At their beginning, when the human population density and interconnectivity was much lower, all these networks were simpler in their structure and carried less payload. Over time, the population grew and, not accidentally, the interconnectivity nodes and vertices increased while the transfers of payloads intensified. Despite continuous growth, each of these networks...
had almost from the beginning a limited transfer capacity for obvious economical reasons. As a consequence, as with any commonly limited shared resource, a conflict of usage appears. The solution to this conflict was some sort of signaling system that would coordinate the access to the network between the competing vehicles, thus efficiently sharing the available capacity.

This signaling system, whatever its implementation details, has continuously evolved to cope with ever-increasing traffic that puts more pressure on these networks' capacity. But what has this to do with system safety? Each of these transportation (and telecom is a form of transportation) networks can be considered a complex system in itself; a system that relies on its signaling subsystem to avoid collision between its payload carrying vehicles. Collision is an undesired negative event in any of these networks because it is a fault that contributes to network failure as the payload is lost (damaged, altered) and/or the network is blocked.

From that perspective, a collision in the information network is only a reliability concern, while in the case of the railway and roadway network, it is a safety concern. That is why the signaling part of a transportation network is an important contributor to its safety.
Rear Turn Lights in the Context of Vehicle Signaling

Signaling is a vital subsystem of the roadways transportation system and is implemented through posted signs and light signals categorized as follows:

- Signals between infrastructure and traffic agents (human-driven vehicles)
- Signals between traffic agents
- Signals between infrastructure and traffic agents
- Signs between traffic agents

Signal lamps are located at the front, rear and sometimes (optional) side of vehicles. The most crowded vehicle "signaling " interface is at the back of the vehicle, where the following [Ref. 3] types of signals are emitted by a combination of lamps (separated or not):

- Rear stop/brake lamps
- Rear position lamps
- Reversing lamps
- Rear fog lamps
- Center high mount stop lamp (CHMSL)
- Rear overtake/turn lamps

In general, overloading a syntactical token with multiple meanings leads to an increased likelihood of semantic ambiguity causing miscommunication and confusion. This is known from a plethora of studies in various fields, from semiotics, linguistics, and ergonomics to object-oriented software [Ref. 4]. The case of rear vehicle lights is an example of multiple meanings assigned to the same or similar signs, so it is not surprising that reducing the likelihood of signal misinterpretation leads to fewer incorrect decisions taken by drivers. As an additional advantage of mandating ARTLs, it has been shown that yellow turn signals, in comparison to red turn signals, lead to significantly shorter driver reaction times to brake signals [Ref. 5].

Safety Analysis of Mishaps that involve Rear Turn Signals

Past studies done on the comparative safety effectiveness of amber versus red rear turn vehicle signals have had a mostly statistical (based on existing accident data), human factors or ergonomic perspective. As an additional argument for introducing universal mandatory amber rear turn lights, this author has chosen a different approach, based on the idea that the vehicles driven on public roads are part of a loose system.

This approach allows looking at the interaction between human-driven vehicles as parts of the system, thus permitting a simple fault tree analysis (FTA). The list of top hazards preliminary hazard list (PHL) for the roadways traffic systems includes: vehicle collision, collision between vehicles and unexpected moving or stationary obstacles (objects, trees, animals, humans, etc.) on the roadway and vehicle exiting the roadway. All of these preliminary hazard analysis (PHA)-level hazards can be further elaborated on and refined through a system hazard analysis (SHA), but the only one that is relevant to the topic of this paper is the vehicle-to-vehicle collision. That is because it is the only one to which rear turn-signaling function failure can be a contributory hazard factor.
Here, we use FTA to elaborate on the vehicle-to-vehicle collision top safety hazard. The FTA tree portion shown in the figure below focuses only on those branches that have as intermediary gates rear turn signaling function failures. It goes further to show possible causes of those functional failures as terminal events.

![Diagram of FTA for vehicle collision caused by rear red turn lights](image)

**Figure 1 — FTA for Motor Vehicle Collision Caused by Rear Red Turn Lights.**

The fault tree methodology [Ref. 6] helped to consider a class of vehicle-to-vehicle collisions that has been underplayed (or equated with front-rear collision) in the previous studies: the front-lateral collision, as shown in Figure 1. The immediate cause of the front-rear vehicle collision hazard is the driver from behind not braking in time, because he interprets a flickering rear stop lamp as a turn signal and consequently, thinks the car in front will clear the lane in time. Two additional faults have to occur for the top hazard to be present: the opposite side rear turn lamp, as well as the CHMSL, have to be failed until, as shown in Figure 2.
Figure 2 — Front-Rear Vehicle Collision Fault Tree Branch.

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A Case of ALARP not being Applied to Automotive Traffic System Safety

by Emil P. Vlad
Aurora, Ontario

The immediate cause of the front-lateral vehicle collision hazard is the driver from behind attempting to pass the vehicle in front on the right because he misinterprets a left side flickering stop signal as a left turn signal (this also applies to the mirror case of passing on the left); thus instead of braking he may even accelerate to pass. If the driver of the front car turns right, which is assumed to be the case in this scenario, then only one additional fault has to occur for the top hazard to be present: the opposite side rear turn lamp has to be failed unlit, as shown in Figure 3.

![Figure 3 — Front-Lateral (Side) Vehicle Collision Fault Tree Branch.](image-url)
In addition to the failures illustrated by the figures, there is also the argument of lesser visibility of red lights compared to amber lights because of the scientifically proven higher sensitivity of the human eye to the light wave frequencies that make up the amber (orange) spectrum, when compared to the red spectrum [Ref. 7]. But this is just one facet of a different type of argument (human factors and statistics) made in several other studies cited in the most recent study done by the U.S. National Highway Traffic Safety Administration (NHTSA) [Ref. 8].

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This FTA-based safety analysis clearly illustrates that certain failure modes of the vehicle’s rear lights could lead to an accident if the rear turn lights are red, as opposed to amber. This also shows that imposing production of vehicles equipped with ARTL is a safety requirement acting as design mitigation for a safety hazard: vehicle-to-vehicle collision.

Of course, ARTL in isolation are not an effective mitigation for traffic accidents, but the large majority of design mitigations against safety hazards in systems are not effective in isolation — that is a characteristic of any complex system like the roadways transportation system. The conclusion of this summary FTA-based safety analysis is that risk of the top safety hazard could be effectively mitigated by having all vehicles equipped with ARTLs.

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The combined effect of this regulation and the voluntary use of DRLs — in vehicles not previously equipped with them — has been an estimated 11.3 percent reduction in daytime collisions involving two passenger cars, vans or light-duty trucks traveling in different directions.

As in the case of CHMSL and DRL, the ARTL are so inexpensive to incorporate into a vehicle that
even if the lamps prevent only a few percent of rear-end collisions, they remain a cost-effective preventive safety feature. Most people know that vehicle airbags and brakes are important safety features of a car, but few people think of turn lamps as safety features. Yet these lights are fairly cheap accident preventive safety features, while airbags are fairly expensive accident consequences containment safety features. All safety features are important, as each has some contribution to increasing the safety of a system, but choosing a preventative or intrinsic safety mitigation for a safety hazard over a containment safety barrier for the same hazard is preferable.
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Conclusion

This author works in a related field of railway signaling, where the transition from manually driven automotive vehicles (albeit larger) is happening now. There is a wave of modernization in the railway industry, based on replacing traditional signaling systems and manually driven trains with partially or fully automated rail transportation systems, virtually eliminating the need for visual signaling systems. This transition from visible signaling to computer "invisible" signaling has brought benefits such as proven dependability improvements, achieved by reducing the human involvement to only exceptional situations (failures, emergency, etc.). Safety has also been improved, mainly because the train driver is taken out of the decision loop, thus avoiding many problems related to traditional signaling, based on similar light signals and posted signs, as in the case of roadway transportation. There are improvements in the efficiency of operation as well (higher frequency, fewer delays, higher capacity, lower energy consumption, etc.). Sometime in the future, driving could be completely automated and humans could be completely eliminated from the picture, thus rendering the ARTL, DRL, CHMSL and other lights irrelevant. Until then, there is a problem. The solution to this problem is to legally require mandatory ARTL for all new vehicles produced for North American roads.

Sometime in the future, driving could be completely automated and humans may be completely eliminated from the picture, thus rendering the ARTL, DRL, CHMSL and other lights irrelevant. Until then, there is a problem. The solution to this problem is to legally require mandatory ARTL for all new vehicles produced for North American roads.

It is a small price to pay to yield small, but tangible, road safety improvements. As in the case of CHMSL and DRL, it is almost certain that ARTL would decrease the number of accidents by a few percent, depending on the accuracy of the method used to estimate it. Whether this reduction is three percent or 20 percent [Refs. 1, 8, 11, 12], it is still worth adopting; if even one percent were applied to the millions of vehicles on North American roads and the similarly high number of collisions, that would still make a difference by reducing the social and personal cost of materialized safety risk.

About the Author

Emil P. Vlad is a safety assurance technical specialist for Thales Canada, where, among other duties, he performs safety audits and assessments for project deployments and product development, and leads process and product-related incident investigations.

He has been practicing in the industry for more than 15 years in various related fields and positions including security systems, telecom and wireless networks testing and integration, embedded software and applications in automation, and systems engineering in telematics, working most recently on RAMS and system assurance in the field of railway signaling systems and urban rail transport automation. He is currently working on bridging the gap between various fields of complex systems engineering, and learning how to manage diversity and complexity from the natural ecosystems following the principles of biomimetics. He has also participated as an attendee or volunteer at various conferences and symposia held by the ISSS, IEEE, SRE and others.
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