# Hybrid Self-controlled vehicles for averting head-on collision

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**Abstract**

The excessive cases of fatal vehicle collisions are major concerns across the globe. Nevertheless, there are insufficient empirical simulations to illustrate the stages involved in head-on collisions between a smart vehicle and another smart vehicle over the years. Studies have also shown that about 90% of instant death recorded on most roads is caused by head-on collisions between two vehicles. Though vehicle collisions can occur between a vehicle and other objects such as tree(s), stumbling block, animal(s), etc, however, significant numbers of training schools do not have access to empirical software products that drivers can use to learn how they can lessen the impacts of head-on collision. Thus, most victims often suffer severe loss such as stern injury, permanent disability, death, when head-on collision in accidentally happen to them. Consequently, several road safety measures have been implemented in recent decades but they have limited success till date. Thus, this paper explores the above issues and proposes self-controlled vehicles to prevent them. The self-controlled vehicles are controlled by four different categories of inbuilt rules that have capabilities to instruct and regulate two vehicles commuting in opposing directions and they are implemented with Python programming language and relevant libraries. Series of evaluations with Gini impurity suggest the distributions of four basic stages before head-on collisions would occur between two vehicles. The results also suggest that there are most excellent distances of separation that two opposing vehicles must take the decisions that would enable them avoid head-on collisions. Finally, the designs can be valuable tools to driving schools in teaching and counseling prospective drivers on road accidents before issuance of driving license to them.

**Key words**: Vehicle collisions, head-on collisions, smart vehicles, Artificial Intelligence (AI), Smart city.



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## 1. Introduction

Modern practical, convenient and saleable vehicles have been manufactured for daily use in villages, towns and cities some centuries ago. The most important reason for inventing them was to achieve convenient transportation of people and goods from one place to another on roads in a faster manner.  Roads can easily connect villages, towns, and cities, together and encouraging transportation flow of goods, services and people across them. However, despite these laudable innovations, safety, structural defects, bad topology of roads and limited landscape to construct viable roads have become major issues and challenges that are confronting the construction of wider roads for vehicles in some geographic locations across the globe.

Road construction is the design, building, extension (or expansion) and maintenance of roads, express ways and related infrastructure such as bridges and canals in the society. Some roads were constructed with asphalt, bitumen and materials such as concrete sand, stones, gravel etc. The construction of some roads may require laborious operations and the road construction workers may take several years to complete them. Studies have shown that the techniques used by road construction workers to construct private and public roads have gradually improved over time. Some studies have focuses on the quality of materials for constructing roads, road traffics, thickness of stone, road alignment, and slope gradients, Emphasis is often placed on the above processes to achieve well-constructed roads that will ultimately enhance operational effectiveness, reduction in the travel delay and ensuring safety of travelers.  Nevertheless, there are excessive cases of fatal head-on collisions of vehicles across the globe.

Besides, feelers believe that there are insufficient empirical simulations that training schools can adopt to illustrate the basic stages involved in teaching drivers on head-on collisions between two smart vehicles over the years.  Unfortunately, recent empirical claims have shown that approximately 90% of instant death recorded on most roads is caused by head-on collisions between two vehicles. WHO (2023) specifically reports that over one million people die every year due to road traffic crashes and leave close to 50 million people disabled. Some contemporary studies have correlated vehicle collisions with reckless driving, distraction, illegal overtaking and driving under the influence of substance abuse such as narcotics and alcohol (Peterson Law Office, 2024; Kardar and Davoodi, 2020). The argument is that drunk driving and intoxication can affect the mental, psychic and instinct of drivers to drive in the way that would avoid vehicle collisions (Sassi et al, 2018).

The correlations between vehicle collisions and road constructions have shown that significant proportion of head-on collisions can be linked to poorly marked detours that mislead drivers to unexpectedly deviate from direct course of travelling. Poor detours can obstruct visibility during driving and drivers that confused could end up experience head-on collisions. In addition, even road surfaces, sudden changes in lanes and road debris on the roads can facilitate head-on collisions. Inadequate warning signs to indicate imminent dangers, construction work in progress and faulty vehicles that have not been towed off the roads can



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increase the risk of head-on collision. Consequently, there are alarming increases in different categories of vehicle collisions around the globe. Road traffic injuries are the leading basis of death among children and adults between the ages of 5 and 29 years (WHO, 2023; Kardar and Davoodi, 2020). Of most significant of these problems are the severe impacts of the head-on collisions whenever they occur among some vehicles that commute via roads that have limited width in some developed and developing countries (Adanu et al, 2023). The above issues have necessitated new challenges and how to immediately institute initiatives that will reinforce public safety and assist regional economy to regulate costs that policyholders and insurance companies could incur on victims of vehicle collisions in the society.

Furthermore, head-on collisions were responsible for practically 11% of the fatal motor vehicle collisions in the USA in 2023 and the age range of the most victims are 20 years and above (Insurance Information Institute (2024). Collision reports have also shown that over 89% death rates due to road accident is linked to head-on collision between two vehicles in most countries of the globe. The victims of head-on collision between two vehicles can be economically ruined and suffer from permanent disabilities. Depending on the speed of the vehicles at the point of head-on collision, the accident can lead to collateral damage. The affected vehicles may be completely condemned or written off. Besides, the repair of the damaged vehicles will surely affect the insurance expenditure, personal overheads and servicing costs for insured vehicles.

Contemporary studies have pinpointed out the possibility of stress, stereotype and phobia been linked to previous experience of head-on collision (Adanu et al, 2023). The attitudes and psyche of people with such traumatic experience may raise public mental health concerns especially if they onboard vehicles and envisage closely related events that may lead to head-on collision. Phobia to travel with vehicles may indirectly affect the profitability that vehicle owners, tax collectors and automobile companies should derive from vehicles that generally ply local and highways in some localities (Sassi et al, 2018). Moreover, the above problems have been triggering the largest global automation crisis in more than two centuries till date without permanent solutions. Some governments, engineers, automobile and construction companies, etc continue to implement strategies and safety measures to counter the above menace over the years. Some roads were constructed to strictly allow two-way travels. The premise is that such roads will enable more than two lanes of commuting and vehicles are allowed to travel in both directions. Conversely, there are some roads that are one-way where all vehicles are mandated to move in one direction. In this case, there is no vehicle that is allowed to commute in the opposite direction. The above contestable issues have made the domains of vehicle safety and vehicle collision very critical to study in a recent time (Mukhtar et al, 2015; Narayanan et al, 2021; Farhat, et al, 2024). The ongoing global economic downtimes, the extent of traffic congestion that is expected (or experienced) in some regions and the economic implication that often associates with the construction of multilane highways are novel issues in recent years (Wali et al, 2018; Liu and Fan, 2020). The reason is that some highways suppose to run up to four, eight,



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twelve lanes, etc. The lanes of such modern roads must be clearly demarcated with strong barriers. Hence, with limited human and material resources, some countries have restricted the construction of their current roads to just two-way or four-ways travels without demarcation. Unfortunately, most of the existing studies have not thoroughly provided pragmatic approach that would enable stakeholders to clearly understand the rudiments of head-on collisions of two vehicles.

Thus, the main objective of this research paper is to use object oriented programming language to design and implement self-controlled vehicles that can prevent head-on collisions. One of the significant contributions of this paper is ability to implement self-controlled vehicles that are capable of avoiding head-on collisions with each other. The paper thoroughly provides pragmatic ways of understanding the categories of stages involved in head-on collisions of vehicles. The remainders of this paper are organized as follows. Section 2 discusses related studies, section 3 provides theoretical basis of head-on collisions between two vehicles. The section also discusses the choice of using Gini Index to evaluate the model. Section 4 explains the methodology that is used to design and implement the above concepts of self-controlled vehicles. Section 5 provides key results of some simulations of the design and section 6 concludes the paper.

## 2. Related work

Vehicle collision is an active area of research in a recent time (Mukhtar et al, 2015; Narayanan et al, 2021; Farhat, et al, 2024). Ji et al (2017) designed path-tracking algorithm that uses 3-D technique and trigonometric functions of the road to predict suitable trajectory that autonomous vehicles can follow to avoid collision with obstacles. The algorithm computes the front steering angle that the single vehicle can safely steer through and prevent it from colliding with a moving obstacle (Ji et al, 2017; Muzahid et al, 2023). However, the simulated algorithm is limited to the existence of moving obstacles on a road.

Marchidan and Bakolas (2020) used collision-avoidance vector fields (CVFs) to produce smooth and intuitive maneuvers curve to avoid collision with static and moving obstacles. Meanwhile, there are some other vehicle collisions that can occur due to driving attitudes of the drivers on the road and sudden drifting and pulling of some vehicles off the road. For instance, some drivers that do not get enough sleep before hitting the roads may suddenly be exhausted especially if they are driving for long hours (Abegaz et al, 2014).

Bram-Larbi et al (2020) use Augmented Reality (AR) projection to propose a model that drivers would require to manage distraction and respond to incoming vehicles that are mostly on emergency services. The advantage of the model is that it may enable beneficiaries to learn through visual and auditory perception. However, the fact that Augmented Reality depends solely on hands-on experiences can make it difficult for some drivers to respond to strange



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distractions such as like distress signals and police siren that are not necessarily related to emergency services.

## 3. Fundamentals of head-on collision of two vehicles

Vehicle collisions are otherwise known as vehicle accidents (Ji et al, 2017). These problems are serious global threats that have claimed significant numbers of people in developing and developed countries (Narayanan et al, 2021). World Health Organization (WHO) reports that over 1.2 million people died yearly as a result of vehicle accident in recent time (WHO, 2023). Vehicle accidents can cause personal injury, severe damage to properties and incurable lost. How to perfectly address various issues involved with avoiding collisions and other factors such as pot holes, unclear road lines or markings, and unexpected weather conditions are attracting global concerns both in academia and industrial sectors (Yuan et al, 2020). There are several causes of vehicle accidents. Some accidents are caused by driver error, distracted driving, drunk driving, over speeding, lack of adherence to traffic rules such running without observing red lights or stop signs, etc. Long hours of drive, fatigue, tiredness and pedestrian negligence also contribute to major causes of road accidents across the globe (Feng et al, 2021; Abegaz et al, 2014).

Basically, there are technical considerations that underlying various causes of vehicle collisions across the globe (Adanu et al, 2023). Usually, there is the most excellent distance for two vehicles to take the decision that would enable them to avoid each other. Besides, vehicles have specific speed and distance location that they can suitably avoid collision with each other. Another important fact is that there is a suitable reaction time that both drivers must take accurate decisions and safely maneuver each other otherwise they are likely to collide. Thus, vehicle accident occurs whenever one vehicle collides with another vehicle that is in a static location or dynamic motion on a road. Studies have shown that significant numbers of accidents had occurred due to head-on (or body) collision where both vehicles are in moving in opposite directions.

A head-on collision occurs whenever the fronts of two vehicles commuting in an opposite direction violently crash with each other. Vehicle accidents are global threats that are claiming significant numbers of people in developing and developed countries (Narayanan et al, 2021). World Health Organization (WHO) reports that over 1.2 million people died yearly as a result of vehicle accident in recent time (WHO, 2023). Vehicle accidents can cause personal injury, severe damage to properties and incurable lost. How to perfectly address various issues involved with avoiding collisions and other factors such as pot holes, unclear road lines or markings, and unexpected weather conditions are attracting global concerns both in academia and industrial sectors (Yuan et al, 2020).

### 3.1. Stages involved in head-on collision of two vehicles

It is unsafe and unethical to arrange two drivers to practice (or simulate) how head-on collision can occur between two vehicles in reality. The depth of damage to vehicles and the



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proportion of the injury that both divers could incur may be severe (Wali et al, 2018; Liu and Fan, 2020). Experience suggests that there are four basic stages that are involved in head-on collision of two vehicles. The first stage occurs where both vehicles are still far apart from each other. This is the stage whereby on no account should they experience head on collision with each other. Conversely, the second stage is a subsequent stage after the first stage. This is the stage whereby both vehicles must sense the imminent danger of experiencing head-on collision with each other and must decide to react to the imminent danger.

In addition, there is the third stage whereby both vehicles must take the decisions to avoid head on collision and steer away from each other. Thereafter, both vehicles must realign and maneuver themselves back to continue their journey on their respective lanes. For all intents and purposes, we premise that head on collisions can potentially occur between two opposing vehicles commuting on the same road whenever their drivers improperly manage the above four stages.

### 3.2. Physical measures for preventing head-on collision of two vehicles

There are some notable techniques that have proved effective in controlling specific examples of head-on collision of two vehicles. For instance, road demarcation is a construction procedure to mark and demarcate some narrow edges along a road, roadside or wayside by lines, pavements, symbols; lettered (or painted) messages (Nigeria Highway Code, 2024). The purpose of road demarcation is to direct the movement of vehicles that are commuting in the opposite (or similar) direction of the same road. Road demarcations are designed to prevent drivers, bikers and pedestrians from getting close to a dangerous region of the road.

Figure 1 illustrates some of the commonest classifications of vehicle collision avoidance measures across the globe. Segregation Barrier System (SBS) is a kind of the metallic braces (or barriers) firmly erected in some high streets, parks and warehouses to protect workers, pedestrian and vehicles from the risk of vehicle collisions. Narrower lane widths are designed to reduce the widths of lanes in streets to create enough space for bike riders and sidewalks. The idea is that sight distance together with suitable parking lane widths can provide extra safety margins required to maneuver head-on collision in conventional streets. Dual carriageway is another physical measure to avoid head-on collision. A dual carriageway road is constructed to have double lanes for accommodating vehicles travelling in opposite directions (i.e. two carriageways) to each other but they are clearly separated by concrete barriers, grasses, etc. In addition, centre line marks are constructed with solid or broken lines to visually appeal to drivers on the side of the center line. The purpose of centre line marks is to forbid the overtaking of vehicles in both the directions that are marked with centre lines. Physical division of lanes is a permanent or temporary strategy to create physical barriers that will divide lanes into two lanes in a road. The method is used to reduce speed of vehicles and organize vehicles to move in orderliness.



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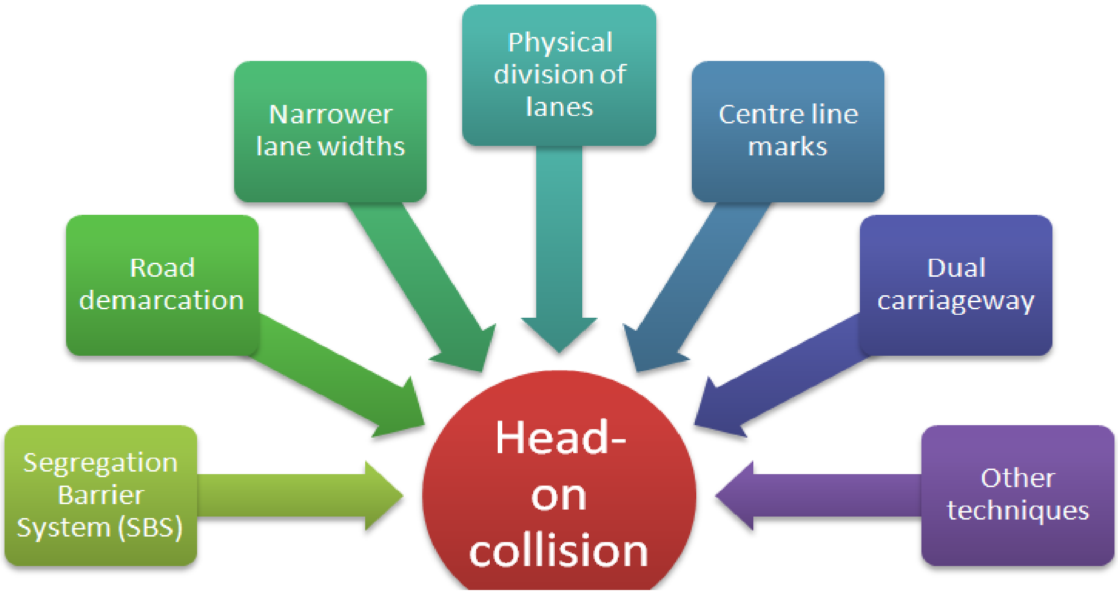


Figure 1: Classification of vehicle collision avoidance measures

### 3.3. Challenges with physical measures for preventing head-on collision of two vehicles

The challenges with physical measures for preventing head-on collision of two vehicles are many. For instance, most vehicle collision avoidance measures can only control head-on collision wherever they physically exist on roads. Besides, human factors such as negligence, disregard of traffic rules, lack of patience, intolerant, miscalculation of suitable distance to maneuver head-on collision and criminality are few of several factors that can limit the efficacies of the above strategies.

Research believes that stress and fatigue due to long driving can make some drivers to have head-on collision. For instance, physical separation of lanes by traffic barricades, barriers or dividing structures must be strong and tall enough so that vehicles would not be able to accidentally jump over them. Vehicles that accidentally jump over dividing structures can as well cause head-on collision in another lane or route.

### 3.4. Gini Index for evaluating self-controlled vehicles

The decisions of two self-controlled vehicles can be monitored to ascertain the level of similarity in them. Gini index is a statistical metric that can be used to estimate the quality and distributions of various stages involved in head-on collision of two vehicles (Tangirala, 2020). Mathematically, gini index is expressed in equation (1) below:



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$$Gini = 1 - \sum_{n=1}^{n} \mathrm{P(i)2} \qquad \text{-----------------------------------} \qquad (1)$$

Where *pi* is the probability of the stage that is to be classified or clustered in each class.
The choice of using Gini index is due to the fact that it requires less computation power and it is not resource intensive compared to other statistical metrics for measuring the distributions of clustered datasets (Lee et al, 2022). In this context, the higher the gini index, the more unique is the decisions taken by the vehicle.

## 4. Methodology

The self-controlled vehicles for preventing head-on collision that is proposed in this paper is designed and implemented with Python programming language and its related libraries. The program has four categories of inbuilt rules to instruct and regulate both vehicles. Figure 2 illustrates the initial distance of both vehicles before the commencement of their journey. The program uses its first inbuilt rules to determine the relative positions of both vehicles to each other and simulate the potential risk that they may engage in head-on collision as they commute towards each other. The simulation distance between both vehicles was 1000 meters.

Figure 2: The design of vehicle collision avoidance system

Furthermore, the program uses its second inbuilt rules to trigger the sensor module, calculate and concurrently log the distances of separation of both vehicles as they are traveling towards the Critical Decision Point (DCP). The DCP is a location between both vehicles must share safety information. The selected DCP is 20 meters and it signifies the particular location between both vehicles must also beep to alert each other of impending collision (danger). The choice of 20 meters as a benchmark is selected based on the series of simulations that are carried out to determine the suitable point that both cars should avoid head-on collision. The third category of the inbuilt rules of the program has three basic functions. The program uses its third inbuilt rules to instruct each vehicle to use their inbuilt sensors to invoke automatic brakes whenever the distance of separation of both vehicles equal to 15 meters apart. Besides, the rules also trigger the Velocity Control Module (VCM) to enable each vehicle to subsequently control their respective velocities. Shortly after that, the inbuilt rules trigger the Sensor Control Flags (SCF) to notify



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Collision Avoidance Decisions (CAD) database. The fourth category of the inbuilt rules of the program performs two basic functions. Firstly, the rules receive input data from the CAD and redirect each vehicle so that they will avoid having head-on collision with each other. Figure 3 illustrates how both vehicles have automatically avoided head-on collision with each other.

Figure 3: Automated vehicle collision avoidance system

Moreover, another category of the fourth inbuilt rules of the program triggers the Alignment Regulatory Module (ARM). The purpose of using the ARM is to automatically regulate the placement of both vehicles back to the main road (or their respective lanes) so that they can continue their journey. Figure demonstrates how both vehicles evidently realign back to their respective lanes after they have automated avoided head-on collision with each other.

Figure 4: Alignment of automated vehicles after avoiding head-on collision

In essence, series of experimental simulations and iterations of the above scenarios are carried out by also varying the distances that separate both vehicles from each other. Some of the key results of the above simulations are tabulated and subsequent discussed below.

## 5. Results and analysis

Figure 5 illustrate head-on collision point of both vehicles if they fail to take necessary caution. Both vehicles were initially at 1000 meters from each other.



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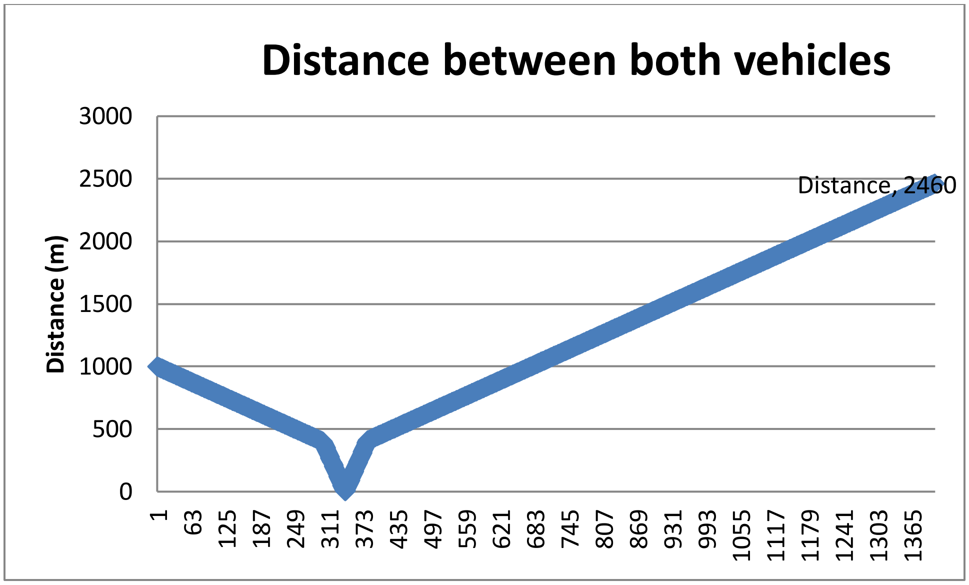


Figure 5: Head-on collision point

The results also suggest that the distance of separation of both vehicles was reducing and they were able to take the decision to avoid head-on collision when their distance of separation has reduced to about 10 meters. In other words, both vehicles were able to successfully drive pass each other when their distance of separation was 0 meter.  In addition, Figures 6 and 7 suggest the trajectory taken by vehicle1 and vehicle2 before and after they avoided head-on collision with each other.

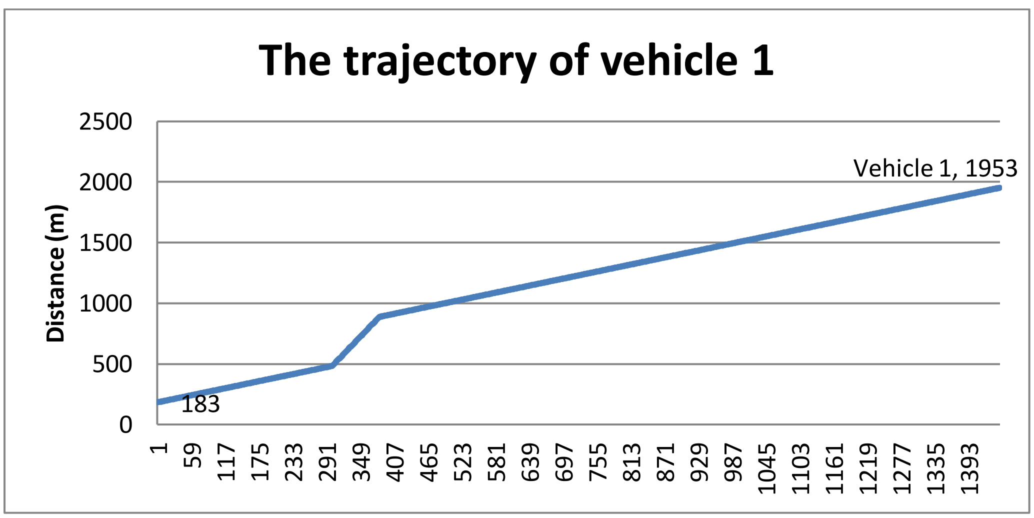


Figure 6: Trajectory of vehicle1 before and after avoiding head-on collision



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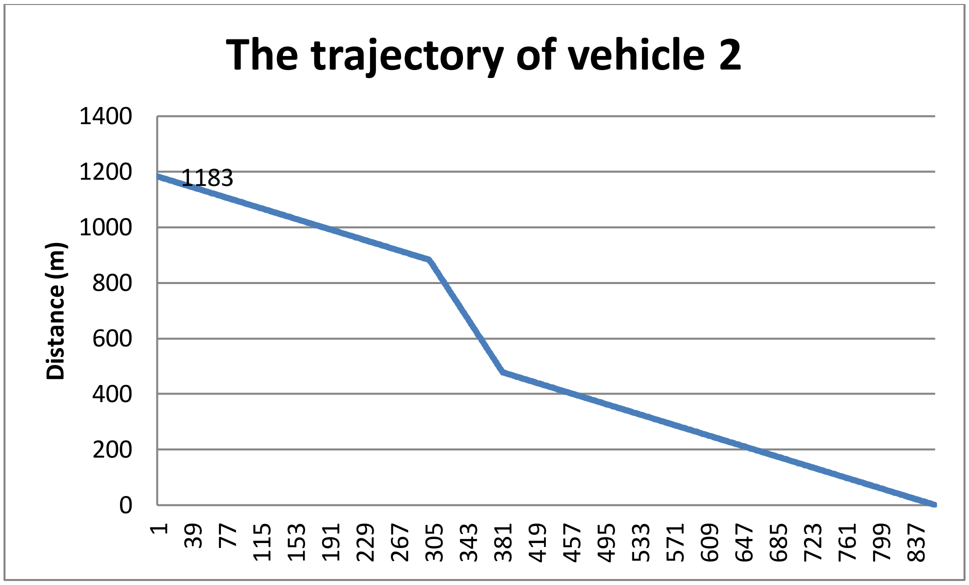


Figure 7: Trajectory of vehicle2 before and after avoiding head-on collision

Figure 8 indicates the tracking of distance of separation of both vehicles during the simulation. The observations suggest that the Gini Index of the vehicles before and after avoiding head-on collision is not the same. The values suggest that both vehicles covered wider distance after they have avoided head-on collision when compared to their distance of separation before avoiding head-on collision.

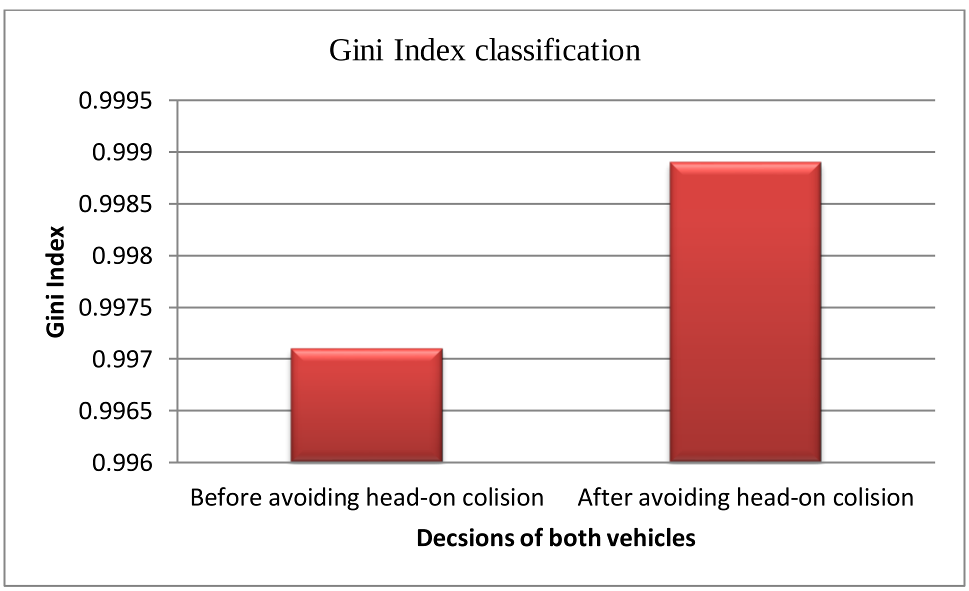


Figure 8: Evaluation with Gini Index



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The above results have several implications required to automatically design automobiles that can avert head-on collision with another vehicle. The fact is that there are several other causes of vehicle collisions other than the above factors. Some vehicle collisions are caused by drivers' errors, distracted driving, drunk driving, over speeding, lack of adherence to traffic rules. Drivers that speed without observing traffic signals such as red lights or stop signs can have head-on collision with opposing vehicles. Long hours of drive, fatigue, tiredness and pedestrian negligence also contribute to major causes of road accidents across the globe. Thus, we suggest the need to also place emphasizes on the technical considerations that underlying various causes of vehicle collisions across the globe. Our findings suggest that there are most excellent distances of separation between two vehicles commuting in opposite directions to take the decisions that would enable them avoid head-on collision with each other than their respective of speed.

## 6. Conclusion

This paper has shown that vehicle collisions are global threats that have destroyed significant numbers of lives and properties both in developing and developed countries across the globe. The impact of the problem on victims can lead to inability to recover from injury, permanent disabilities, severe damage of affected properties and incurable financial and material lost. Several strategies and measures have been deployed by governments and automobile companies to counter the menace of head-on collisions between vehicles over the years. However, the best strategies that can perfectly address the various issues that associated with how commuters can always avoid collisions are obscure till date. Some feelers have discussed factors such as pot holes, unclear road lines or markings, psychological disposition of drivers and unexpected weather conditions as issues that should attract global concerns both in academia and industrial sectors to reduce the frequency of the above problems over time. Some of the above issues have been thoroughly explored and implemented with a suitable programming language in this paper.

The above findings suggest that vehicles have specific speed and distance locations that they can suitably avoid head-on collisions with each other. Another important fact is that there is a suitable reaction time that both drivers must take accurate decisions and safely maneuver each other otherwise they are likely to collide. Thus, we argued that vehicle collisions can occur whenever one vehicle collides with another vehicle that is in a static location or dynamic motion on a road once the above findings are not taken into consideration. This paper has discussed some of the factors that can induce head-on collisions of vehicles on roads. The paper believes that training schools should incorporate the concepts of vehicle collisions into the scheme for training drivers to lessen the above problems.

There are several ways that head-on collisions can occur. Some head-on collisions may involve one vehicle and pedestrian or objects such as houses, animals, roadside demarcating blocks, and stationary bodies such as drums, trees, electric poles, etc. We arguably state that severity of the impact of head-on collisions were not studies in details in this paper. We believe



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that victims of head-on collisions and how they incur wounds, temporary or permanent disabilities, property damage, financial loss or bereavement may not always associated with the speed of the vehicles that cause the collisions in all cases. Besides, two vehicles may not necessarily have to commute in opposite directions before they can collide together. Besides, head-on collision can also occur when one the above two vehicles is not self-controlled.

Several other factors can as well contribute to the risk of head-on collisions between two vehicles or between a vehicle and any other object. Thus, future research can focus on autonomous vehicles for learning impact of vehicle design, vehicle speed; road construction, driving attitudes and driving skills on head-on collisions to extend the coverage of the above research. Finally, we intend to explore the above issues and other forms of vehicle collisions in our future research.

Reference

Adanu EK, Agyemang W, Lidbe A, Adarkwa O. and Jones S (2023). An in-depth analysis of head-on crash severity and fatalities in Ghana. *Heliyon*. 4;9(8):e18937. doi: 10.1016/j.heliyon.2023.e18937. PMID: 37600396; PMCID: PMC10432195.

Adanu E.K., Riehle I., Odero K. and Jones S. (2020). An analysis of risk factors associated with road crash severities in Namibia. *International Journal of Injury Control and Safety Promotion*.;27(3), pp. 293–299.

Abegaz T., Berhane Y., Worku A., Assrat A. and Assefa A. (2014). Effects of excessive speeding and falling asleep while driving on crash injury severity in Ethiopia: a generalized ordered logit model analysis. *Accident prevention & analysis*.71: pp. 15–21.

Bram-Larbi, K. F. , Charissis, V., Khan, S. , Lagoo, R., Harrison, D. K. and Drikakis, D. (2020). Collision Avoidance Head-Up Display: Design Considerations for Emergency Services' Vehicles, Proceeding of the 2020 IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, USA, , pp. 1-7, doi: 10.1109/ICCE46568.2020.9043068.

Feng, S., Qian, Y., & Wang, Y. (2021). Collision avoidance method of autonomous vehicle based on improved artificial potential field algorithm. *Journal of Automobile Engineering*, 235(14), pp. 3416-3430.

Farhat, W., Ben Rhaiem, O., Faiedh, H., & Souani, C. (2024). A novel cooperative collision avoidance system for vehicular communication based on deep learning. *International Journal of Information Technology,* 16(3), pp. 1661-1675.

Insurance Information Institute (2024). Facts + Statistics: Highway safety. Available at: https://www.iii.org/fact-statistic/facts-statistics-highway-safety. Accessed on 12/06/2024



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Ji, J., Khajepour, A., Melek, W. W. and Huang, Y. (2016). Path Planning and Tracking for Vehicle Collision Avoidance Based on Model Predictive Control With Multi-constraints, *IEEE Transactions on Vehicular Technology*, vol. 66, no. 2, pp. 952-964, doi: 10.1109/TVT.2016.2555853.

Kardar A.and Davoodi S.R. (2020). A generalized ordered probit model for analyzing driver injury severity of head-on crashes on two-lane rural highways in Malaysia. *Journal of Transportation Safety & Security*;12(8):1067–1082

Liu P. and Fan W. (2020). Exploring injury severity in head-on crashes using latent class clustering analysis and mixed logit model: a case study of North Carolina. *Accident prevention & analysis*;135, 105388

Lee, S., Lee, C., Mun, K. G., and Kim, D. (2022). Decision tree algorithm considering distances between classes. IEEE Access, 10, 69750-69756.

Mukhtar,A., Xia, L. and Tang, T.B. (2015). Vehicle Detection Techniques for Collision Avoidance Systems: A Review, *IEEE Transactions on Intelligent Transportation Systems*, vol. 16, no. 5, pp. 2318-2338, , doi: 10.1109/TITS.2015.2409109.

Marchidan, A. and Bakolas, E.(2020). Collision Avoidance for an Unmanned Aerial Vehicle in the Presence of Static and Moving Obstacles. *American Institute of Aeronautics and Astronautics*, 43 (1). https://doi.org/10.2514/1.G004446

Nigeria Highway Code (2024). Nigeria Highway Code, 2015-2023. Available at: https://www.highwaycode.com.ng/vii-road-markings.html. Accessed on 10/06/2024

Peterson Law Office (2024). What Is the Death Rate of Head-On Accidents? No. 2424 Harrodsburg Road, Suite 205, Lexington, KY 40503

Available at https://www.justinpetersonlaw.com/car-accidents/what-is-the-death-rate-of-head-on-accidents/ Accessed on 12/06/2024

Sassi S., Hakko H., Räty E.and Riipinen P. (2018). Light motor vehicle collisions with heavy vehicles-psychosocial and health related risk factors of drivers being at-fault for collisions. *Forensic Science International journal*. 291: pp. 245–252.

Tangirala, S. (2020). Evaluating the impact of GINI index and information gain on classification using decision tree classifier algorithm. International Journal of Advanced Computer Science and Applications, 11(2), 612-619.

World Health Organization (2023). Road traffic injuries. Available at: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries. Accessed on 12/06/2024



14

Wali B., Khattak A.J. and Xu J. (2018). Contributory fault and level of personal injury to drivers involved in head-on collisions: application of copula-based bivariate ordinal models. *Accident prevention & analysis*;110: pp. 101–114.

Yuan, Y., Tasik, R., Adhatarao, S. S., Yuan, Y., Liu, Z., and Fu, X. (2020). RACE: Reinforced cooperative autonomous vehicle collision avoidance. *IEEE transactions on vehicular technology*, 69(9), pp. 9279-9291.



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