

The Plague of Aggressive Driving: Definitions, Causes, Severity, Consequences, and Solutions

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Abstract

The paper looks into aggressive driving as a whole. First, different definitions from different sources were introduced. The differences in definitions were discussed depending on the reporting entity, including newspaper articles, research studies, and legal documents (laws). Then, the authors provided a comprehensive definition to accommodate all purposes of an aggressive driving definition. Next, to better understand aggressive driving, the causes of aggressive driving were discussed, and vulnerable groups were highlighted. The causes are split into demographic, societal, environmental, situational, and personal traits. The severity and consequences of aggressive driving were illustrated to provide an image of the issue's intensity. One highlight is that 89% of drivers admit to participating in aggressive driving behaviors [1] [2]. The currently adopted solutions to combat the problem were divided into engineering, education, and enforcement. An elaboration of each tactic was discussed. Then, some creative solutions were addressed. Engineering and education solve the problem before it becomes an issue on roadways. As for enforcement which, as it increased, fatalities decreased; can ensure all drivers comply with the rules. The conclusion is that a combination of all three solutions is needed to achieve an efficient model of fighting aggressive driving.

Keywords

Aggressive Driving, Traffic Engineering, Driver Behavior, Transportation

1. Background and Introduction

1.1. Definitions of Aggressive Driving

Aggressive driving behavior, more commonly referred to as road rage, is a prevalent global issue. In a paper published by The United Nations Economic Commission for Europe (UNECE), aggressive driving was described as beha-

vivors that include speeding, not leaving enough safety gap between the vehicle in front of the driver, weaving improperly, not abiding by the traffic rules, tailgating and the list goes on and on [3] [4]. In some extreme cases, aggressive driving might take the form of cursing, physical violence, or even murder [5]. The definition and driving actions listed under the road rage umbrella vary depending on the entity defining the phrase.

1.1.1. Definitions Based on News Articles

When reading news articles reporting aggressive driving incidents, road rage is often defined by the action taken to inflict harm onto another driver. For instance, in an article reporting a case of road rage, the title included the words “shooting incident”; later, the article identified this as a case of road rage [6]. Another report described the road rage incident as two men shooting at each other’s vehicles during a fit of road rage [7]. Many other news articles list examples of such incidents filing them under the road rage umbrella, varying from actions such as stabbing [8], assaulting [9], punching [10], and so on. The extreme wording or actions reported can be attributed to news outlets having an exaggeration bias where only the most extreme cases of road rage are reported. Therefore, this has led to road rage being associated with the action rather than the underlying causes of it or the more general consequence of inflicting harm in whichever form possible.

1.1.2. Definitions Based on Legal Documents

Suppose aggressive driving is to be explored from a legal standpoint. In that case, the definitions will be steered towards identifying what specific driving patterns violate existing rules and are considered to fall under aggressive driving behaviors. Then, as expected, the associated legal consequence of said violations would be listed. For example, in Delaware, aggressive driving behaviors were listed as violations of specific driving rules and the fines associated with said infringements [11]. Some violations were about driving within a traffic lane, speed restrictions, following too closely, yielding to the right of way, and so on. The consequences of participating in aggressive driving actions in the state of Delaware varied from fines, imprisonment, and mandatory driving courses [11]. Legal documents against aggressive driving follow a pattern of defining actions considered aggressive and listing the consequences of said actions [12].

1.1.3. Definitions Based on Research Articles

Aggressive driving can be explored from a research standpoint. In a study attempting to distinguish the difference between driving errors and violations, driving violations were broken down further into “normal” and “acting aggressively” [13]. The group categorized as aggressive was defined as “acting aggressively toward other road users.” These include becoming angry, giving chase, and indicating hostility toward another driver.” Another study described aggressive driving with more attention to the several forms in which it might present itself. The actions included inflicting harm physically, emotionally, or psycho-

logically on other drivers [14] [15].

On the other hand, aggressive driving was described as the consequence of the driver's stress [16]. The stress, in turn, led to aggressive behaviors such as tail-gating and generally increased irritation. While these studies attempted to define road rage as its precursor causes or direct consequences, another definition focused more on the specific actions that characterize aggressive driving by listing hostility, increased risk-taking behavior, speeding, and reckless maneuvers as the indications of "angry driving" [17].

1.1.4. Summary of Definitions

The listed definitions thus far were from three different reporting entities, as shown in **Figure 1**. The first source was news articles that looked into aggressive driving strictly as the specific action taken in the reported incident. The news outlets focused on violent cases of aggressive driving, which are more appropriate for news reporting to grab the reader's attention. However, aggressive driving can be much more than just those extremely violent incidents and can be identified within a smaller scale of actions. Therefore, legal definitions were also introduced. Legal definitions of aggressive driving, while detailed on the type of action considered as road rage and the legal consequence of it, still neglected the core of aggressive driving. Thus, this is where the research-based definitions come in. As previously stated, the listed studies mainly investigated aggressive driving as the emotional base of the action and the more general consequence for the general population of motorists. Therefore, an all-encompassing definition would combine the intent, consequence, and cause of the act of aggressive driving.

1.1.5. Authors' Definition of Aggressive Driving

In this paper, aggressive driving will be defined as operating a motor vehicle with the intent to cause any form of harm, whether physical, mental, or emotional, to other individuals or property, leading to an increased risk of accidents, injury, or death due to impatience, frustration, general stress, or hostility. The actions and consequences of said behavior are to be defined by the appropriate governmental entity, such as the police. The specific actions considered to be aggressive driving can be a combination of several driving incidents happening simultaneously or in succession. The list can include failing to abide by the posted speed, recklessly overtaking another vehicle, failing to comply with the lane markings, driving on the shoulder, not permitting other drivers to pass, failing to abide by signals, stop signs, or yield signs, driving too closely to another vehicle for a considerable amount of time, purposefully driving into another vehicle, the use of any violent or suggestively threatening gestures, words, or devices such as guns or knives.

1.2. Paper Content Summary

The paper will elaborate on some literature reviews, including causes of aggressive

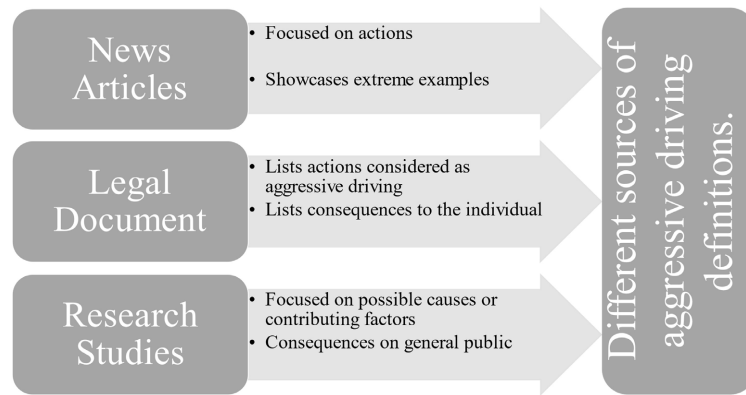


Figure 1. Aggressive driving definition sources.

driving, severity, and consequences, and currently adopted solutions. Then, a discussion of the presently adopted solutions will be provided while highlighting both pros and cons of each approach. Next, the authors will offer suggested solutions based on literature and improvements to currently adopted solutions. Finally, a conclusion will be provided as a summary of the paper. The flow of the paper is illustrated in **Figure 2**.

2. Literature Review

This section will provide a literature review of the current state-of-the-art research on aggressive driving. The details of said current research will include causes, severity, and consequences and currently adopted solutions for aggressive driving.

2.1. Causes of Aggressive Driving

As previously discussed, aggressive driving has many definitions, as it is difficult to pinpoint its source and varying attitudes. To better understand the underlying causes of aggressive driving, first, the actions considered aggressive driving must be elaborated. The list was adopted from a research report on aggressive driving by the Foundation for traffic safety [18] and is as follows:

- Following improperly.
- Improper or erratic lane changing.
- Illegal driving on the road shoulder, in a ditch, sidewalk, or median.
- Passing where prohibited by posted signs, pavement markings, hill or curve, or school bus displaying a warning not to pass, passing on the wrong side, passing with short distance or inadequate visibility, or failing to yield to overtaking vehicle.
- Operating the vehicle erratically, recklessly, carelessly, or negligently or suddenly changing speeds.
- Failure to yield the right of way.
- Failure to obey traffic signs, traffic control devices, or traffic officers, and failure to observe safety zone traffic laws.

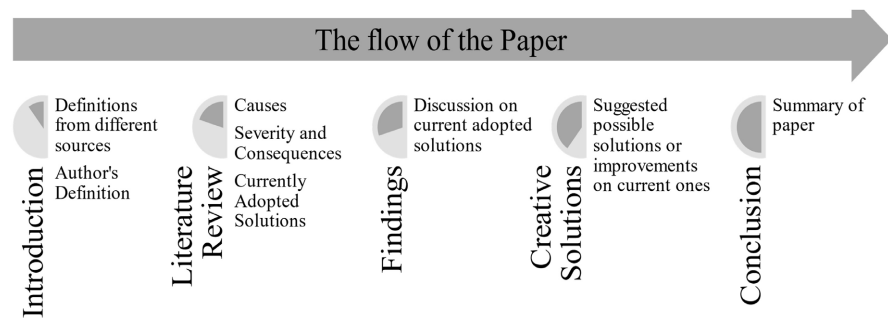


Figure 2. The flow of the paper.

- Failure to observe warnings or instructions on vehicles displaying them.
- Failure to signal.
- Driving too fast for conditions or more than the posted speed limit.
- Racing.
- Making an improper turn.

No one cause can lead a person to participate in road rage; rather, it is a combination of several factors. The causes of aggressive driving vary from environmental, demographic, personal traits, situational, or cultural factors, as shown in **Figure 3**.

2.1.1. Demographic Factors

Age group, race, education level, and gender are all contributing factors to the likelihood of an individual committing act of road rage. Statistically, white males under 30 with a poor educational background are more likely to be the perpetrators of road rage [3] [19]. In another study, within the years 1998-2000, 96.6% of road rage incidents were committed by a young male driver [20]. Depending on how aggression is defined, male drivers were more likely to participate in overt aggression, while there was no difference between genders in displaying mild aggression [15]. Furthermore, female drivers might demonstrate elevated levels of restraint out of self-preservation rather than a reduced inclination for aggression. The restraint is due to the fear of physical confrontation that might lead to bodily harm [21].

Furthermore, younger age groups were more prone to participate in dangerous driving behaviors. For instance, it was reported that 30% of accidents in the US are caused by the age group of 15 - 24 when they only comprise about 15% of the population [22]. The contradicting percentages were attributed to either lack of experience or a higher inclination for risk-taking behavior [22]. In another example, 58.8% of aggressive driving behaviors were recorded within the young age group drivers [18].

2.1.2. Societal Factors (Cultural)

Culture and society significantly shape what is deemed acceptable or unacceptable, depending on cultural values. For instance, the differences in gender-driving behavior are further attributed to societal perceptions of genders. Men are

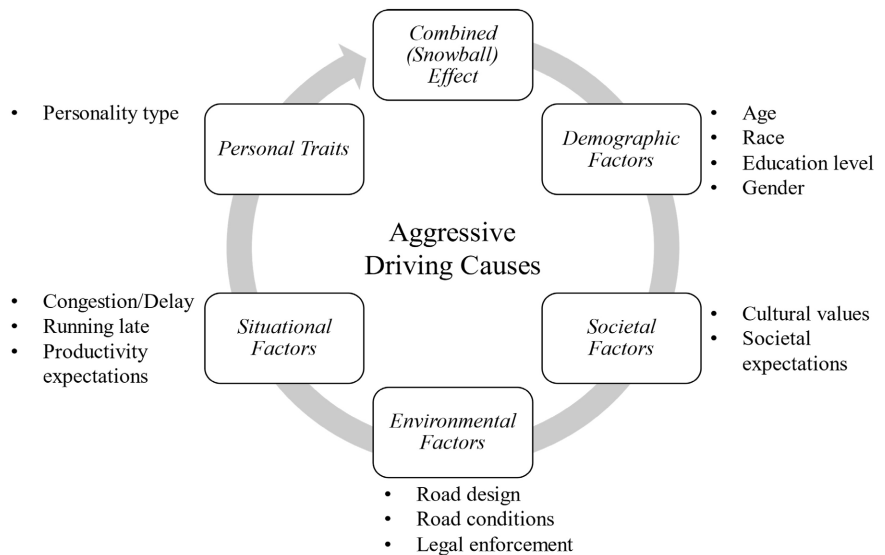


Figure 3. Possible causes of aggressive driving.

encouraged to demonstrate dominance, assertion, and general display of risk-taking behavior. On the other hand, women are encouraged to show restraint against violent acts as it takes away from their femininity [21].

Bener *et al.* [23] investigates driver behaviors in Qatar and the United Arab Emirates, drivers in those countries scored higher by all measures in demonstrating aggressive driving attitudes. The analysis method was through a Manchester Driver Behavior Questionnaire (DBQ). Qatar and UAE scored higher, indicating aggressive driving than British, Australian, Finnish, Dutch, Greek, and Turkish drivers. The increased aggression scores were attributed to a lack of consistency in legal reinforcement and a cultural tendency in Arab Gulf drivers to be in a hurry.

2.1.3. Environmental Factors

The state of the road and legal enforcement are also likely to affect driving behaviors [23]. For instance, the lack of legal consequences for aggressive driving behaviors is likely to permit an increase in road rage incidents [24]. Furthermore, drivers are more likely to engage in aggressive driving patterns if the roadway environment encourages or allows it [3] [25].

In cities or countries with increased congestion, frustration is also increased and can become the catalyst for more aggressive driving attitudes. Also, the driving environment promotes anonymity in which each driver has an illusion of being protected within the privacy of their vehicle [3] [5]. Hence, some people might be more inclined to commit such acts as they are not as concerned with external judgment. Therefore, switching from what is supposed to be a group activity to what is perceived as an individualistic experience.

2.1.4. Situational Factors

Another frequently discussed factor is anger or frustration, which can be caused

by reported congestion and traffic delays [4] [17] [26]. While this was briefly discussed under environmental factors, it is more appropriate to be elaborated on situational factors.

Being in a hurry, while more significant in some cultures or regions, has been recently growing across the globe. The illusion of productivity is the primary cause; being productive and getting more work done is coveted. However, the individual is still expected to maintain a healthy personal life has been aggressively promoted across all social media platforms. The general advertised idea is “work hard, play hard.” Those ideologies of a productive and healthy life have pushed for somewhat unrealistic expectations of what can be accomplished within the span of a day. Hence, the commute can quickly be viewed as a waste of time, encouraging people to find ways to cut driving time by either speeding, cutting off other drivers, not permitting other drivers to overtake them, or ignoring other traffic rules.

The increasing congestion across the globe further compounds the issue, leading to increased frustration, where some drivers might lose their temper and act violently [5]. Combined with the increased stress levels people have been experiencing due to the increased complexity of navigating life, those factors can create a concerning driving attitude [4]. In a study of aggressive driving behavior, length and type of commute were found to affect aggressive driving tendencies significantly. The longer the commute and the more congested the area with increased frequency of stops, the more anger ratings increased [1].

2.1.5. Personal Traits

Specific personality traits might make a person more prone to being an aggressive driver or someone who might be the perpetrator of road rage incidents. The most likely personality types to be more inclined to such violent tendencies are antisocial and competitive [3] [4] [5]. Another not-so-obvious personality type is the vigilante, in which some individuals might feel some sense of authority to correct the driving behaviors of others on the roadway [4].

These personality types might display impulsive behavior, macho attitude, impatience, unrealistic expectations, poor problem-solving skills, egocentrism, selfishness, and thrill-seeking attitudes [3].

2.1.6. Combined (Snowball) Effect

The snowball effect is a perfect example in this case, as it takes more than one factor or causes to lead to the act of aggressive driving. Nevertheless, when such a level is reached, the consequences are dire and can lead to serious adverse outcomes of endangerment of the lives of the collective on the roadway.

2.2. Severity and Consequences

According to the fatal crash reports, about 55.7% of the crashes were possible due to participating in one or more of the listed actions considered as aggressive driving, with a total of 119,475 killed between 2003 and 2007 [18]. 56.3% of the

fatalities were the driver who was the instigator of aggressive driving, 21.6% were the passenger, and 22.1% were occupants of other vehicles or innocent bystanders [18]. Those statistics suggest that aggressive driving is not an issue to be taken lightly. Of the drivers who engaged in aggressive driving behaviors, 58.8% were in the 16-year-old category, 35.3% were in the 35-year-old category, and the remaining 26.5% were in the 60-year-old driver category [18]. Those percentages indicate that younger drivers are more prone to display aggressive driving behavior, and more education should be directed toward these age groups.

It is also reported that aggressive driving leads to a significant proportion of all car crashes in the US. More surprisingly, aggressive driving kills two to four times more people than drunken drivers [3]. In another report, 33% of fatalities associated with major accidents are caused by reckless/aggressive driving behaviors [27]. In a study conducted in 1998, when drivers were surveyed, a shocking 89% admitted to sometimes participating in aggressive driving behaviors [1] [2]. Those behaviors included chasing other drivers, sounding the horn to indicate annoyance, and displaying hostility through physical gestures or verbal insults [2].

These issues are not unique to the United States and have been discussed worldwide, such as in Europe and the Middle East [23] [26]. For instance, the United Arab Emirates is another country plagued by aggressive and reckless driving behavior [22] [23] [28]. An article by the Khaleej Times reported that 4420 drivers were fined for aggressive driving on Dubai roads. At the same time, 49 vehicles were seized within a short window of driving behavior observation [28], and tens of more articles reported similar incidents.

Thinking about the presented data on aggressive driving, it is not just a problem but a plague that infects drivers. Others, such as passengers, pedestrians, bikers, other roadway users, governments, countries, and drivers themselves, are collateral damage to the tragic results. Also, from cited reports, studies, articles, and government documents dating back to 1980 to currently in 2022, the issue does not seem to have reduced in intensity. Hence, this indicates that more needs to be done or better approaches must be adopted to further combat aggressive driving from plaguing society.

3. Findings: Currently Adopted Solutions

Most countries and government entities chose two approaches to deal with the problem [26]. The first is targeting the source of the behaviors and treating them through training, driving safety camping, and mandatory driving lessons before obtaining a license [4] [22]. The second is strict reinforcement of roadway safety and aggravated fines and consequences for drivers demonstrating reckless driving behavior on the road [11] [26] [29]. However, despite the heavy reinforcement and educational approaches that some countries have adopted, the issue of aggressive driving seems to persist.

3.1. Roadway Geometry Adjustment Approach

Roadway geometric design and roadway/environmental conditions are major components of driver behavior and attitudes [30]. Some conclusions were drawn in a research study on the relationship between drivers' behavior and driving on horizontal curves in two-lane rural areas [31]. The authors investigated the optimal geometric design of horizontal curves under the aforementioned specifications. As the radius increased, so did aggressive driving behavior of speeding when it would be dangerous to do so [31]. The increased aggression was attributed to the increased level of driver confidence due to underestimating the perceived danger. Hence, despite the Green Book [32] recommending minimum radii depending on roadway conditions, a maximum radii limitation would allow designers to reduce the potential for such driving attitudes. Drivers should be comfortable while driving to avoid accidents due to nervousness and elevated stress but not too comfortable that they grossly underestimate the perceived danger of aggressive driving behavior. Also, a more aggressive driving attitude was observed under rolling terrain conditions [31]. Thus, more attention must be paid when designing rolling terrain roadways to avoid encouraging aggressive driving attitudes.

It is worth noting that within this study, improper speeding and underestimation of perceived danger were listed under aggressive driving. While this can fall under aggressive driving, it might also fall under the reckless driving umbrella. Reckless or aggressive, it does not negate that designing roadway systems while considering driver behavior, whether aggressive or reckless, results in safer driving conditions.

Another study argues that designing roadways for a "design driver" while ignoring the evident variability of driving behaviors is not optimal [33]. The authors offer two options, either reducing variability or accommodating it. The first option involves education programs for drivers, safety campaigns, and police enforcement of driving rules. The second involves increased safety measures, specialized education programs based on driver's needs, and segregation on roadways, when possible, for different types of drivers [33]. The forgiving design was introduced as a third design consideration along with desired and absolute design criteria. The newly introduced concept is aimed at evaluating the behaviors of non-design drivers and providing roadway design that considers those drivers along with the design driver. The suggestion aims at accommodating variability in driving, such as older, inexperienced, or drivers who are unfamiliar with the area.

Congestion, as previously mentioned, is one of the causes of aggressive driving as it increases frustration [4] [17] [26]. Hence, introducing solutions that optimize the roadway's capacity to accommodate the traffic volume could reduce aggressive driving incidents [3]. Also, the design of the roadway system has a significant influence on drivers' attitudes. Properly designed roads that minimize confusion and frustration can aid in reducing aggressive driving tendencies as

well. However, this on its own is not sufficient and must be applied in conjunction with other approaches.

3.2. Education/Training Programs Approach

The creation of an education program to reduce people's inclination for aggressive attitudes is not possible without a clear and in-depth understanding of the causes. The causes of aggressive driving, which were elaborated on in this paper, along with many available research studies, are available for governments to take advantage of to create driving education programs.

An example of a government entity applying the education approach is the Florida Department of Transportation [34]. The FDOT launched a Strategic Highway Safety Plan in 2021 to compact aggressive driving [29]. The program listed three adopted solutions of enforcement, education, and engineering. On the enforcement end, the program aims to train police officers, increase enforcement in high-risk areas, and coordinate with other legal entities on appropriate actions against aggressive driving. As for education, strategies include outreach programs targeted towards drivers who need it most, training beginner drivers, and training all participating safety professionals on best practices to counter aggressive driving. On the engineering front, providing safe roadways for users through adopting creative solutions such as Intelligent Transportation Systems was suggested [35]. This example is slightly expansive on solutions and includes multiple categories, but the highlight of the strategy is education on all three fronts for roadway users and enforcers.

3.3. Government/Law Enforcement Approach

Adequate roadway design and education programs are insufficient to ensure drivers follow the rules. One approach to enhancing the legal portion of aggressive driving prevention is the application of strict laws and consequences for participating in aggressive driving behavior. However, for consequences to be applicable, a well-defined definition of aggressive driving, along with acts considered as aggressive driving, must be listed. One example in the United States is the state of Georgia [12] [36]. The state of Georgia defines aggressive driving as "A person commits the offense of aggressive driving when he or she operates any motor vehicle with the intent to annoy, harass, molest, intimidate, injure or obstruct another person." Then, the document lists offenses considered as aggressive driving, which includes "overtaking and passing another vehicle; traffic lane violations; following too closely; turn signal, lane change, slowing or stopping violations; impeding traffic flows, or reckless driving. A person convicted of aggressive driving shall be guilty of a misdemeanor of a high and aggravated nature."

Since it would not be possible to cover every law of every state in the United States or country worldwide, a few examples will be highlighted. The selected samples are meant to show a comprehensive example of different enforcement approaches. **Table 1** will highlight the varying laws and consequences of violation.

Table 1. Examples of laws to prevent aggressive driving.

United States	
State [12]	Consequences
Delaware	A fine of \$100/\$300, 10 to 30 days prison sentence. Possible 30 days license suspension.
Florida*	A fine of \$1000/\$5000, 1 to 5 years prison sentence.
Utah*	A fine of \$1000 and six months of jail time with a three-month license suspension.
Indiana	Maximum fine of \$5000 and imprisonment of one year.
Global	
Country	Consequences
United Kingdom [48]*	A fine of \$125 - \$3060.
United Arab Emirates [49] [50]*	A fine of up to \$5445 and the vehicle impounded for 60 days. Possible prison sentence depending on the case.
Japan [51]	A fine of \$9200 and imprisonment of up to five years with license suspension for two years.

* No laws against aggressive driving but list aggressive driving behaviors such as tailgating as an offense.

After looking into laws against aggressive driving in certain areas, the statistics of aggressive driving per state or country are discussed. The statistics will only cover the already mentioned states/countries to maintain consistency of presented data and to provide informed discussion on aggressive driving preventative measures.

In the case of the state of Florida, it headlines most of the statistics on aggressive driving incidents using a firearm, with 147 (highest in the US) incidents during 2014-2016 [37] and 304 (second highest) during 2017-2021 [38]. In a report by the FDOT, the total number of fatalities due to aggressive driving is 2,020 during 2015-2019 [35]. It can be noted that until the date of writing this paper, Florida still has no laws against aggressive driving. Yet, they have launched a comprehensive education program targeting issues like aggressive driving [35]. Delaware, which has minimal restrictions against aggressive driving, reported 116 fatalities in 2015-2017 [39]. It is also worth mentioning that Delaware scores 10th on the list of confrontational drivers in the US [40]. In the case of Utah, despite being voted as the state with the most confrontational drivers in 2022, it has a relatively lower road rage-related fatality at 67 during 2015-2019 [40] [41]. The reduced fatalities might be attributed to the presence of rather strict laws against aggressive driving [12]. As for Indiana, there were a total of 273 reported fatalities due to aggressive driving during 2016-2020 [42].

On the global end, in the UK, fatalities due to aggressive driving were 147, 114, 110, and 102 in 2015, 2018, 2019, and 2020 [43] [44] [45]. The UAE, with somewhat stricter laws against aggressive driving, has a total of 791 deaths due

to aggressive driving during 2015-2019 [46]. In the case of Japan, the total number of fatalities due to aggressive driving incidents during 2017-2021 was 93 [47].

The reported numbers were retrieved from several sources, from statistics reported by governmental entities such as the Department of Transportation, statistics published by research studies, newspaper articles, insurance companies' statistics, and databases containing necessary information. In the case of UAE and Japan, there were no specific reported numbers under "aggressive driving." Thus, accident databases with a classification of the cause of the accident were retrieved. Then, accidents caused by actions that fall under aggressive driving attitudes, such as "not abiding by right-of-way rules," were summed and considered to be as aggressive driving incidents. The causes of each country considered as aggressive driving by the author are detailed in **Table 2**.

Those numbers were converted to unit values that accounted for the population per year and summed, as shown in **Table 3**. Then, the results were plotted in reference to the strictness of law enforcement and the presence of an education program, as illustrated in **Figure 4**. The utilized dataset is limited, but there is a noticeable correlation between fatalities and enforcement /education efforts. As enforcement or education against aggressive driving increased, the fatalities decreased. The variability in sources might lead to varying definitions of aggressive driving; thus, the data might not be representative. Yet, this is just an attempt to point out that stricter laws with proper enforcement can lead to lowered fatalities.

In the UAE, despite its stringent laws and enforcement through various technologies such as speed cameras, cameras that detect tailgating, and cameras that detect improper merging or diverging maneuvers [52], fatalities are almost twice as Indiana's fatalities with similar monetary fines. The discrepancy can be attributed to the fact that road rage is somewhat of a common issue in that region [53]. The reason behind this goes back to causes of aggressive driving of environmental, situational, and cultural influences. UAE is famous for considerable traffic congestion, which is frustrating that can lead to upwards of 13-minute delays per 30 minutes of driving and upwards of 40-minute delays per trip [54] [55]. Also, the country is booming with a heavy focus on work productivity, which leads to anxious and exhausted drivers. As for cultural influence, the culture encourages macho and conformational male behavior. The risk-taking behavior is demonstrated in the striking statistics of men being 63% more likely to be involved in car accidents than women [56]. Another report indicates that women were the cause of only 9.4% of accidents in the emirate of Dubai, with about 3.2% of fatal accidents [57].

4. Creative Solutions

After covering all currently adopted approaches to prevent or reduce the issue of aggressive driving, it is only appropriate to new solutions to aid in this cause. The solutions included three important fronts engineering, education, and laws.

Table 2. Accidents cause linked to aggressive driving fatalities in UAE and Japan.

Country	Actions Considered to be Aggressive Driving
UAE	<ul style="list-style-type: none"> Excessive Speeding Relating to obedience to traffic-control devices; Relating to yielding to the right-of-way Relating to following too closely Driving with the intent of harming oneself or others
Japan	<ul style="list-style-type: none"> Speeding Impeding deliberately Disregarding traffic signals deliberately Violation of the prohibition of passage

Table 3. Unit values of fatalities across reported years.

	Florida	Delaware	Utah	Indiana	UK	UAE	Japan
Total Reported Deaths	2020	116	67	273	995	791	93
Year	Population in Millions						
2015	20.219	0.942	2.984		65.224	8.917	
2016	20.627	0.950	3.044	6.638		8.994	
2017	20.977	0.958	3.104	6.662		9.068	126.662
2018	21.255		3.155	6.698	66.433	9.140	126.256
2019	21.492		3.203	6.731	66.779	9.212	125.792
2020				6.786	67.059		125.245
2021					67.281		124.613
Deaths Per 100,000 population	1.93	4.07	0.43	0.81	0.30	1.74	0.01

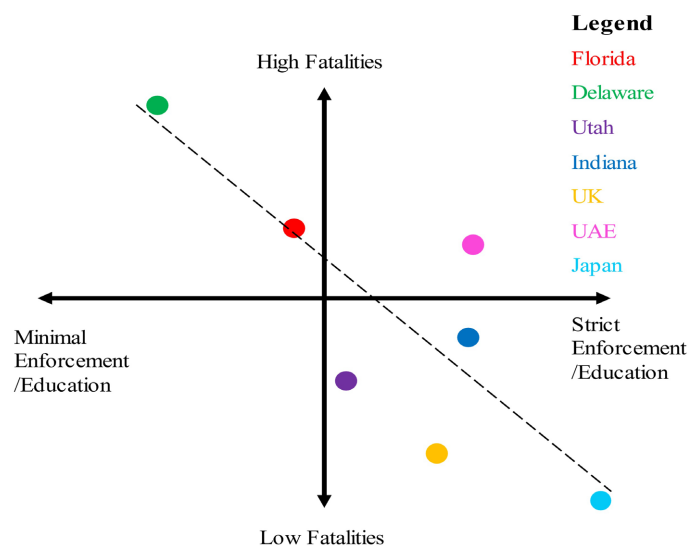


Figure 4. Relationship between applied strategies and aggressive driving fatalities.

4.1. Engineering Solutions

In the case of the engineering aspect, the primary driving force behind reducing aggressive driving incidents is decreasing congestion when possible. Some possible ways of accomplishing such improvements are as follows [3]:

- Reducing wait times at signalized intersections. Wait time reduction can be achieved by either optimizing the signal timing or using sensors to determine the optimal timing for each approach, depending on traffic.
- Ensure adequate visibility of signs or traffic signals. Better visibility means fewer split-second decisions for drivers. If not possible, add warning signs approaching the “hidden” elements of the road.
- Prepare drivers for possible congestion through media or signs that report potential delays.
- Clarify any possible changes. Increased clarity can be done by providing signs for merge zones, areas with expected elevated congestion.
- Provide devices that can alert drivers if they are speeding or driving behind another driver too closely.
- Provide Traffic-calming devices such as speed bumps and speed radars when appropriate.
- Ensuring well-designed roadway systems such as appropriate merge lanes, adequate-sized freeway entrance and exit ramps, proper bike and bus lanes, and picking appropriate times for roadwork.

4.2. Educational Solutions

On the education front, a great example would be the previously discussed education program launched by FDOT [35]. The program covered all aspects, from roadway users to enforcers. Another study included many innovative suggestions and strategies for reducing aggressive driving incidents on the roadway. The techniques include using the media to paint an image of the ugliness of aggressive driving and providing education on how to deal with it if you are the victim of an aggressive driving incident or how to avoid being the aggressor [3]. More strategies can be requiring court-mandated anger management classes for aggressive drivers or driving lessons on how to avoid participating in aggressive driving. Some education outlets can be signs on the road, car radio programs, or media campaigns. Professional drivers such as ride-share, taxi, and truck drivers should receive mandatory classes as they are on the higher end of miles traveled per a specific period. Also, on the end of the employers, monitoring measures of driver performance should be enforced either through dash cameras or speeding monitors/enforcers in the vehicle [3].

4.3. Laws and Enforcement Solutions

Perhaps the most critical of all three solutions is the proper enforcement of laws and regulations. That is, of course, given that strict laws are implemented to address such a significant problem. Fatalities decrease as enforcement increases,

with Japan being the perfect example. While engineering and education solutions contribute significantly to solving the problem of aggressive driving before it even becomes an issue, there will always be drivers who do not comply unless there is active enforcement. Hence, combining all three solutions is the optimal approach to combating aggressive driving.

To be able to enforce laws, detection methods are needed. Some possible offender detection methods can be speeding cameras, red-light cameras, and cameras that detect actions such as following too closely or improper lane usage. Also, phone numbers can be provided for victims of aggressive driving to call and report a certain harassing vehicle/driver. Tinting of windows can be legally required not to surpass a certain limit. The ongoing theme is to remove the driver's anonymity to discourage aggressive driving behaviors.

Another interesting approach is the one adopted by U.S. insurance companies of providing a driving monitor with the incentive of lowering insurance rates for safe driving behavior [58]. This solution might be a beneficial approach to study and adopt on a larger scale to investigate its effectiveness. However, the obvious limitation is the issue of privacy which people seem to give up for incentives significant enough as insurance rate reduction. A valuable study developed a machine-learning model that can predict reckless driving behaviors [27]. The developed model can detect reckless drivers and alert drivers and neighboring vehicles in real time through in-vehicle sensors. The approach aims to reduce reaction time to other drivers' dangerous driving by providing a warning before a potential incident. The application of such a model can be extended to aggressive driving as it overlaps considerably with reckless driving. The driver's level of aggression can be identified by analyzing driving style, whether a honk is used, if they are flashing their lights, driving to another driver too closely, or even shouting. The data can also be shared with local enforcement as it records and reports data in real time. The system again shares that same privacy limitation as in the insurance company monitor but has the added advantage of real-time data sharing. Therefore, similar incentives of reduced insurance rates can be provided with laws against misusing or sharing data with other entities without drivers' consent.

5. Conclusions

The word plague was used to reference aggressive driving; while that might seem odd considering the context, it was intended to emphasize the severity of the problem. The definition of aggressive driving was introduced through newspapers, research studies, and law enforcement points of view. The reports varied depending on the source, where news outlets highlighted extreme action such as "shootings" for increased readability. Research studies focused on the causes and sources of aggressive driving, hoping to produce solutions. As for law enforcement, it defines what actions are considered aggressive driving for possible enforcement and driver liability. Next, the authors provided an encompassing definition for a better understanding of the issue as a whole; thus, an encompassing

solution can be provided.

Nothing can be solved without understanding the underlying causes. Therefore, the causes of aggressive driving, including demographic, societal, environmental, situational, and personal traits, were elaborated. Each of the causes was discussed with a deeper explanation, focusing on valuable groups. Then, the severity, along with the consequences of aggressive driving, was highlighted. The best statistics to highlight the problem is that aggressive driving causes two to four times more crashes than drunk driving, with 89% of drivers admitting to participating in such attitudes, and 33% of fatalities on the roadway are due to aggressive driving.

Next, currently adopted solutions to reduce aggressive driving were introduced, focusing on engineering, education, and law enforcement. Strict law enforcement was concluded to significantly aid in combating the issue. Also, some creative solutions on all three fronts were suggested based on reports and studies. The machine-learning model that can predict and alert against reckless driving holds significant potential to aid in aggressive driving reduction. Finally, all three approaches must be adopted for the best outcome. With better roadway design that accommodates all drivers combined with an efficient education program, the problem of aggressive driving can be solved at its root. Strict enforcement, such as in Japan, will ensure that all drivers comply, thus reducing fatalities due to aggressive driving.

Aggressive driving is an essential issue for travel safety studies. This research aims to be helpful in understanding the concept of aggressive driving and its solutions. Future studies can obtain more data and apply the solutions to real-time problems. Also, solutions can be compared with real-time data analysis methods.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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