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# *"Help Car Roof Project"*. A light to save lives

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**Abstract**
Vehicle visibility is very important for road safety and for the reduction of road crashes. Emergency rear lighting systems significantly increase vehicle visibility but are limited, as they cannot be seen from a long distance and act exclusively parallel to the road axis. Present research demonstrates the validity of an innovative project able to transform a light into a *lifesaving* instrument. The project is based on the use in emergencies or during poor visibility driving conditions, of a colored lighting system, on a vertical axis, installed on the vehicle roof. According to a hypothetical point of view, the adoption of this innovative system ensures better visibility of the vehicle in all directions at long distance, and increases the safety of drivers and passengers. The system operates simply and its adoption does not represent a high cost so it can easily be implemented as best practice by vehicle manufacturers.

*Keywords:* vehicle safety, road safety, emergency lights, car visibility, UCD, HMI.

## 1. Introduction

The visibility of vehicles is a fundamental element for road safety (Hubele and Kennedy, 2018; Khan et al., 2022). During the last decade many road collisions have been caused by lack of vehicle visibility, especially in adverse weather conditions and during the night (Mateen et al., 2022; O'Malley, Glavin and Jones, 2011; Wang et al., 2016). Statistics have highlighted that most of the collisions, especially on motorways and during the night, were caused by poor visibility of vehicles. Other collisions were caused by vehicles stopped on the roadway or parked in the emergency lanes (Rix, Walker and Brown, 1997; Shinar et al.,1997; Wang et al., 2016). Research has developed a number of warning lighting systems to improve visibility in case of emergency. These systems are part of the standard equipment on all vehicles (Banikhalaf et al., 2018; Krishan et al., 2001).

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Red (or differently colored) LED rear vision systems have been developed for vehicles in general, while vehicles used for police or emergency services have additional specific signalling and visibility systems (Cabani, Toulminet and Bensrhair, 2005; Rix, Walker and Brown, 1997). Most of the current systems use flashing red rear light, in a low position additional to the rear lamps, and parallel to the road axis (Alpar, 2016; Banikhalaf et al., 2018; Iozsa, Ilea and Fratila, 2020). Red and amber colours internationally represent danger, and the use of these colors allows following vehicles to detect, from a variable distance, the presence of a stopped vehicle in distress (Huhn, Ripperger and Befelein, 1997; Hye, Jong Ryoul and Byung Do, 2016). In this situation it is very important to determine the effective distance, the operating time and the response time to stop, after sightingthe flashing beam created by the high intensity red signal (Flannagan, Blower and Devonshire, 2008).

Statistics show the presence of a significant lack of visibility related to vehicles parked or proceeding, as well as vehicles obstructing the roadway or in the emergency lane, even when they had activated emergency signals (Krishnan et al., 2001).

Some researchers have examined this potential lack of effectiveness of visual signalling, and have suggested possible solutions to the problem (Iozsa, Ilea and Fratila, 2020; Thammakaroon and Tangamchit, 2009).

It has been highlighted that all emergency signals installed on cars develop the light projection horizontally and parallel to the road axis, exhausting its effectiveness according to the height of the road, the distance from the following vehicles and to the flashing intensity of the light (Basu et al., 2013; Cabani, Toulminet and Bensrhair, 2005; Chen and Peng, 2012; Schaudt et al., 2013). Vehicles on police and emergency duty, however through the installation of additional light devices with red, amber, white and/or blue lights, have greater visibility, due to the higher location of the supplementary emergency systems and because of the different projection of light flashing parallel to the roof of the vehicle (Oliva et al., 2003).

The more effective is the luminous impact perceived at a distance, the more effective is the visibility of the vehicle in terms of safety.

At night time and in low visibility conditions there is a lack of effectiveness of the standard visual signalling. In specific situations the standard visual signalling is not sufficient itself especially at distances exceeding the average perceptual distance as well as when drivers are distracted (Wierwille et al., 2006).

A driver who is following a vehicle at a greater distance than the average attention cone, or if horizontal vision is partially or completely obscured, runs the risk of not realizing in time the possible presence of an obstacle (Breuer and Gleissner, 2006; Bullough, Skinner and Rea, 2019).

The aim of this study is to analyse the possible adoption of a different emergency lighting solution for increasing vehicle visibility in emergency situations, during the night time or in adverse weather conditions, such as the presence of fog or heavy rain. The basic idea is founded on a different hypothesis concerning the light projection, which can ensure improved visibility even at greater distances and is less affected by the road profile (Oliva et al., 2003).

The system is based on the presence of a horizontal fixed light bar installed on the roof of the vehicle, parallel to the road axis. The system emits, in the event of an emergency or in conditions of reduced visibility that recommend its activation, a conical vertical flashing beam of light, visible from a long distance.

During the vehicle's cruise, it could be used in the *normal* configuration with a horizontal fixed light, and in case of necessity it would be activated in its *emergency* configuration, with high visibility vertical conical flashing light beam projection (Breuer and Gleissner, 2006; Cao, Wu and Huang, 2016; Khan et al., 2022; Mehmood and Easa, 2009).

## 2. Methodology

### *2.1 Literature review*

A literature review was performed to analyse the effectiveness of the warning lighting systems currently in use and their impact on road safety.

Particularly interesting appears the research titled *Assessment of the effectiveness of emergency lighting, retroreflective markings, and paint color on Policing and law enforcement safety* (Terry, 2020).

A summary of most important literature referred to in Terry's research is in Table 1.

**Table 1** – Review of Terry(2020)

| Author | Text | Findings |
|---|---|---|
| Allen, M.J. (1970) | *Vison and Highway Safety*. Philadelpia PA.Chilton Book Co | In LEDs, the luminaire is turned on and off, and it can achieve higher frequencies because no mechanical motion is required. Head and tail lamps can be flashed as well, adding more visual salience, and outlining the vehicle. Visual fixations typically last between 0.2 and 0.25 s, so flashes of less than 0.2 s could be missed entirely |
| Trenite, D. G. A. K. N., Binnie, C. D., Harding, G. R. F. A., & Wilkins, A. (1999) | *Photic stimulation Standardization of screening methods.* Epilipsia, 40, pp.75-79 | Caution must be exercised when using flashing lights because they can trigger photosensitive epilepsy. Flashing at frequencies between 5 and 30 Hz is most likely to trigger seizures, so flash rates should be kept below 5-10 Hz or above 30 Hz. |
| Cook, S., Quigley, C., Clift, L. (1999) | *Motor Vehicle Cospicuity. An assessment of the contribution of retro-reflective and fluorescent material.* Loughborough Editions. | Flashing lights are highly visually salient but can also cause driver discomfort. Flashing lights in some cases might cause glare, reduce visibility, and even blind oncoming traffic. |
| Tijerina L.(2003) | *Cospicuity enhancement for Police Interceptor rear-end chash mitigation*. Committee Report. | *"Seeing"* is a complex visual-cognitive process. How drivers register motion in their periphery, detect and recognize objects in front of them, and avoid collision are intertwined. Prior to describing the characteristics of various visibility treatments, it is important to outline the cognition behind what causes objects to appear more visible, less visible, or distracting. Avoiding Collisions Moving persons detect their relative velocity to the stationary objects around them in a number of ways |
| Mortimer, R.G. (1990) | *Perceptual factors in rear-end collisions.* Paper presented at the Human Factors and Ergonomics Society 34th Annual Meeting, Orlando, Florida. | The object or vehicle is growing in a driver's visual field; as they approach it, it appears wider. However, using the perceived width of an object/car in front of a driver, the visual angle, is problematic, because the visual angle increases non-linearly with closing distance. By the time the change in visual angle is large enough to cause a driver to startle and brake, a driver travelling 55 mph is already about 40.5 meters from a parked car. |
| Gibbons, R., Lee, S. E., Williams, B., & Miller, C. C. (2008) | *Selection and application of warning lights on roadway operations equipment* | People's peripheral vision is sensitive to movement, so flashing lights in the periphery are highly visually salient, with slower flash rates slightly better at attracting attention in the periphery than faster flash rates. |

| | | |
|---|---|---|
| | (NCHRP Report 624). Washington, D.C. | |
| Charles, M. T., Crank, J., & Falcone, D. N. (1990) | *A search for evidence of the fascination phenomenon in road side accidents.* | In the absence of other visual cues to heading, such as in dark or foggy environments, drivers are more likely to reorient themselves towards parked vehicles with lights on. |

The present study has collected, in the following Table 2, a list of patented or registered inventions related to object warning and emergency scene lighting systems as well as other technical equipment able to avoid collisions caused by lack of vehicle visibility.

**Table 2** – Patented or registered inventions on warning and/or emergency scene lighting systems.

| Device | Patent | Description |
|---|---|---|
| WARNING AND SCENE LIGHTING SYSTEM (D1) | United States Patent Application Publication nr.: US 2013/0194090 Al McLoughlin et al. Pub. Date: Aug. 1, 2013 Inventors: John E. McLoughlin, Hauppauge, NY (US); Neocles G. Athanasiades, E. Setauket, NY (US); Kiam Meng Toh, St. James, NY (US) | A lighting system for use with an emergency vehicle comprising at least one lighting bar mounted to an exterior surface of the emergency vehicle. The lighting bar comprises a plurality of lighting elements operable to emit light. At least one lighting bar can be placed in a first substantially horizontal lowered position and a second bar on a substantially vertical raised position. A controller can be electrically coupled to the at least one lighting bar and configured to receive user input and controllably place the at least one lighting bar in one of a raised and lowered positions in response to the user input. |
| AUTOMATIC WARNING DEVICE USING SMOKE AND FLAME IN THE CASE OF A CAR ACCIDENT (D2) | World wide Patent Application Publication nr.: WO 2014/098371 A1 Jeong Seonghoon. Pub. Date: June. 26, 2014 Inventor: Jeong Seonghoon (KR) | A specific device for warning of the occurrence of an accident by automatically or manually operating a smoke and flame on the roof of a vehicle in the event of an accident in order to prevent secondary or tertiary collision accidents. Smoke and fire have been used for long periods of time, and have been used in the event of an accident or distress. Currently, there are different ways to warn of a car accident: to operate the emergency flasher of the car, to install the safety signs, and to manually ignite the smoke bomb. First, most automobiles now use an emergency flasher, which is the only way to warn of an accident. However, the problem with the method of operating the emergency flicker in case of an accident is that it is overlapped with the method of using the emergency flicker as a sign of caution when the driver can not secure sufficient visibility due to heavy rain, snowstorm. Even if the emergency blinker is activated after a collision, the driver of the rear vehicle can not recognize the accident quickly, and mistakenly thinks that the vehicle is still running. |
| VEHICLE-WARNING SIGNAL LIGHT (D3) | United States Patent Number: 4,835,515 McDermott et al. Date of Patent: May 30, 1989 Inventors: Julian A. McDermott; Mildred A. McDermott, both of 1639 Stephen St., Queens, New York, N.Y. 11385 | The device relates to a signal warning light designed to be mounted on the roof of an emergency vehicle. Normally this device, in use, would appear to be a frame holding a line of lights across the top of the vehicle. However, at the scene of an emergency, under control of the driver, bars pivoted at the two ends of the frame would be automatically swiveled upward. When raised fully, the bars would appear vertical and with its vertical array of lights would provide approaching drivers with an advanced warning. By limiting the movement of one bar to an acute angle and not fully raising the other bar the effect of a pointing arrow or spear head would be obtained. Thus by selectively controlling the bars to be raised, traffic could be directed to proceed left or right or |

| | | |
|---|---|---|
| | | if the both bars were raised partially, signals to stop, slow as well as right and left may be given. Sequential flashing of the bar mounted lights would emphasize the message when directed toward the *"point"*. Reflex material can also be used instead of electric lights. |
| EMERGENCY SIGNALING SYSTEM (D4) | United States Patent Application Publication nr.: US 2007/0197084 Al Darolfi et al. Pub. Date:Aug. 23, 2007 Inventors: Rinaldo Darolfi, Woodbridge (CA); Massimo D. Tad, Woodbridge (CA); Alfredo Darolfi, Woodbridge (CA) | A signaling device comprises a housing. The housing being arranged for mounting on a roof section of a vehicle. The housing having an upper housing portion and a lower housing portion. A transfer portion for transferring the upper housing portion relative to the lower housing portion between a closed position and an open position. The upper and lower housing portions being further provided with complementary peripheral regions which, when engaged in the closed position, form a weather resistant inner chamber. The upper housing portion have an inner surface, and a plurality of signaling elements mounted on the inner surface. The inner surface and/or the signaling elements being operable to be visible to oncoming traffic when the upper housing portion is in the open position. |
| LIGHTING SUBSYSTEM AND A LIGHT BAR STRUCTURE (D5) | United States Patent Application Publication nr.: US 2009/0256697 Al Tallinger Pub. Date:Oct. 15, 2009 Inventor: Gerald G. Tallinger (TX) | A lighting subsystem and a light bar structure upon which the lighting subsystem is mounted. The lighting subsystem has a display that incorporates both warning signal lights and a programmable message display. It is configured to enable the positioning of the lighting subsystem in multiple positions, including a low-profile position and a higher profile position. In one embodiment, the lighting subsystem utilizes a LED matrix display which includes interleaved message-display LEDs and warning-signal LEDs. The system may be positioned at an aerodynamic pursuit angle, and the LEDs may be oriented to maximize forward intensity of the emitted light in the pursuit position. In the low-profile position, the lighting subsystem may be retracted into a recessed compartment in the roof of an emergency vehicle. The message display may be configured to display preprogrammed messages or user-programmed messages, and may be operable by a user outside the vehicle using a remote control. |
| ROOF RACK ASSEMBLY WITH INTEGRATED LIGHTING (D6) | United States Patent Application Publication nr.: US 2012/0031939 Al JUTILA et al. Pub. Date: Feb. 9, 2012 Inventors: Brian J. Jutila (M), Robert E. Boniface (MI), Jeffrey A. Diegel (MI), Joel T. Bachler (MI), Ronald J. Wojciechowski (MI) | A roof rack assembly for a vehicle having a roof . The roof rack assembly includes a first stanchion for structural attachment to the roof, a second stanchion for structural attachment to the roof, and a bar coupled between. The system held above the roof by the first stanchion and the second stanchion. The bar has a securing feature integrally formed therein, which holds an electric powered light-emitting component. Accordingly, the roof rack assembly employs a roof rack bar, having a light-emitting element integrated therein. |

From a careful analysis of the literature related to the existing patented systems, it is clear that the problem of vehicle visibility when stopped on the road, in the emergency lanes or operating in conditions of reduced visibility or in particular weather situations (heavy rain, fog, hail, etc.) or during the night time, is significant and it was subject of extensive investigation.

In particular, it emerged that the visibility of vehicles, even if indicated by warning LED lights of adequate intensity, parallel to the road axis, is strongly affected by the

position of the vehicles on the road, by the road vertical profile and by many competing human factors, including possible driver distraction and the driver's responses.

In each analysed study, the effectiveness of the warning light emission is highlighted, differentiating the relative colours (red, amber or blue, depending on the danger situation and on the vehicle on which the system is installed) and representing how the perception of danger is different from driver to driver, decreasing significantly in particular conditions.

Similarly, it is stressed that the distance from the front vehicle is a very important element of difference in perceiving the danger, especially in conditions of poor visibility and driving during the night. In these circunstances, it is only when the following vehicle is close to the vehicle in front that the driver is able to recognize the risk. The vertical profile of the road and the distance between vehicles are elements able to cause an exponential decrease in the immediacy of the perception of danger or obstacles.

The complex of visual difficulties in emergencies or in particular situations, as illustrated in the Table 1 review, constitutes an element of criticality for road safety and the need for potential solutions.

One solution is the installation on the roof of the vehicle of an emergency/warning flash lighting system, able to be seen by following vehicles at a greater distance and in poor visibility conditions, or during the night.

Technically, solutions D1, D2 and D3 proposed in Table 2 show emergency and warning flash lighting systems suitable for activation in the event of road collisions

. To be clearly visible by vehicles arriving on the scene, the systems are applied on the roof of the vehicle.

Basically, D1 and D3 describe lighting structures applied on a support that can be adjusted. To make the accident and the vehicle more visible from afar D2 suggests use of a system of smoke (maybe coloured) signalling upwards (or even production of flames).

D4, D5 and D6 illustrate different, useful systems for warning flashing lights placed on the roof of the vehicle, able to be activated and functional through the emission of a beam of flashing light horizontal and parallel to the road axis.

### *2.2 "Help Car Roof Project"*

In many cases, physical placement of the warning red triangle, to signalate an obstacle, has been difficult and ineffective.

It is evident that the idea of projecting a flashing beam of light at a higher level from the road surface and with a vertical rather than horizontal direction could be a valid solution to improve visibility.

With this proposed system, visibility is increased because a beam is projected upwards. Other vehicles, even in case of difficult weather situations, can quickly detect a car stopped on the road, stopped in the emergency lane or involved in a traffic collision. The concept of projecting a flashing light upwards (at different angles) is a substantial innovation.

Until now, however, only solution D2 seems to suggest using a system of smoke signalling upwards (or flame production), presenting the development of a different, more effective solution, safer and more immediate use of warning signalation in particular conditions.

The *"Car Roof Light System"*, moreover, in normal conditions of driving, is able to facilitate sighting of vehicles.

The system is installed on the roof of the vehicle, preferably along the positioning of the roof bars and be capable of projecting static or flashing light. The projection should be parallel to the road axis and directed vertically, from the right to the left and vice versa, creating an X cone of light, vertical and perpendicular to the road axis.

Therefore, two possible light projections develop, respectively in the *"cruise"* condition A (Figure 1) and in the *"emergency"* situation B (Figure 2).The two lighting possibilities A and B are used with an actuation mechanism within the self-ignition.

System A is activated while the vehicle is cruising in conditions of poor visibility and at night by means of a special button installed on the vehicle control panel, which can be activated directly by the driver.

The lighting of system A assists the visibility of the vehicle during normal driving.

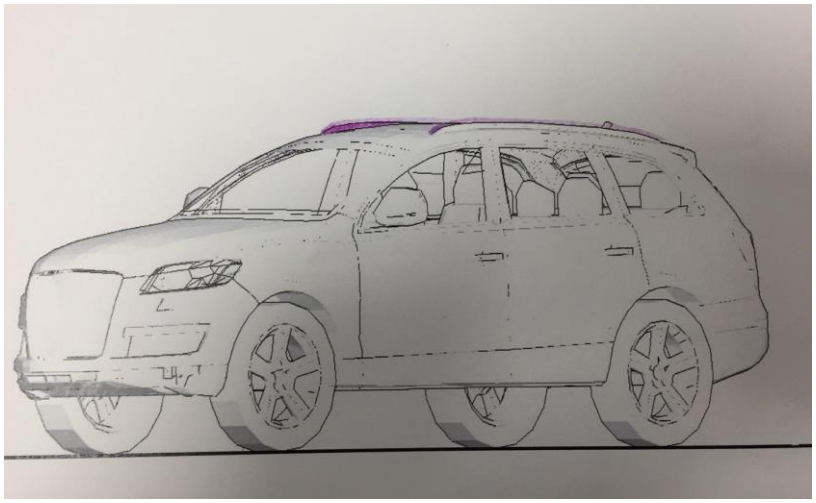

**Figure 1**- The *"Car Roof Light System"* during cruise condition.

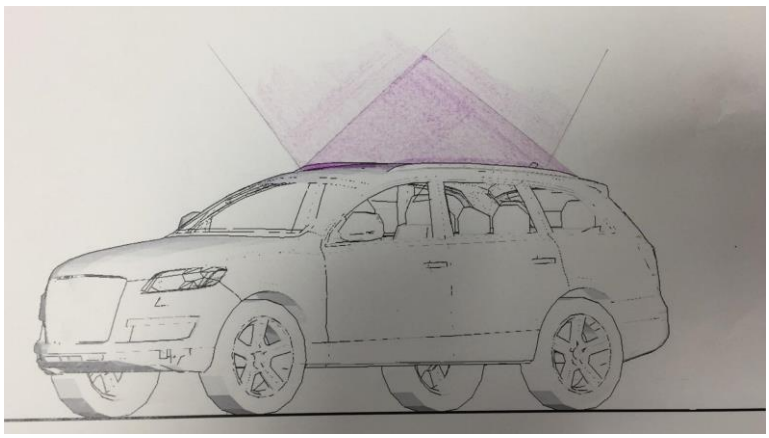

**Figure 2**- The *"Car Roof Light System"* in an emergency situation.

Furthermore, the positioning of the lighting system on the longitudinal structure of the vehicle roof allows vehicles traveling in the opposite direction or that are alongside the vehicle to be warned of the presence of difficult conditions.

System B, on the other hand, can be activated by the driver when emergency conditions occur, as for system A, or indirectly when the car airbags are activated. In fact, by connecting the activation to the airbags, automatic activation of the proposed system is guaranteed in the event of a road collision.

Figure 3 is a top view showing the possible location of the warning flash lighting system. The light emitter is placed parallel to the roof of the vehicle and the flashing lights are positioned in such a way as to project a conic beam of light upwards. The illuminating warning triangle crosses from the right to the left and vice versa, indicating that the vehicle is in an emergency and stopped on the road or in the emergency lane.

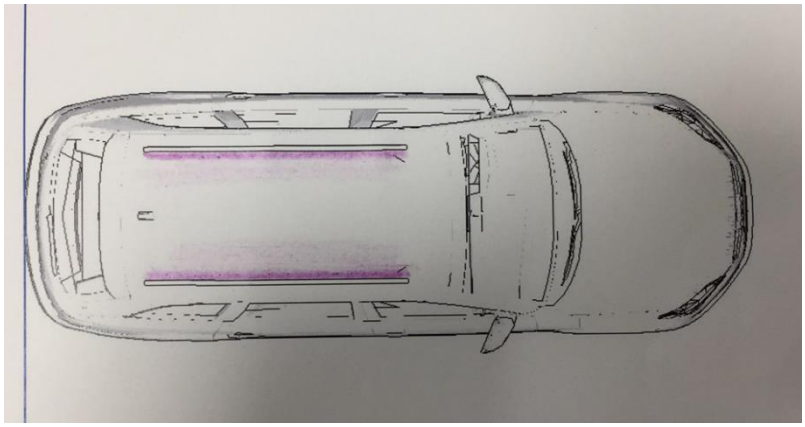

**Figure 3**- Top vision of the *"Car Roof Light System"*.

All the mechanical and electronic elements can be replaced by other technically equivalent elements, and the materials can differ according to need and the LED light inserted into the bars. The lighting bars could preferably be installed by the manufacturer on the roof of the car. The *X*-shaped light cone guarantees maximum visibility even at great distances, during dark or foggy conditions (Figure 4)

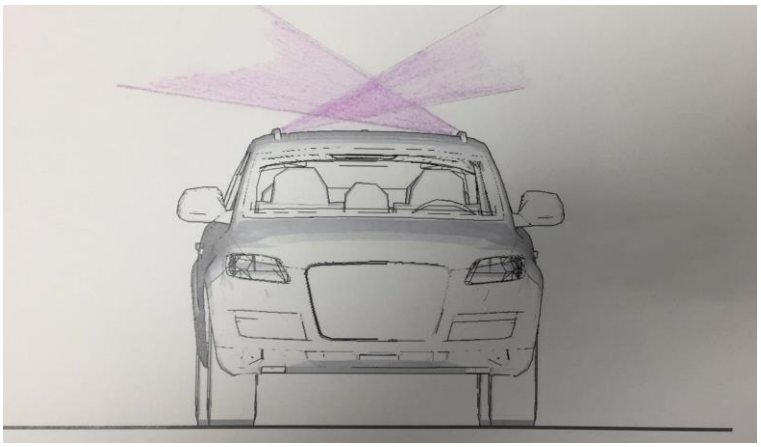

**Figure 4**- Frontal vision of activated *"Car Roof Light System"* during dark time or foggy conditions.

The system positively affects the visibility distance ***Da*** necessary for safe stopping following vehicles, which is determined by the variables $\boldsymbol{D1}$ and$\boldsymbol{D2}$, where:

***D1*** is the distance traveled in time $\boldsymbol{\tau}$ **,** determined by the formula:

$$\boldsymbol{D1 = \frac{V0}{3,6} * \tau}$$

where $\boldsymbol{\tau = 2{,}8 - 0{,}001\,V\,[s]}$, indicates the overall reaction time (perception, reflection, reaction and manoeuvre implementation) with V expressed in km/h and **V0** is the vehicle speed at the start of braking (Vp is derived from DdV) [km/h]

***D2*** is the braking distance, according to the formula:

$$\boldsymbol{D2 = -\frac{1}{3,6} * \int_{V0}^{V1=0} \frac{V}{g + [f1(V) \pm \frac{i(\%)}{100} + \frac{Ra(V)}{m} + R0(V)]} - dV}$$

with **V1** equal to the final speed of the vehicle (V=0 in case of stop) [km/h], **g** determined by the acceleration of gravity [m/sec], with $\boldsymbol{f1}$ as the longitudinal coefficient of adhesion, $\boldsymbol{i}$ as the longitudinal slope [%], **Ra(V)** indicating the aerodynamic resistance [N], **m** the mass of the vehicle [kg] and $\boldsymbol{R0}$ is the rolling resistance.

***f1*** was **determined using** Table 3, which results in about 85%, 90% and 95% of the maximum longitudinal adherence available for different types of road

**Table 3** – Adherence coefficients

| **Speed km/h** | **25** | **40** | **60** | **80** | **100** | **120** | **140** |
|---|---|---|---|---|---|---|---|
| $\boldsymbol{f1}$ **Motorways** | - | - | - | **0,44** | **0,40** | **0,36** | **0,34** |
| $\boldsymbol{f1}$ **Other roads** | **0,45** | **0,43** | **0,35** | **0,30** | **0,15** | **0,21** | - |

Consequently, the necessary visibility distance for safe stopping ***Da,*** according, *ex multis*, to Maltinti (2009), is determined by the formula:

$$\boldsymbol{Da = D1 + D2}$$

## 3. Results

The proposed *"Help Car Roof Project"* produces a significant contraction of $\boldsymbol{t}$ that should be reduced by a theoretical value of $\boldsymbol{x\%}$ compared to the normal, changing $\boldsymbol{t}$ to $\boldsymbol{(t - x\%)}$**.**

Consequentially the new ***D1*** is determined by the formula:

$$\boldsymbol{D1 = \frac{V0}{3,6} * (\tau - x\%)}$$

The decrease of ***D1*** decreases censequentely the ***Da*** value, which identifies the distance of visibility necessary for safe stopping of the following vehicle(s).

The result is that the system ensures more visibility and is more effective in poor weather conditions. The maximum effect, in terms of visibility, is determined by flashing light.

## 4. Limits of the research

The used methodology is appropriate for a pilot research and needs for additional researches and experiments.

The research assumes that people who drive have a perfect vision, without pathologies affecting both the cone system and the ros system, as well as the $\boldsymbol{t}$ value is fixed assuming this.

The usefulness of the tool is verified only from an hyphotetical point of view.

## 5. Discussion

Collisions with stationary, broken-down and stopped vehicles on roads or emergency lanes are about 41,7% of the total number of road crashes recorded each year (ETSC, 2022). An appreciable number of such collisions involve vehicles in police and emergency services and death following a road crashes is the main cause of death for police officers on duty (NSC, 2021).

One of the main causes of this type of road collisions is the lack of visibility of the vehicle, inadequate warning systems, as well the following drivers' inability to avoid the obstructing vehicle due to reduced visibility, road conditions, brightness, weather conditions and night hours.

Systems have been introduced to mitigate this type of risk and the most widely used rear hazard warning lights provided in all vehicles.

The level of effectiveness of this system depends on the depth of view, the flashing light output of the device and its location upon the vehicle.

The main problem encountered in the warning systems currently in use is that the light beam projects horizontally, parallel to the road axis, with the consequence that, in particular circumstances of reduced visibility, the following vehicle drivers are unable to perceive and react to the hazard in time.

The proposed system would decrease the total time to react (perception, reflection, reaction and implementation of the maneuver) $\boldsymbol{\tau}$ with a consequent decrease in the distance of visibility **Da** necessary for the safe stopping of the oncoming vehicle.

To obtain this result, it is necessary that the emergency warning, and in particular the light beam, is visible in time and at a longer distance. The projection in the raised position above the roof of the vehicle is the recommended solution. A conical beam of light projected at X in the direction perpendicular or inclined to the road axis and not parallel, produces a noticeable improvement in passive perception.

The visibility of the obstacle is ensured from a longer distance, in presence of fog/rain, at night and on roads with poor sight distance.

The system, in its cruise configuration, could be an element of knowledge for other drivers, and such a warning could be very useful in the event of a car crash.

The activation of the light system installed on the roof of the vehicle also seems very simple, being able to be operated by the driver using a button installed on the dashboard. Future researches can verify and confirm system's usability and learnability in a comparative way.

In case of emergency, however, the conical vertical or inclined X flashing beam can be activated in a dual mode, by the driver or automatically, at the same time as the activation of one of the airbags.

The emergency signaling system with a vertical cone can be seen from a greater distance than that with a cone parallel to the road axis. The increase in visibility leads to

greater safety in seeing the possible obstacle and a decrease in the times to perceive the danger.

The greater impact in terms of safety of light projected upwards, with a large visible cone at a distance, allows safer travel in poor weather conditions, during the night hours and in poor visibility. At the same time, the call of attention due to the conical beam of light directed upwards impacts with better results than the front one, which the other emergency instruments have, which, in constant movement and in particular conditions, ends up even with the cause distraction for those who follow.

The impact of a warning light directed upwards and visible at a greater distance is much more effective than that produced by lighting parallel to the road axis and allows attention to be drawn more immediately. Because of this, the reaction time for perception of the possible obstacle decreases.

It is opportune the necessity of an experiment, in a simulator or in a real field, which can verify not just its feasibility but also the magnitude of the beneficial effects, using a user centered design procedure. It is appropriate to verify whether the system is accepted, understood and appreciated by possible road users.

The simplicity of implementation of the proposed system and its flexibility of use, as well as the possible immediacy of activation, suggest a real ease of application.

In summary, the system offers:

(a) very high cost-effectiveness and the possibility of dual uses;
(b) greater visibility of the vehicle, in traffic when there is reduced visibility due to poor weather conditions, complex road geometry and during night hours;
(c) the possibility of using the same system during normal driving, with different colors of beams, to indicate the presence on board of children, animals or the transport of particular goods and/or materials;
(d) increased visibility of vehicles in a broken down or emergency situation;
(e) the possibility of activation in manual or automatic mode.

## 6. Conclusions

A visual alarm system capable of projecting a conical beam of light upwards and visible for oncoming vehicles even from a long distance is certainly a useful tool for road safety.

This instrument is sufficiently innovative in the current technical landscape, also taking into account the fact that the current warning and signalling tools are based on a rear light beam technology facing parallel to the road axis.

The increased attention drawn by a cone of light pointing upwards which can be seen from a distance allows a significant reduction in the number of road collisions caused by distraction and the failure to ascertain an accurate estimate of the true distance from a vehicle in a hazardous position on the roadway.

The ease of activation and application to each vehicle, allow the instrument to contain production and installation costs, making it economical in terms of development and use.

Considering the advances in automation, the proposed system could contribute to foster the interaction between automated vehicles and the other road users (Straub and Schaefer, 2019) especially when the automation fails (AV's resilience, takeover time, etc.).

In the future the idea, according to the concept of mental workload (Wickens, 2021), could be adapted to specific other solutions. One possibility is, according to specific national and international legislations, to signal the possible presence on board of children or animals, or to notify the transportation of particular materials and goods.

It is highly desirable that the system be further developed and then trialled and the feasibilty of installation on vehicles used for the police service should be also investigated.

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*Contribution Statement*

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