The employment of multi-criteria assessment methods in the study of road safety

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Abstract. Intelligent driver assistance systems and traffic assistants are becoming more technological and widespread. Due to the great diversity, there is a need to compare their effectiveness in different conditions and choose a set of systems that is the most efficient and inexpensive. The article considers possible comparison criteria. Some features that are worth considering when conducting a study are identified. The analysis of statistics on road traffic accidents.

The problem of evaluating the feasibility of installing a particular set of active safety systems requires an integrated approach. When considering a set of active safety systems for a car, it is necessary to take into account the fact that most of the systems are software extensions or additions to those already installed on the car.

Antilock Brake System ABS acts as the basis for most other systems, such as ASR Automatic Slip Regulation and BAS Brake Assist System [1]. Electronic Stability Program ESP is a complex that includes ABS, BAS, ASR, EDB (Electronic Brake Distribution), EDS (Elektronische Differenzialsperre, or Electronic differential lock) and is the basis for the Emergency Steer Assist, Drive-Steering Recommandation DSR, Downhill Assist Control and Hill-Start Assist Control. Since ASR is developed on the basis of ABS, it also acts on the brake system, but in addition it also controls the electronic differential lock and some parameters of the power plant. The Electronic Stability Program (ESP) combines the functionality of several systems, and together with the Antilock Brake System, it is the basis for the Emergency Steer Assist, Drive-Steering Recommandation, and Downhill and Hill-Start Assist Control. In its work, the ESP control unit interacts with the engine control system and the automatic transmission (through the corresponding units). Tipping over is achieved by reducing lateral acceleration by braking the front wheels and reducing engine torque. Additional pressure in the brake system is created using an active brake booster. The road train stabilization system prevents the yaw of the trailer when the car is moving, which is achieved by braking the wheels or reducing torque.

The most famous and popular active safety systems are:

- Antilock Brake System;
- Automatic Slip Regulation;
- Electronic Stability Programme;
- Electronic Brake Force Distribution;
- Brake Assist System;
- Pedestrian Detection System;
Electronic differential lock.

For clarity, a diagram showing the software extensions and systems of active safety systems of the car is shown (figure 1).

**Figure 1.** Scheme of active safety systems of the car.

Auxiliary active safety systems (assistants) have also been developed to help the driver in difficult driving situations. In addition to timely warning the driver of a possible danger, the systems also actively intervene in driving, using the brake system and steering system. Assistance systems are especially useful for novice drivers and older drivers.
Each assistant performs its highly specialized functions. Some systems are aimed at a smooth start to movement, others help with movement, others provide safe parking. At the same time, they are also subdivided into information systems, systems with partial intervention in driving and automatic systems that independently drive a car. Several systems perform several functions or participate in different driving modes. The Night View Assist and the Drive-Steering Recommendation perform an informative function and help with driving and parking. Stop-and-Go traffic assistant, or traffic jam assistant, being an extension of adaptive cruise control, when turned on, it automatically starts moving, moves, brakes and stops the vehicle based on environmental data received from sensors, video cameras or radars. Adaptive cruise control performs the following tasks:

- accelerates the car to a predetermined value;
- slows it down to a complete stop;
- holds the set speed, providing not only comfort, but also by 10% or more reducing fuel consumption.

The Lane Assist, or Lane Departure Warning System, has two functions within the driving process - it informs the driver and partially affects the steering. The executive devices of the lane departure assistance system are a control lamp, a sound signal, a vibration motor on the steering wheel, a windshield heating element, an electric motor of an electromechanical power steering. The driver is warned by vibration of the steering wheel, as well as the supply of visual sound and light signals. Vibration is generated by a vibration motor integrated in the steering wheel. The heating element is located on the windshield, if necessary, automatically turns on, eliminates fogging and icing of the camera window. Correction of the trajectory is carried out by forced steering of the steering system using an electromechanical power steering or braking the wheels on one side of the car. The functional distribution of systems and assistants is shown in figure 2.
The question has been asked which set of systems to install on a car so that it is not expensive and most effective in the field of security. When choosing systems, it is necessary to consider that some of them are improved previous versions, so their joint installation is impossible. The optimal solution is sought by calculating the utility function. To solve the problem, comparison criteria, their values, the weight of each criterion are needed. Since the criteria will be considered as qualitative parameters, they must be expressed in points on a 5-point, 10-point or other scale [2].

Comparison criteria may be as follows:
- the likelihood of accident prevention in general;
- degree of mortality reduction in road accidents;
- the degree of reduction in injuries in road accidents;
- the life of the systems and / or their components;
- coverage of road conditions preceding or leading to accidents;
- the cost of installing systems or packages;
- the cost of maintaining and repairing systems.

It must be taken into account that at different speeds the systems react and act differently. For example, how well the emergency braking system operates at speeds of 20, 40 and 60 km / h in the city and at 80 and 100 km / h in the country. The division into urban and suburban driving can also be due
to the nature of the work or lifestyle of the driver. Intelligent systems from different manufacturers can be installed on cars of different brands, so you need to take into account some technical features. For example, the range of radars, the quality of the video cameras in conditions of pollution or lack of visibility (fog or dark).

The service life of the system as a whole can be longer than the service life of individual components, so you should consider how many times during the entire service life which spare parts will require, how much the spare part will cost and how much the replacement will cost when it is serviced. In this criterion, it is worth considering different manufacturers and different price categories.

Intelligent systems and assistants can be installed on a new car during the assembly process, but there may be a situation when it is necessary to equip a car whose design initially did not require additional devices. Accordingly, in this case, the installation cost will be different.

The degree of coverage of traffic situations can be assumed from the analysis of accident statistics from the website of the State Traffic Safety Inspectorate. Based on the number of accidents and their separation by type, as well as the conditions preceding or leading to accidents, we can assume a list of systems whose action would probably help to avoid an emergency or at least reduce the speed before an accident [3].

Example. When analyzing accident statistics for the Nizhny Novgorod region, accident with passenger cars was revealed by type: 138 collisions, 103 collisions (including collisions with pedestrians, cyclists, obstacles and standing vehicles), 13 rollovers and 3 others (such as a cargo fall). The diagram is shown in figure 3.

![Types of accident with light auto](image)

Figure 3. Types of road accident.

According to statistics, an analysis is made of the road conditions that preceded the collisions. The most common causes or previous events for the study period were: lost control, went into the oncoming lane; did not choose a safe distance; when turning left, did not provide an advantage in movement; when leaving the secondary road, did not provide an advantage in traffic (figure 4).
Figure 4. Causes of road accident (collisions).

Proceeding from the reasons, systems are proposed whose action could prevent them. Next, it is analyzed what percentage of all events this or that system could prevent. For example, did not choose a safe distance:

- Adaptive Cruise Control;
- Traffic jam assistant;
- Downhill Assist Control and Hill-Start Assist Control;
- Area View;
- Pedestrian Detection System, Obstacle Detection System.

Re-collision:
- Emergency Steer Assist
- Post Crash Braking.

Further elements of a multicriteria assessment are applied. Edgeworth-Pareto method and the construction of scales of criteria are applicable for graphic representation of alternatives. The Pareto method is usually considered as preliminary, and if it is possible to evaluate alternatives only by 2 criteria, then the number of scales is not limited, although it will be overloaded with a large amount of data.

In decision making, it is customary to distinguish between continuous and discrete ratings scales, quantitative and qualitative rating scales. So, for the criterion of "cost" can be used a continuous quantitative scale of assessments (in monetary units). For the criterion “system availability”, a qualitative binary scale can be used: whether or not.

The following types of scales can be used.

- Scale order — scores are ordered by increasing or decreasing expert preferences.
- The scale of equal intervals is the interval scale. For this scale there are equal distances in quality change between grades.
- The proportional scale is an ideal scale. An example is the scale of assessments according to the cost criterion, the countdown in which begins with a set value (for example, from zero cost).
Analytically, the choice of the best solution can be made by calculating the utility function. For this, the criteria were previously expressed in points, and by the method of expert evaluations, the criteria are assigned the weight and the utility function is calculated. An example of a formula that takes into account 2 criteria is given.

\[ F = S \cdot W_s + Y \cdot W_y, \]

where \( F \) is the utility function;
\( S \) - evaluation of the cost criterion;
\( Y \) - assessment of the criterion for improving security;
\( W_s \) is the weight of the cost criterion;
\( W_y \) is the weight of the safety improvement criterion.

From the calculations, the set of systems with the highest value of the utility function is revealed, we assign it the best option.

The selection of comparison criteria is a difficult task, on which the accuracy and objectivity of the solution can depend, therefore, in the process of research, it is possible to attract experts, as well as consider the intervals of values.

The multicriteria optimization method helps to choose one of the likely optimal solutions, but does not guarantee that this solution will be uniquely optimal for all criteria.

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