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Autonomous Vehicle Radiation Based on Traffic Flow Analysis

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Abstrak

Sektor transportasi sedang bersiap menuju era baru, era kendaraan yang sepenuhnya otonom. Radar, Lidar, dan Sonar dianggap sebagai aspek penting suksesnya teknologi ini. Namun radiasi yang dipancarkan ketiga sensor diprediksi memiliki dampak berbahaya baik bagi pengguna maupun bagi lingkungan. Prediksi yang dibuat berdasarkan klasifikasi tingkat pelayanan jalan (*level of service*) ini menunjukkan bahwa akan ada paparan radiasi yang berlebihan ketika kendaraan mendominasi lalu lintas. Prediksi ini harus menjadi pertimbangan saat merancang armada otonom level 5 yang menggunakan begitu banyak sensor.

Kata kunci: Kendaraan otonom, emisi radiasi, bahaya, prediksi paparan

Abstract

The transportation sector is heading to a new futuristic era, the fully-autonomous vehicles. Radar, lidar, and Sonar are considered critical aspects of self-driving technology. However, these sensors come with inherent danger. Their exposure has a hazardous impact on humans and living things. A forecast made using the level of service classification shows that there will be excessive radiation exposure when these cars dominate the traffic. This prediction must be taken into account when designing a level-five autonomous fleet.

Keywords*: Autonomous vehicle, radiation emission, hazardous, exposure prediction*

INTRODUCTION

The transportation sectors have set an ambitious target for sustainable development of halving the global number of death and injuries from road traffic crashes by 2030. Yes, the target is overly ambitious; it is already the end of 2022, but this challenge must be accepted to save the loss of human life. The interest in developing a safety vehicle to overcome the issue has been overgrowing for the past few years. Research and development have been prompted to support safe driving and the independent driving system. The electric car's invention, integrated with the self-driving system, is intended to solve three transportation problems simultaneously; accidents, traffic jams, and carbon dioxide emission (Sung et al., 2018).

Moreover, it looks like the transportation sector is heading into a new futuristic era. Automotive companies worldwide are now manufacturing self-driving cars with an Integrated Transportation System (ITS); this ITS allows the fleets to navigate without a human driver and communicate and share data to avoid congestion and hazardous situations. The target is the vehicles that will be entirely autonomous without human intervention. Hence, 94% of the human error factor that costs collision can be eliminated. In addition, autonomous fleets allow transportation and cities to be designed in a revolutionary way with the

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idea that this technology is infinitely better at driving than humans are (Anastasiadou, et al., 2021; Xiao et al., 2021).

However, as with technology concerning human transportation from one site to another, there will always be an inherent threat. Accepting self-driving cars will be a challenge until the public feels assured of their safety and security, to the passenger and the pedestrian. Some critical technologies like Artificial Intelligence, safety and security cameras, network infrastructure, and sensor technologies (radar, lidar, and Sonar) are considered the core of this approval. All these technologies must ensure safe and successful autonomous-vehicle functions (Farid et al., 2021). Correspondingly, this research will focus on the most critical elements of self-driving motorcars; The sensor, Radar, Lidar, and Sonar, which are acknowledged will have significant effects on the surrounding. Imagine, According to General Motors' data, they use at least 21 radars for one car to be autonomous, besides another additional 5 Lidars and 16 cameras.

LiDar, Light Detection, and Ranging, a method for calculating an object's exact distance on the earth's surface, is another virtual device in the automotive industry. Uber, Waymo, Cruise, and several others rely on LiDar's ability to see through challenging weather and light since lidar creates better imaging than a camera. Still, the safety rating leaned on exposure direction, divergence angle, power, pulse duration, and wavelength. A 1550-nm laser can safely radiate more power than a 905-nm laser before it becomes unsafe for the eye. The necessity to sense the surroundings has forced a race to determine the best LiDar to implement. However, the diversity of approaches brings significant uncertainty to the decision. They often depended on manufacturers and developers, which usually had some interest in the dispute.

Sonar (Sound Navigation and Ranging), the device that helps explore and map the ocean, has become another virtual device in a self-driving fleet. With LiDar and radar, Sonar has the advantage of good reading transparent or black surfaces, with a larger wavelength than LiDar. Therefore, most automotive manufacturers utilize sonar technology to avoid collisions. What about the side impact? Unfortunately, there is no specific study on how self-reliant vehicle sonar will affect the human auditory system (Bevly et al., 2016).

Nonetheless, a previous investigation said that even at the lowest powers, Sonar could cause lung hemorrhage or other tissue trauma that leads to death of marine mammals, temporary and permanent hearing loss, feeding disruption and physiological stress, and the change in distribution, abundance, as well as productivity. To humans, depression, memory disturbances, intellectual impairment, and other neuropsychiatric changes are mentioned in different studies. Similarly, how autonomous vehicle sonar will affect humans and the surrounding environment still needs to be determined.

Presume all those sensors put together in one car to reach its objective, a non-human driving car. Also, imagine half of the cars we use today will be equipped with all these sensors. While we know for sure based on the previous study, the sensor that we know could harm humans and other living things.

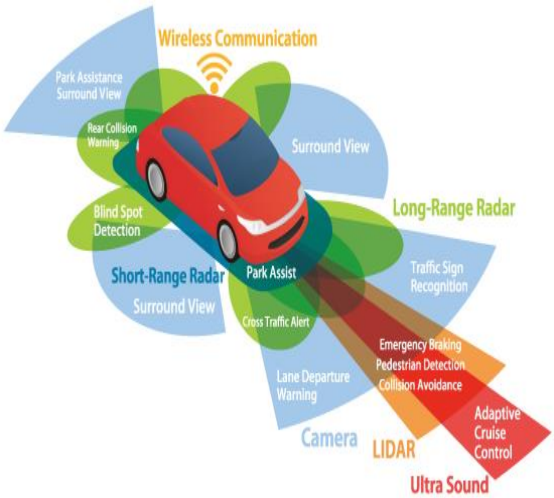


Figure 1. Self-Driving Car Crucial Technology

Literature Survey

When estimating radiation strength, some elements must be taken into account; they are :

1. Self-Driving Cars Level

According to SAE (Society of Automotive Engineers), there are s

ix levels of autonomous fleet.

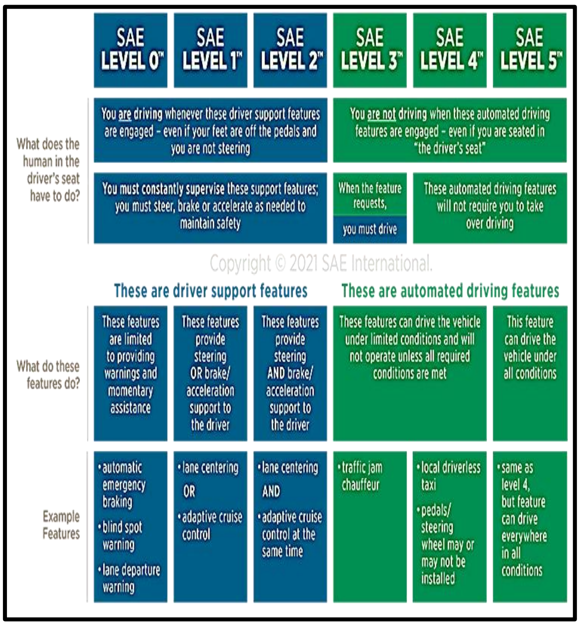


Figure 2. SAE Level of Driving Automation

The higher the level-the more sophisticated the technology and the more lidar, radar, and Sonar are involved. Now, let us investigate the technology installed in 2022 best driverless car.

Table 1. Technology Installed in Driverless Cars

Company	Level Reached	No. Technology Used			
		Lidar	Radar	Sonar	Cameras
Waymo	Level 4	5	6	-	29
GMCruise Aptiv Tesla Autopilot Uber Volkswagen	Level 4 Level 3 Level 3 N.A Level 4	5 9 - 7 6	21 10 1 7 11	- - 12 - -	16 2 10 20 14

Table 1 will help us recognize the strength of radiation emitted by Lidar, Radar, and Sonar from their lowest to their highest frequency.

2. Strength of EMF Radiation

An EMF is broadly classified into three major classifications: a) Magnetic fields; b) Radio-frequency; and c) Electric fields. The units commonly used to measure EMF radiation strength are Volts, Watts, and Gauss. The electric unit is volts per meter (V/m), and the magnetic unit is expressed as amperes per meter (A/m).

3. Factors to Consider When Measuring EMF Radiation

Here are some aspects that require to be assessed when measuring EMF Radiation:

a) Seasonal Radiation. There may be a season when the radiation might rise due to some factors. For instance, the ambient EMF radiation emitted from a power line. Higher radiation levels were recorded during hot temperatures when most air conditioning systems turned on. Likewise, the level of radiation might be higher in the evening than at any other time of day. The amount of electricity utilized at that time of day will be higher.

b) Multiple Types of EMF Radiation Emission. Many household appliances emit multiple types of EMF. There will be a good chance of generating both magnetic and electric-field radiation. For example, an induction cooktop, a hairdryer, Also, it is strongly likely to emit copious amounts of electric field radiation, radio-frequency, and magnetic field radiation. Like when working on a laptop while it has connected to Wi-Fi (Marti et al., 2019).

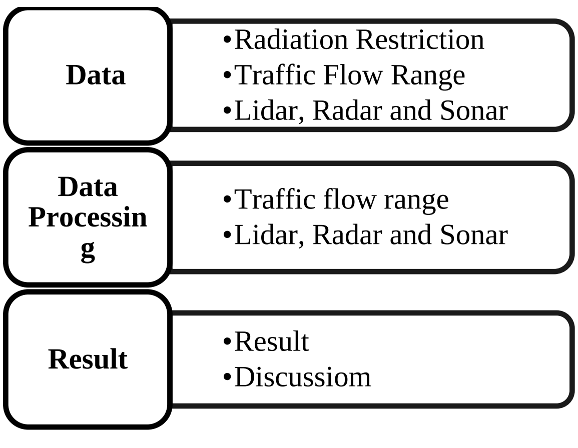
4. IEEE Standard for Safety Levels

Institute of Electrical and Electronics Engineers (IEEE) standard has designated limits and exposure criteria to prevent damaging human health effects related to magnetic, electric, and electromagnetic exposure in the frequency range of Hz to 300 GHz. These limits are expressed in dosimetric reference limits (DRL) and exposure reference levels (ERL);

a) Dosimetric Reference limits (DRL). DRLs, specific absorption rate (SAR), and epithelial power density, will not be discussed further in this journal.
b) Exposure Reference Levels (ERL). The journal will focus on ERL, which is easier to be determined. The variables are limits on external electric, magnetic fields, power density, and contact voltages intended to ensure that the DRLs are not exceeded. The limits will prevent adverse health effects associated with tissue electrostimulation and whole-body heating. However, patients under the care of medical professionals will be excluded from these exposure levels (Zang et al., 2019).

METHOD

This journal will examine and predict how worst Lidar, Radar, and Sonar could become in the range of each level of road density.



1. Radiation Restriction

Since there is no international standard for radiation limitation, this study will use the IEEE standard. Again, this journal will specifically discuss ERL exposure only, mainly frequency between 0 Hz to 100 kHz, which most car factories approve for autonomous sensors.

Within areas designated as power line rights-of-way (or similarly designated areas, e.g., easement or corridor), the ERL for persons in unrestricted environments is ten kV/m.

Table 2. Electric Field URLs (0 Hz to 100 KHz) Whole-Body Exposure

Persons in Unrestricted Environments		**Persons Permitted in Restricted Environments**	
Frequency Range (Hz)	***E*** c,d,e **(V/m)**	**Frequency Range (Hz)**	***E*** c,d,e **(V/m)**
0 to 368	5 000 [a]	0 to 72	20 000[b]
368 to 3000	$1.84 \times 10^6 / f$	272 to 2953	$5.44 \times 10^6 / f$
3000 to 100 000	614	2953 to 100 000	1842
NOTE 1-At five kV/m, induced spark discharges are painful to approximately 7 % of adults (well-insulated individuals touching the ground). NOTE 2-Painful discharges are readily encountered at 20 kV/m and are possible at five kV/m to 10 kV/m without protective measures.			

The limit of 20 kV/m may be exceeded in restricted environments when a worker is not within reach of a grounded conducting object. A specific limit is not provided in this standard. Tabulated values are given as RMS quantities. The assessed value shall be the spatial average of the RMS field strength over the projected height of the human body determined in the absence of the body (see D.1.2.1 for a discussion of spatial averaging and field perturbation caused by the observer). f is expressed in Hz.

2. Level of Sevice

Level of service (LOS) is defined as traffic service quality to analyze roadways and intersections by categorizing traffic flow into six levels; A, B, C, D, E F The performance was counted by traffic density, congestion, and vehicle speed. Moreover, it assigns traffic quality levels based on performance criteria like vehicle speed, traffic density, congestion, etc. Here is the standard used by AASHTO (American Association of State Highway and Transportation Officials) and other transport officials to categorize the traffic level and condition:

A: Free flow. The average vehicle spacing is about 550 ft(167m) or 27 car lengths. Drivers and riders are highly physically and psychologically comfortable. Level A occurs in urban areas and frequently in rural areas late at night.

B: Reasonably free flow. Where speeds are maintained, the traffic stream maneuver is slightly restricted. The lowest average vehicle spacing is around 330 ft(100 m) or 16 car lengths. Drivers and riders are still highly physically and psychologically relaxed.

C: Stable flow, at or near free flow. The lane maneuverability is noticeably restricted, and driver awareness is required to change lanes. Vehicle spacing is around 220 ft(67 m) or 11 car lengths. Still comfortable for most experienced drivers, road efficiency is close to capacity, and speed is maintained. Minor incidents may still have no effect, but traffic delays will follow behind the incident.

D: Approaching unsteady flow. Speeds slightly slower as traffic volume increases. Limited maneuver freedom and driver comfort levels decrease the spacing around 160 ft(50m) or eight car lengths. Minor incidents will create delays.

E: Unstable flow, operating at capacity. Irregular flow and varies speed vary unexpectedly. No usable gaps to maneuver in the traffic stream, and speeds rarely reach the posted limit. The spacing is around six car lengths. The speeds are still at or above 50 mi/h(80 km/h). Any disruption will create a shock wave affecting traffic upstream. Any incident will create severe delays a poor level of drivers' comfort.

F: Forced or breakdown flow. The maneuver of the vehicle is in lockstep with the front vehicle. Unpredicted travel time, with higher demand compared to capacity. There will be a constant traffic jam.

Service flow rates at LOS C or D are typically used in most design or planning phases to ensure a satisfactory operating service for facility users.

3. Traffic Flow Range

There is an association between traffic speed, volume, and density for a highway, and how these factors correlate to Level of Service ratings. Traffic speed and flow on urban streets are specified primarily by intersection capacity, which is affected by traffic volumes on cross streets and left turn signal phases. As these tables indicate, traffic congestion is a non-linear function. A slight reduction in urban-peak traffic volume can cause a proportionally more significant reduction in delay. For example, a 5% reduction in traffic volumes on a congested highway (for example, from 2,000 to 1,900 vehicles per hour) may cause a 10-30% increase in average vehicle speeds (for example, raising traffic speeds from 35 to 45 miles per hour). As a result, even relatively small changes in traffic volume or capacity on congested roads can significantly reduce traffic delays.

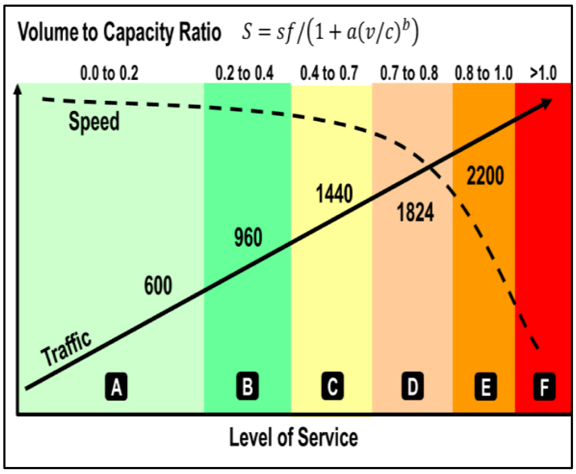


Figure 3. Graphic Levels of Service for Road Transportation

Grafik Source: Transportation Research Board (1994) Highway Capacity Manual, 3rd Edition. SF = free flow speed, v = volume, c = capacity, a = 0.15 and b=4.

(The Geography of Transport Systems, 2022)

Table 3. Level of Service Indicators

LOS	Speed Range (mph)	Flow Range (veh/hour/lane)	Density Range (veh/mile)
A	Over 60	Under 700	Under 12
B	57-60	700 – 1.100	20-Dec
C	54-57	1.100 – 1.550	20-30
D	46-54	1.550 – 1.850	30-42
E	30-46	1.850 – 2.000	42-67
F	Under 30	Unstable	67

Source: The Geography of Transport Systems, 2022

Table 4. Level of Service for Multi-Lane Road

LOS	A	B	C	D	E
4-lane freeway	700	1.100	1.550	1.850	2.000
2-lane freeway	210	375	600	900	1.400
4-lane highway	720	1.200	1.650	1.940	2.200

Source: The Geography of Transport Systems, 2022

RESULT AND DISCUSSION

The image illustrated the road situation with traffic dominated by autonomous vehicles.

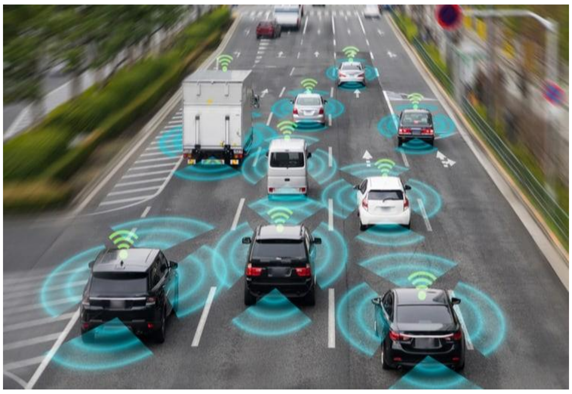


Figure 4. Self-Driving Cars Traffic Flow Illustration

Table 1 in the top, will help us identify the strength of radiation emitted by Lidar, Radar, and Sonar from their lowest to their highest frequency.

Table 5. Self-driving Technologies, Its Restriction, and Exposure.

Sensor	Frequency	Autonomous Vehicle Exposure	Restriction
Radar	24,74,77, and 79	1000 V/m	5000 V/m
Lidar	905-1550 nm	55 W	0.39 MW
Sonar	300 kHz up to 600 kHz	100 W/m2	190 W/m2

Seeing all these numbers, none exceeding its restriction, but all these counted per vehicle will no longer be relevant when traffic flow calculation is involved.

Soon, when autonomous cars become popular and dominate the road, the radiation based on the autonomous fleet's traffic flow must be considered. So to illustrate the condition, we will calculate this three-radiation based on each flow range in the level of service present in table 6.

Table 6. Future Prediction of Radiation Exposure by Level of Service Differentiation

LOS	Flow Range (veh/hour /lane)	Radar Exposure (V/m)	Lidar Exposure (W)	Sonar Exposure
A	Under 700	6,99x105	3,8x104	6,99x104
B	700 - 1.100	1,1x106	0,6x105	1,1x105
C	1.100-1.550	1,55x106	0,85x105	1,55x105
D	1.550-1.850	1,85x106	0,1x106	1,85x105
E	1.850-2.000	0,2x107	0,11x106	0,2x106
F	Unstable	>0,2x107	>0,11x106	>0,2x106

The calculation above shows a rough illustration of the exposure might be. The number of the calculation is excessively exceeding what is restricted on the safety level. Although many factors need to be evaluated before settling, at least the data will be beneficial to alert us that the future of autonomous fleets might not be as anticipated. Visualize having a long road lane with much radiation emitted, and you are stuck in one part of it as a passenger. Not to mention that dosimetric limits are also another issue to be resolved.

CONCLUSION

Since most autonomous car manufacturers have reached levels 3 and 4, measuring the accumulation c are obligatory. Moreover, unfortunately, all the technology utilized today has its thermal effect. With approximately 26 devices that radiate thermal effect in one car, we should be concerned about how it will affect the direct passenger or the living things around the lane.

Traffic flow is one the most straightforward methods; another technique for this prediction is applying the traffic vehicle density. Regardless, remember, the calculation is only a forecast. Thus, future analysis of what inherently affects the emission is critical. Although several other variables should be assessed for a more reliable outcome, the radiation rate shown in table 6 considerably displays the situation when the road is dominated by self-driving automobiles. Levels A, B, and C should be emphasized since one no-human intervention motorcar purpose is to avoid congestion. Accordingly, we should assume that levels D, E, and F will rarely be reached.

Automobile manufacturers need to take this prediction thoughtfully. Since the advancement of transportation technology can not be avoided, these manufactories must make improvements where needed to prevent the danger of their sensor's radiation.

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