlash sensors in order to prevent accidents forced by those reasons [7]. Backlash sensors relate to onboard diagnostic function.

Speed limitation and spatial orientation functions interfere closely. The former is capable to distinguish road signs by means of video camera or receive signals from external transponders. The latter is meant to define vehicle's location on map correcting basing on result of visual recognition of environment. Thus, the functions mentioned above interfere actively with different intellectual transport systems, related to transport telematics [8].

#### **IV. DRIVER STATE MONITORING**

Researches show that 20% of accidents, especially during the night and the morning hours, happen due to fatigue and drowse of drivers [9]. In 1977 an engineer of "Nissan" received patent for a vehicle drive alertness apparatus monitoring steering wheel oscillations [10]. However works were postponed and restored almost 30 years later.

Engineers and scientists switched their efforts towards systems that register and correct vehicle behavior directly. In 1978 anti-lock braking system appeared the first ever active safety system. Basing on anti-lock braking system, anti-spin regulation (in 1986), electronic stability control (in 1995) and active cruise control (in 1998) were invented. Such innovative systems as blind spot assist (in 2000) and lane-keeping assist (in 2001) were applied in series production. Popularization of those became an important step towards accident rate reduction.

In the middle of 2000's driver attention monitoring systems (DAMS) of two types appeared, direct and indirect. Direct DAMS control driver's pulse, behavior of eyes and eyes-lids, head position, mimicry. Indirect DAMS estimate adequacy of driver's action by indirect signs such as vehicle behavior or effect on controls (for example, a long-time constant pedal position). Also remote DAMS are being invented [12].

Initially, blind spot assist, lane-keeping assist, and DAMS were strictly informational. In this case those only warn the driver and do not interfere in work of other control systems. But modern tendency is introduction of preventive systems capable to correct vehicle's trajectory by influencing on anti-lock braking system modulators or active steering system.

Vigilance systems widely used in the railway transport have two features in comparison to DAMS:

- 1) Interval between trains is calculated subject to the float for driver's vigilance check. On the road distance changes unpredictably and at any moment is able to shorten down to the critical one;
- 2) A train follows the rails while stops automatically without driver's action. For a vehicle it is not always right decision to keep going straight as the road can become bent or some obstacle can arise.

Driver vigilance system can also be applied in motor transport. But its pushbutton must be situated under driver's hand, not under foot. It is advisable to have two pushbuttons under each hand that are activated by turns in random order. The system should warn after several minutes of driver's inactivity. Reaction of the system should be vibration of driver's seat and acoustic signal. Vigilance system is effective on falling asleep prevention, but useless against loss of

consciousness, because the road situation changes abruptly and unpredictably, as opposed to the railroad where no other train is expected on the distance of two light signals.

Installation of tachograph is considered one of important measures on decreasing rate of accident by controlling driver's actions. However, in general, any controlling measures are always less effective than preventive ones and not able to solve the problem. Accidents should be prevented.

Analysis of accidents involving fixed-route buses happened in Russia during last several years shows that introduction of any named active safety system separately is only a partial measure and will not allow to reach desirable effect on rate of accident decrease. For example, switching turning signals on deactivates lane-keeping assist system, and if driver feels bad right after that (as it happened in Saint-Petersburg in June of 2014) it would not help. Besides, those systems are not designed to stop the vehicle.

Late accidents involving buses show high importance of driver monitoring function that should fulfill all the tasks of direct, indirect, and remote DMS, as well as driver vigilance system. Driver monitoring function controls the vehicle via side gap function that overlaps tasks of blind spot assist, lane-keeping assist and cross-traffic assist. The mission of driver monitoring function is to determine driver's disability, send signals to distance regulation function that should stop the vehicle smoothly, while course stabilization and side gap control functions help to keep it in the chosen lane (fig 3). Thus, driving monitoring is the key function of preventive motion control system.

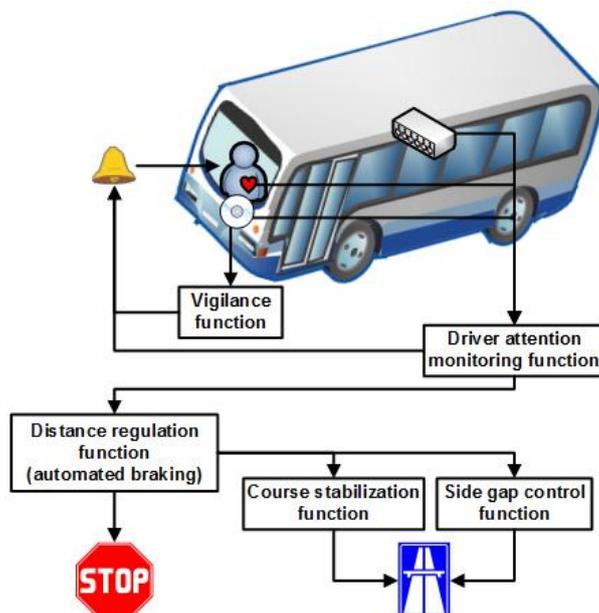


Fig 3. Functional diagram of driver monitoring

## V. CONCLUSION

During the research executed the author has formulated:

- 1) Problems of inverse effect from active safety systems introduction;

- 2) New links in the DARES, conditioned by the human factor;
- 3) New classification of active safety systems by development directions;
- 4) Set of primary and secondary functions of preventive motion control system;
- 5) Connection of preventive motion control system functions with sensors and actuators of vehicle.

The aspects gained in the current research provide improvement of algorithms for the modern preventive motion control system.

The complex approach allows optimizing the ratio of efficiency of an active safety system to set of sensors and software taking links in DARES and directions of development of vehicle control systems into consideration.

Efficiency of an active safety system is calculated by the following formula:

$$\varepsilon = \frac{S}{C}$$

Where S – number of critical situations solvable by given system; C – total multiplicity of critical situations.

The author considers invention of a preventive motion control system and its introduction in buses and commercial vehicles one of the priority tasks in the field of road traffic safety improvement.

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