Study on the improvement of the vehicle deceleration signalling system

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Abstract. Our paper presents a study regarding the improvement of the vehicle deceleration light signalling system. Based on global statistics on the number of road accidents caused by non-compliance with the safety distance and a market research on the availability of purchasing an extra option to allow drivers to be informed about the speed reduction of the vehicle in front, we have applied the Product Life Cycle Management (PLM). For this purpose, we made two market researches. Based on the results of the primary market research and the technical solutions currently in place, a new market research was carried out through an opinion poll. All the results of the opinion polls were discussed in a brainstorming session, which was attended by representatives of automotive companies, representatives of academia and professional drivers. At the end, we have demonstrated the possibility of developing a new product that aims to reduce road accidents caused by rear-end collisions. The working method, proposed has led to the need to find new constructive solutions and ways to apply them.

1. Introduction

The driver of one vehicle driving behind another is obliged to keep a sufficient distance from it to avoid a collision, in the event that the one in front slows down or brakes suddenly. It goes without saying that drivers must always adapt their speed to road conditions so that they can perform any maneuver safely. Drivers' attention must be constantly focused on the road [1]. In most European countries, the general rule is that each driver should keep a sufficient distance between his vehicle and the front vehicle to avoid an accident in the event that the front vehicle suddenly stops or slows down. This rule is not always imposed by specific distances to be observed, such as the minimum distance or time required between vehicles. In cases where minimum distances or times are required, the figures vary, from country to country. The second rule or the half-distance rule can be applied. Different specific rules can be applied to heavy goods vehicles. The second rule is often used as a rule of thumb and taught in driving schools. Some devices, such as road markings, are used to help drivers follow this rule.

Acording to Asociation for Safe International Road Travel approximately 1.35 million people die in road crashes each year, on average 3,700 people lose their lives every day on the roads and an additional 20-50 million suffer non-fatal injuries, often resulting in long-term disabilities [2]. Unless action is taken, road traffic injuries are expected to become the fifth leading cause of death by 2030. One of the most common causes of road accidents is non-compliance with the safety distance.

2. Methodology and problem description

The proposed methodology is that of the product life cycle management (PLM). Thus, when analyzing the customer's need, a stage prior to conception, two phases of market research can appear: a first overall research, aiming at the opportunity to design a new product or improve an existing one, and another more detailed research, mostly qualitative, to determine in detail the needs and demands of consumers towards the product [3].

If a driver does not respect the safety distance, he cannot accurately estimate how aggressively he brakes the vehicle traveling in the same direction and thus road accidents occur.

The brake lamp lights come on several times in traffic. The cases in which they can ignite are the following:

- There is a need for braking to stop the vehicle or avoid obstacles;
- Press the brake pedal lightly (preventively);
- Voluntarily or involuntarily supports the foot on the brake pedal;
- There are technical problems with the drive system - the lights are on permanently or not at all.

It is often very difficult to estimate how aggressively the vehicle in front brakes. The question arises: How much will the vehicle in front do? Will it stop? Slow down? Or is the driver just resting his/her foot? Or maybe something else? In such circumstances, fuel consumption is also increased because the driving style is not very fluid.

2.1. Market research - the primary source

In order to discover the need for a product to help reduce road accidents caused by rear-end collisions, a market research was conducted using a questionnaire. The survey was conducted on a sample of 100 people from urban areas, 80 men and 20 women with a driver's license, aged between 21 and 60 years.

According to the answers in the questionnaire, 17% of respondents stated that they were involved in a traffic accident while driving, and 23% that they were involved in a traffic accident but not in the driver's position. Of those involved in traffic accidents, 20% said the accidents were caused by non-compliance with the safety distance.

Regarding the questions related to the automatic safety systems and the degree of confidence in the autonomous braking system, the majority of respondents (65%) answered that they trust the modern automatic safety systems and 45% that the degree of confidence in the autonomous braking system, is medium. Only 30% said there was a high degree of trust in these systems. According to 20% of respondents, the human role in traffic can be replaced by automated systems, with a majority of 70% stating that the human role in traffic can only be partially replaced by automated systems.

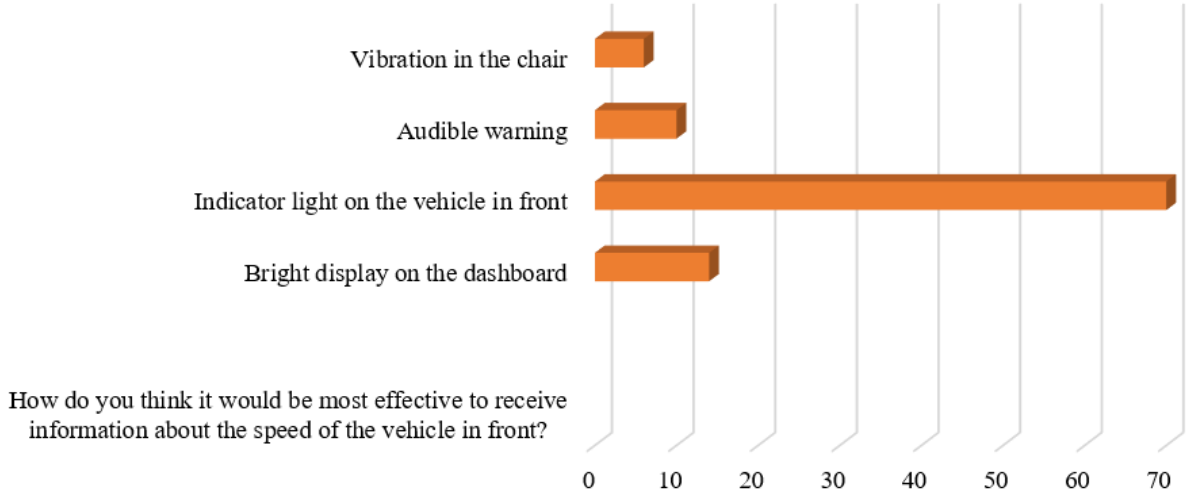

Figure 1. Results of the exploratory research

Given that 50% of respondents stated that in certain situations they would find useful in traffic information about the degree of speed reduction of the vehicle in front, and 55% would be available to purchase an extra option to inform drivers of rear vehicles about the degree of braking (regardless of price), there was the issue of how to receive information and the degree of reduction of the speed of the vehicle in front. The answers to this question are shown in figure 1.

Analyzing the results of the first questionnaire, it was concluded that it is appropriate to implement a light signaling system to warn the driver of the rear vehicle about the degree of deceleration, when the need for braking occurs. It will be referred to as the "Flash Deceleration System".

2.2. Market research - current market solutions

The regulations of the Convention on Road Traffic from Vienna suggested the activation of red lighting lamps with a higher light intensity than the rear position lamps, when the driver applies the brakes of the vehicle [4]. These are officially called stop lamps and are mounted in multiples of two, symmetrically at the left-right edge of the rear of each vehicle.

As regards the Center High Mount Stop Lamp (CHMSL), in Europe since 1998 United Nations Regulation No. 48 has been applied: a mounted central stop lamp (brake) is higher than the left-right lamps. CHMSL is sometimes informally called "central brake lamp", "third brake light", "eye level brake lamp" [5]. CHMSL can use one or more filament or led bulbs or a neon tube strip as a light source.

The CHMSL module is intended to provide a warning, but due to certain overlaps, left or right brake stops cannot always be observed. Also, in the event of a stop lamp failure, they provide a redundant stop light signal.

2.2.1. Autonomous Emergency Braking - AEB

From 2014, all car manufacturers are required to offer on newly launched cars an autonomous emergency braking system entitled AEB - Autonomous Emergency Braking [6]. All vehicles sold in the European Union must be equipped with autonomous automatic braking systems. These systems generally provide a warning for the driver before acting on the brakes.

As of mid 2022, all new cars put on the EU market will have to be equipped with advanced safety systems. Following an agreement with the European Parliament on lst of March 2019, the Council has adopted at the end of 2019 a regulation on the general safety of motor vehicles and the protection of vehicle occupants and vulnerable road users in a bid to significantly reduce the number of road casualties [7].

The European New Car Assessment Programme – Euro NCAP provides the consumer with information on the safety of new cars. The Safety Assist score is determined from tests to the most important driver assist technologies that support safe driving to avoid and mitigate accidents. In these tests, Euro NCAP tests system functionality and/or performance during normal driving and in typical accident scenarios [8].

The autonomous emergency braking system uses a radar, lasers or a video camera to detect an imminent danger, namely a collision with the car in front. The software alerts the driver and prepares the braking system. If the driver does not react, the technology intervenes on the brakes and actuates them. Twenty carmakers have agreed that their cars will have a very important option as standard: automatic braking if the danger of collision is imminent. The transition will be gradual, starting in 2022, depending on the class they belong to, but it is expected that in 2025 absolutely all cars to be built will benefit from this equipment [9].

2.2.2. Emergency stop signal (ESS)

Regulation No. 48 of the Economic Commission for Europe of the United Nations (UNECE*)* - uniform provisions concerning the approval of vehicles with regard to the installation of lighting and light-signalling devices requires that the lamps supplying the ESS flash at 4 Hz when a passenger car decelerates by more than 6 m/s^2 or a truck or bus decelerates by more than 4 m/s^2 [5].

Emergency Stop Signal, or ESS, was taken over by companies such as Toyota, Mercedes-Benz, Volvo, BMW that launched equipped vehicles that transmit a special light signal when the vehicle is braked quickly and severely. This is officially called the "emergency stop signal". Mercedes vehicles flash the stop lamps for the ESS, while vehicles in the Volkswagen manufacturer's group (VW, Audi, SEAT, Skoda) light up the flashes. Other methods of indicating severe braking have also been implemented; some Volvo models make the brake lights brighter, and some BMW cars have an "adaptive brake lamp" that effectively increases the size of the brake lights in high braking conditions by illuminating the brake lights at higher intensity than normal [10].

There is currently considerable debate about the measurable increase in safety performance of the system, as studies on in-service vehicles have not shown significant improvements. The idea behind these emergency braking indicator systems is to draw attention to the fact that it is a special emergency.

2.2.3. Emergency Brake Blinker - EBB

Another solution that can be used as an alternative to ESS systems pre-installed on some newer models from the factory, is the electronic module "Emergency Brake Blinker" - intermittent signal to brake. The EBB electronic module is an electronic module based on an electronic accelerometer assisted by a microcontroller that detects sudden braking and quickly flashes the 3rd stop on the brake and in case of very violent braking also activates the breakdowns, making the car much easier. to be noticed by the one behind.

There are currently several safety systems on the car in terms of braking systems, but even the most advanced automated safety systems cannot yet replace the human input from traffic. Most have limitations on speed or visibility. That is why it is necessary for the driver of the vehicle to have as much traffic information as possible. The information must be available in real time, and be as easy to observe and understand as possible.

2.3. Identification of product requirements and proposed solutions

Based on the results of the primary market research and the technical solutions currently in place, the question arises of identifying a solution that would create a brake light of variable and/or gradual intensity that would respond to the intensity of the deceleration. This will increase traffic safety by preventing rear-end collisions and reducing fuel consumption.

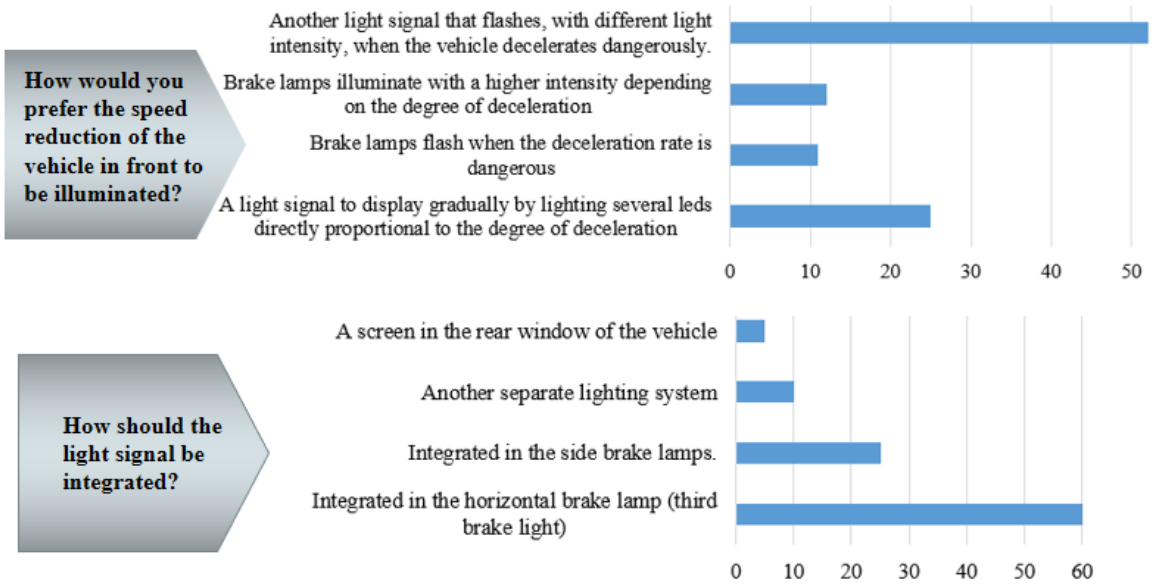

Figure 2. The answers to the first two questions in the questionnaire

In this sense, a new market research was carried out through an opinion poll. The questionnaire distributed to a number of 100 drivers had as its theme the characteristics related to the new product (light system for decelerating the vehicle). Figure 2 shows the first two questions in the questionnaire and the corresponding answers.

In order to determine customer preferences for product features, the following questions were asked to choose the preferred feature depending on how useful/appropriate they consider them. The questions and answers are shown in figure 3.

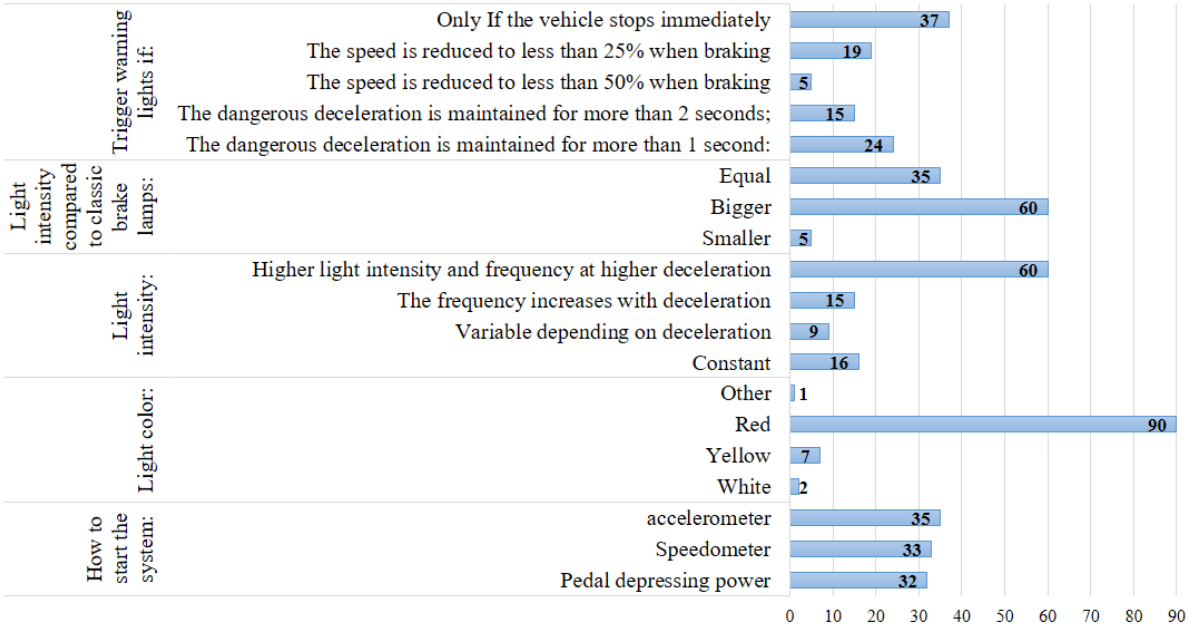

Figure 3. Customer preferences for product features

After analyzing the results of the second questionnaire, the following requirements for the proposed product were reached:

- Another light signal that flashes, with different light intensity, when the vehicle decelerates dangerously;
- The light signal should be integrated in the horizontal brake lamp (third brake light);
- The triggering mode should take into account the information received from both the accelerometer and the speedometer;
- The light should be red;
- The lights should be of higher intensity and frequency at higher deceleration, as at low intensities they may not be observed, and in certain situations, especially in daylight, the light intensity may not be properly assessed;
- The system should automatically trigger the fault signal (flashing) if deceleration is dangerous.

All the results of the opinion polls were discussed in a brainstorming session, which was attended by representatives of automotive companies, representatives of academia and professional drivers. Implementation, at the end of which a new list of requirements is drawn up. The requirements have been ranked according to cost, utility and field of use. The requirements and the way of their implementation are presented below:

- The product must provide information on the braking degree of the vehicle in front. This information is provided by displaying the degree of deceleration by means of the central (horizontal) brake lamp. At a deceleration of more than 6 m/s^2 in motor vehicles and 4 m/s^2 in trucks and coaches respectively, the leds in the middle lamp will flash, with a frequency similar to the hazard warning lights and will gradually increase with increasing deceleration.

- The product must have low manufacturing costs, so that it can also be mounted on low-cost vehicles. In addition to the ideas resulting from the opinion poll, the development of a communication system (radar, satellite, etc.) with the car on the same direction of travel was also discussed. It is hoped that this “Flash Deceleration System” will have a low cost to create the preconditions for a large-scale implementation in all cars regardless of the range they belong to.
- The product must comply with European and global automotive regulations.The provisions of the Romanian road legislation are aligned with the European standards, so the product will comply with the legal norms only if it will be integrated in the factory car, and will not be available as an attachable extra option. Due to the legislation, the product is not intended for physical customers, but is addressed to automotive manufacturers.
- Information to be available in real time. Due to the fact that the product will be electronic, the information will be available instantly.
- The information must be easily intelligible, visible from a sufficient distance, in adverse weather conditions, or in various light conditions. To meet these requirements, the leds in the lamp will be red and will have at least as much intensity as the classic brake lamps.
- The information should be unmistakable. The location of the central brake lamp, the horizontal orientation, as well as the ignition mode will provide unmistakable information.
- The product can be easily integrated functionally, regardless of the make or model of the vehicle. The product will be easy to integrate, functional because it does not require bulky components.
- The design of the product must be easily integrated into the design of any vehicle. Due to the fact that no new components are added to the exterior of the vehicle it will not affect the design.
- The identity element (main feature) of the product should derive from the way it solves the problem.The main feature of the product is the unique way it provides information in traffic, so the identity element is strong.
- The product has the potential to become a standard in the automotive industry. It is recommended to use a standard number of leds to avoid confusion in interpreting the data.
- The product to comply with the automation trend of vehicles. The product is also integrated with modern automatic braking systems, due to the fact that it does not receive data from the brake pedal, but from the speedometer and accelerometer. So, whether the car brakes "alone" or the driver brakes, the data will be the same.
- The product should be eco-friendly - environmentally friendly. Due to the fact that it will help to use a more fluid finish style, with less braking, the product will also contribute to fuel economy. Also the components from which it will be built will be 95% recyclable (plastic and metal).
- Abbreviated name - the brand should be easy to remember and inspire. The name must be easy to pronounce in any language. The English abbreviation for "Flash Deceleration System" is the most appropriate (FDS).

2.4. Product concept

In order to attract the attention of drivers in traffic and even more on the very strong braking, the proposed system should fave the light intensity of the leds can also increase by flashing 2 rows of leds intermittently. The first row will illuminate normally when braking with deceleration below 6 m/s^2, respectively 4 m/s^2, and above this value the second row will also light up, both rows flashing. Thus, the middle lamp, located in the rear window area, is also visible by the drivers in the column. The system does not disturb traffic because it only works in extreme situations, thus avoiding the risk of chain jamming. In this case of high deceleration, when the vehicle is stopped this system automatically controls and the emergency system starts.

This system also operates in the event of an accident (when the driver of the vehicle may have problems and cannot operate the emergency system), thus informing other road users, of the existence of a special situation forcing them to stop to avoid an accident. This system called Flash Deceleration System works independently of the braking system, based on a deceleration sensor that controls the leds and the car's emergency system via an electronic circuit.

The product itself will consist of 2 components: one hardware and one software. Regarding hardware components the product will be composed of the following physical components:

- Speedometer interface - a module that must take data from the speedometer or on-board computer about the vehicle's speed per unit of time and turn it into percentage deceleration data.
- Sensor accelerometer that measures acceleration based on vehicle inertia.
- Microcontroller the data processing center coming from the speedometer interface and the accelerometer using special software. It will calculate how many leds will need to receive current depending on the degree of deceleration.
- Led display - a component that must be easily configurable depending on the design of the car model on which the system will be mounted.
- Electrical cables - connect the physical components of the product.

The software component will have the role of calculating if one or both rows of leds light up, of course with the help of software. The software must take into account the degree of deceleration (based on the information received from the speedometer) from the moment the brake pedal was depressed, but provided that the accelerometer records a certain value for a certain period of time. The values will be defined after performing several tests. Figure 4 shows schematically the logical scheme of the operation of the proposed system.

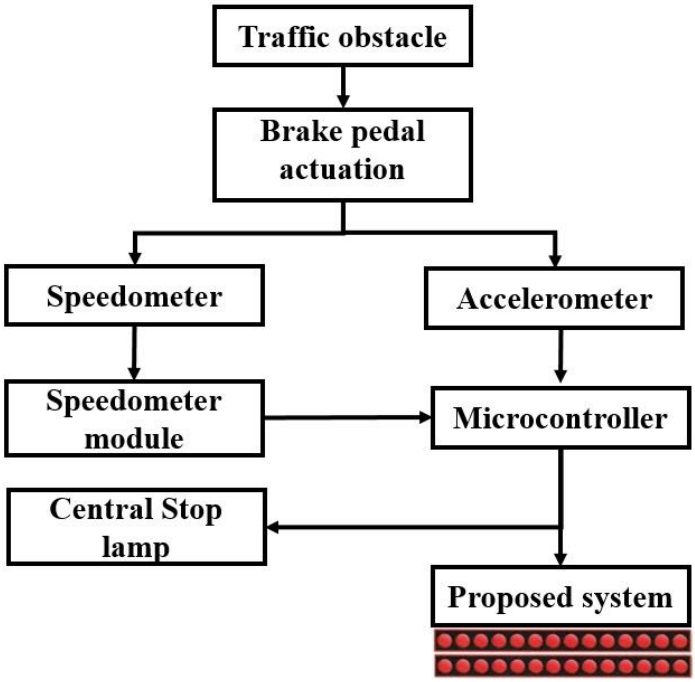

Figure 4. Logical scheme of the operation of the proposed system

- When the need arises to brake, either modern automatic braking systems come into operation or the driver actuates the brake pedal;
- The speedometer records the reduction in travel speed, and sends the data to a data processing module;
- The accelerometer records the deceleration of the vehicle;
- Data related to deceleration, speed and time are processed by a microcontroller;
- The microcontroller calculates with the help of a software what is the degree of deceleration and controls how many leds will receive electricity.

- When the deceleration percentage reaches 100%, or a critical level established after the tests, the second lamp will flash intermittently to draw even more attention to the danger. The emergency lights shall be operated under the same conditions.

3. Conclusions

The approach through the PLM prism of the light signaling system of the vehicle deceleration facilitated the detection of the shortcomings, and the studies clarified the needs and highlighted the ways to improve it. This working method has led to the need to find new constructive solutions and ways to apply them.

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