Safety in Autonomous Vehicle: A Review

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Abstract

This paper aims to analyse features which can consider drivers safety by referring pre-existing numerous features in vehicle that specifically considers vehicle safety so far. In the first section research based on surveys has been carried out in this paper which deals with safety in AVs (autonomous vehicle) and different scenarios when driver drives alone and when with passengers. Also, the importance and need of AVs for those who are physically disabled, and the preferences of AVs based on different age groups. It has also been revealed at entire global level that AVs are fruitful to the economy of the country and had a great impact in enriching current as well as future scope of the country. Analysis done on various safety precautionary measures which are mandatory for vehicles on road. this basically classified under various rules and regulations which are baselined by government strategies in different countries as per the safety norms. vehicle behaviour has been studied and acknowledgement on all safety aspects have been identified and accepted religiously by human drivers. in case, the negligence been done in a during these rules AVs are designed to play a smart role in safety of vehicle and passengers, but still due to some lags which are existing in safety features, possibility of mishap still exists. Also design methodologies of AVs had been channelized and based on that all the features were properly assessed considering all pros and cons. Inter linkages between hardware, software, functional, non-functional, safety features had also been well studied and how the entire development and testing cycle on vehicle works before the on-road vehicle rolls out and comes into real time scenario. From the overall illustrations and studies, we came across yet, the challenges which were identified had also been captured and were triggered in our research

activity to get the resolution for future benefits of Av’s.

Keywords- Autonomous vehicles (AVs), Connected and Autonomous Vehicles (CAVs), Surrogate Safety Assessment Model (SSAM), Auto Drive Vehicles (ADV’s), Original equipment manufacturer (OEM), Anti-Lock Braking System (ABS), Electronic Brake-Force Distribution (EBFD), Electronic Control Unit (ECU’s), Vehicle to Everything Communication (V2X), Radio Detection and Ranging (RADAR), Light Detection and Ranging (LIDAR), external Human-Machine Interface (eHMI)

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1. Introduction

1.1 About Autonomous Vehicle [21].

Autonomous vehicles are basically defined as those vehicles which moves from one point to another without any kind of human interaction and to achieve this well-placed sensor are used which detects and continuously monitors position and motion of other vehicles, person, and traffic signals etc. It was found that human insight and response time: 1.5 seconds and that of AV response insight time: 0.1 second**.**[11].

In today's world autonomous vehicle is the necessity for convenient mobility, comfortability, safety reduction of accidents on roads/highways. Self-governing vehicle has done a lot of improvement in creating dependable, sheltered, and reasonable vehicles resulting further improvement in commercialisation too. AVs minimise the necessity for human drivers and are more poised to day-to-day movements. Autonomous vehicles comprise of equipment’s that are more advanced in technologies, and which reduces accidents which usually occur due to driver being fatigue or drivers’ negligence [11].

To achieve advanced aspects in autonomous vehicles, investigation has been done for evaluating infrastructure requirements needed in AV. guidelines and framework was established for prioritising safety, capability and conveniency when integrated Av’s accompanyingtraditional vehicles and multi model utilizers such as commuters, pedestrians, and conveyance users. Hence, infrastructure requirement has been reviewed and approaches were made that guided urban planners to get detailed understanding and further prioritization has been done on how to implement on AV's [7][17].

1.2 An era of autonomous vehicle

The Automotive Research Centers and major automakers have both been developing automotive automation technologies from a very long time. Their combined efforts are expected to significantly alter how we perceive and utilise transportation networks as shown in Fig.1. Centuries before the first automobile was ever built, the concept and design for the first automated vehicle was developed. A car that could go back and forth without needing to be pushed or dragged was invented by Leonardo Da Vinci around 1500. The power and steering were given by springs, and the steering was pre-set to allow the car to go along a specified course [35].

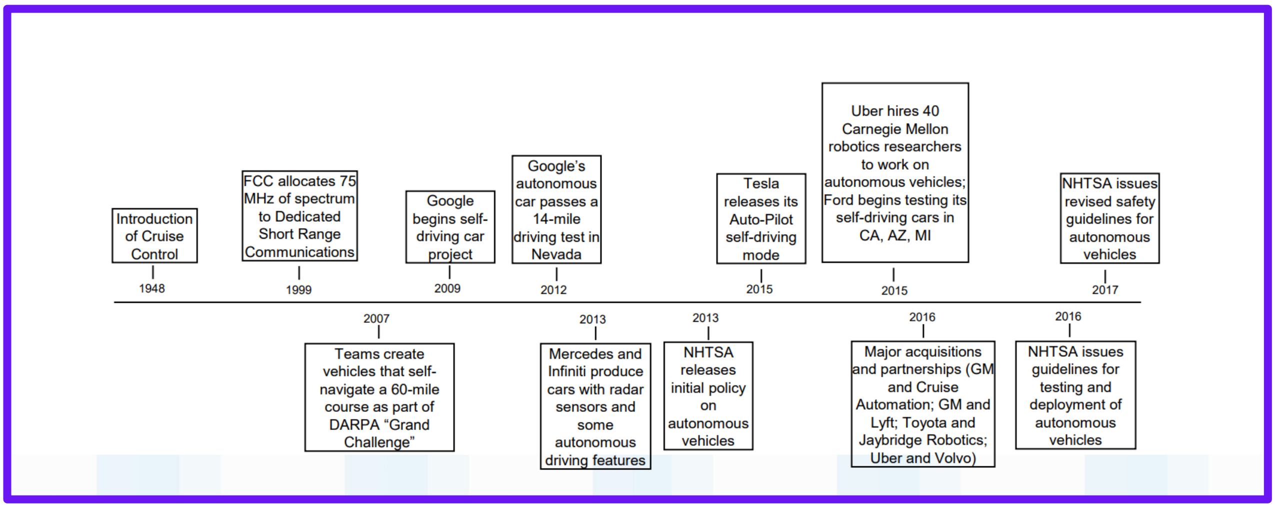


Fig. 1: History of enhancements in featuresofautonomous vehicle[35].

A summary of the rivalry between the major automakers is shown in Figure 1. The AV market may outstretch its maturity around the middle of the present regulation time. By the time we reach 2040, AVs are predicted to report for around 55% of vehicle dealing, 35% of cars, and 45% of all passage based on the deployment and adoption of prior agile vehicle technologies (such automatic transmission and compound-electric drive). Therefore, it is crucial to be ready for such occurrences, comprehend the difficulties that lie ahead, and embrace and welcome the chances that result [35].

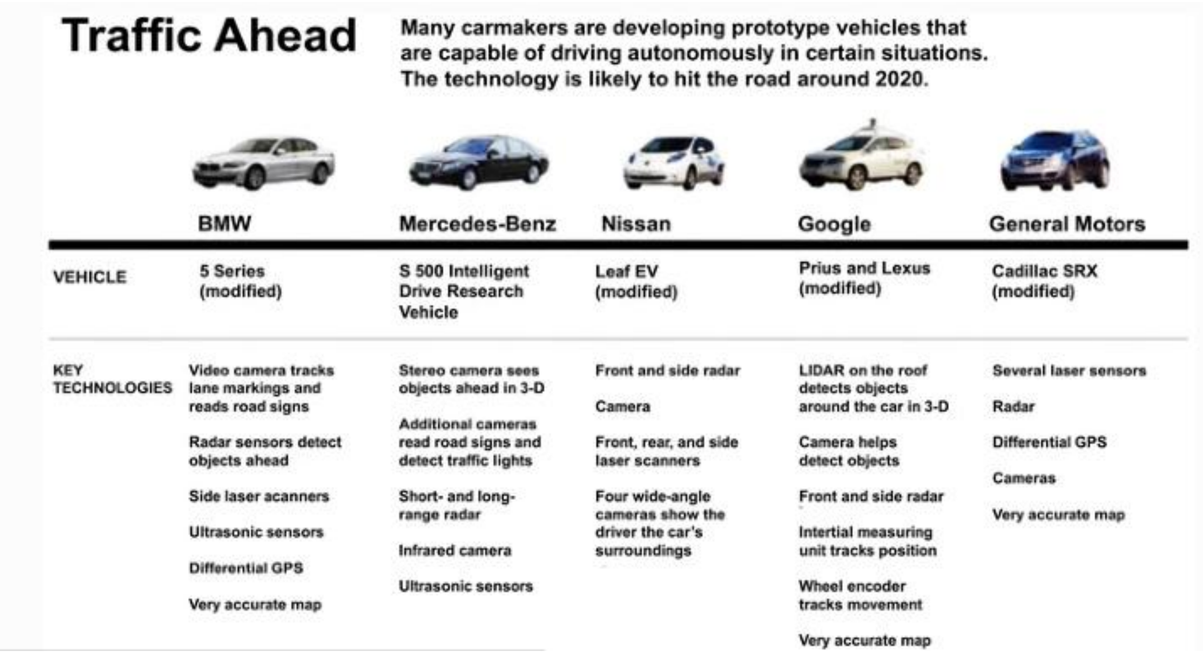


Fig. 2:Major contributors in autonomous vehicle with key technologies[35].

1.3 Major necessities for information, functioning of AVs

An expected possible convenience of autonomous vehicle considering safety benefits, fuel economy, minimum emission will be accomplished only when the consumer gets satisfied with vehicle design. The consolidated method of imitative study has been done in autonomous vehicle simulator to evaluate the impact of driving scenarios in 2 different conditions; one where driver was driving alone another with passengers. Rich data has been elicited from the scenarios and it was identified that presence of passengers in vehicle do you have impact on information and functioning of vehicle [8].Presence of passenger do impact the activities of driver while driving. While driving with passenger drivers do involve in some participatory activities, though not physically but mentally too[4].

Table 1: Tabular briefing of necessities for information, functions[8].

Classification	Information	Function	Interaction
Activities related to Driving	Information related to traffic: traffic situation, traffic signs,	• Showing, informing the surrounding traffic/road situation • Alerts related to hazards	• visual information: projected on the windscreen/head up visual screen in

	road situation • Navigation • Information related to vehicle: speed; general parameters • Location •Surrounding vehicles distance	• Adjusting the driving mode example speed as pervariations in the environment or coherent status of the driver • adopting driving style of a driver • Informing all surrounding vehicles in autonomous driving mode	the centre dashboard • real time information to be controlled either manually or via voice • shifting driving modes accordingly • as per the environment changes adjustment of driver's mode • adjustment of driving mode as per physical status of driver • voice control • controlling of touch screen • controlled via mobile phone.
Activities related to non-Driving	• Inside the vehicle temperature of the environment, luminance, noise level, air condition) • information of the areas which are getting crossed while driving. • News related to weather forecasts • Social networking information's	• Adjustable seats: rotatable, reclining, message function, memory function • windscreen projection • screen on the surface of steering wheel • screen on the centre console • integrating the mobile phone with system • PC for work • playing music/audio programmes videos • digital gaming • connecting to the Internet movable or smaller steering wheel hide when not in use • Moe in vehicle space to move around • space for preparing/storing food/drinks • movable or smaller steering	

		wheel hide when not in use • simply gym equipment • more in vehicle space to move around • an intellectual Steward	

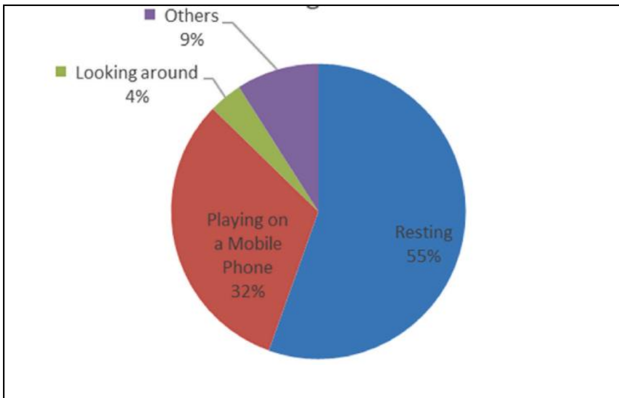


Fig. 3: Simulator study while driving without passenger scenario Restingsituation when the participant was sitting in the seats without engaging in any activities. The other activities involvedrinking, eating, writing, reading etc. [8].

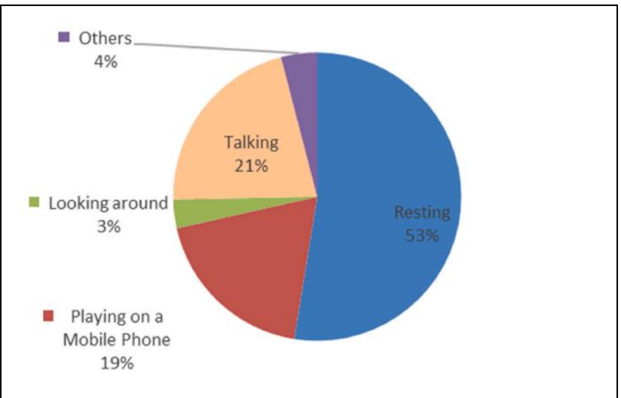


Fig. 4: Simulator study while driving with passenger scenario Resting situation when the participant was sitting in the seats without getting indulged in any activities. The other activities involvedrinking, eating, writing, reading etc[8].

Control over vehicle is still mandatory for autonomous vehicles, which may be ascribed to the concerns about safety as well as comfortability in autonomous driving. Various non-driving related activities was also identified, along with a usual requirement for interior metamorphosis, findings of Jorlov et al. (2017) and Large et al. (2017). Some engaging and interesting adjustments in design were proposed. Example, due to the presence of passenger, the interior-vehicle space was anticipated to be a private space when driver is undergoing solo driving, providing support for the driver in abstaining from social interactivities. In contrast, it was anticipated to support socialising in circumstances where presence of passenger is there. Also, the accord between concerns about convenience and safety was found necessary, especially when it is regarding some complex controls.

2. Understanding and need of vehicle safety

2.1 Safety:

The condition in which hazards and scenarios leading to physical, psychological, or material harm are somehow managed to maintain the health and comfort of particulars and society this is known as safety. Dashing of vehicle can carry massive cost for employees specific to injuries ailments and losing of potential productive work age. Upcoming front line technologies can provide huge advantages in terms of encouraging secured on road behaviour[6].

2.2Need of vehicle safety:

Vehicle safety is one of the most significant and critical aspect that ensures security of automobiles and passengers. System which grants safety features are crash avoidance system and crash mitigation systems. Investigation has been done on safety, adequacy of vehicle, which is reliable i.e.., remains computationally amendable & controllable while considering compounded situations**.** [6]. Various research investigation studies were carried out which defines the safety aspects of AVs or Connected and Autonomous Vehicles (CAVs) using numerous methods. A study by Morando et al., conducted at the University of Monash, Australia, is the first absolute extensive study on the influence of autonomous vehicles on traffic safety. Morando used the Vissim software to simulate AVs and inspected the main cause of accidents with the Surrogate Safety Assessment Model (SSAM). Five different scenarios were simulated of 0%, 25%, 50%, 75%, and 100% which confirmed existence of AVs in the network connectivity in Vissim and depicted that by rising penetration rate of AVs, the average number of accidents in the studied segment remarkably drops down.[6].

There are various scenarios where safety is highly important. One such scenario is when person with certain disabilities had to travel in autonomous vehicle and there is recently very limited information that details about possible obstacles as in individual faces when it comes to mobility study has been done to identify accessible needs which an individual with disability requires and the perception and feedback from this population towards autonomous it was observe that person with certain disabilities are convinced and ready to move towards autonomous vehicles and willing to pay more on autonomous vehicles for proper safety features and accessibility[5].
A survey was performed which shows that aged participants tented to consider autonomous vehicle slight safe than a conventional vehicle.

A survey has been performed where, considering sample of n=468[5].

Table2: -Distribution of selected disability. more than one disability type could be identified by respondent.[5].

Disability Type	# Of Responders	% Of Responders
Ambulatory	256	55
Self-care	115	24.5
Independent living	76	17.0
Cognitive	57	12
Hearing	44	9
Visual	25	5.5

Respondents had reported modes of transport as percent. The most common modes of transports are identified in 3 categories- [5].

1. family and friend's vehicle
2. Public transportation with the caregiver
3. personal vehicle

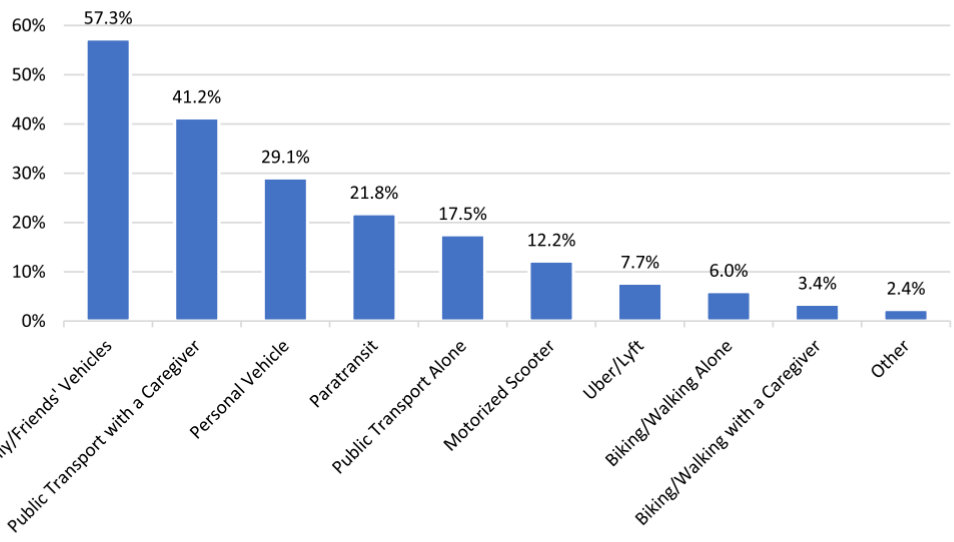


Fig. 3. Categorization of modes of transport in %by respondents[5].

In survey it was found that, in AVs three-fourth of users evaluated AVs much safer (15%), moderately safer than (37.5%), or perceiving same safety as a standard vehicle (26.4%). Safety levels which were perceived were relevant across disorder types, with maximum respondents rating AVs much safer or moderate safer despite of disability type (Fig. 4). Respondents between the ages of 40-60 also recorded a perception of inflated safety levels than those over 60 (Fig. 5). Few of the respondents below the half have mentioned that they would pay the cost of public transport (45.3%) or around the cost of shared rides (42.8%) to use an AVs, with hardly few people stating that they would pay nothing (5.78%). Use of autonomous vehicles was also conditional on the establishment of specialized technologies (36.6%) or well-developed autonomous vehicle lanes (35.2%). A third group indicated that they would aspire to have a driver (with the AV technology) in the vehicle (32.5%) for them to feel comfortable and safe. Besides all these, the utmost usual type of accessible technology solicited were electronic displays (49.5%), a navigating (GPS) app (45.3%), and ramps or wheelchair access (40.6%)[5].

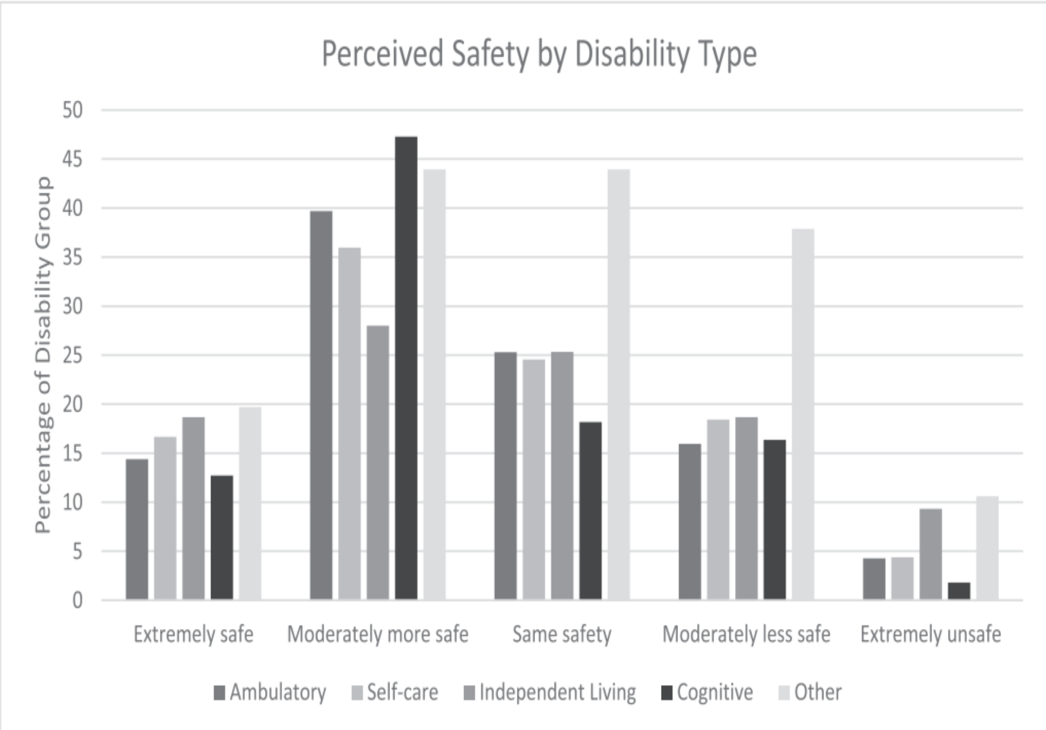


Fig.4: Perceived safety as per Disability type. Distribution of selected disability. multiple disability type could be detected by respondent[5].

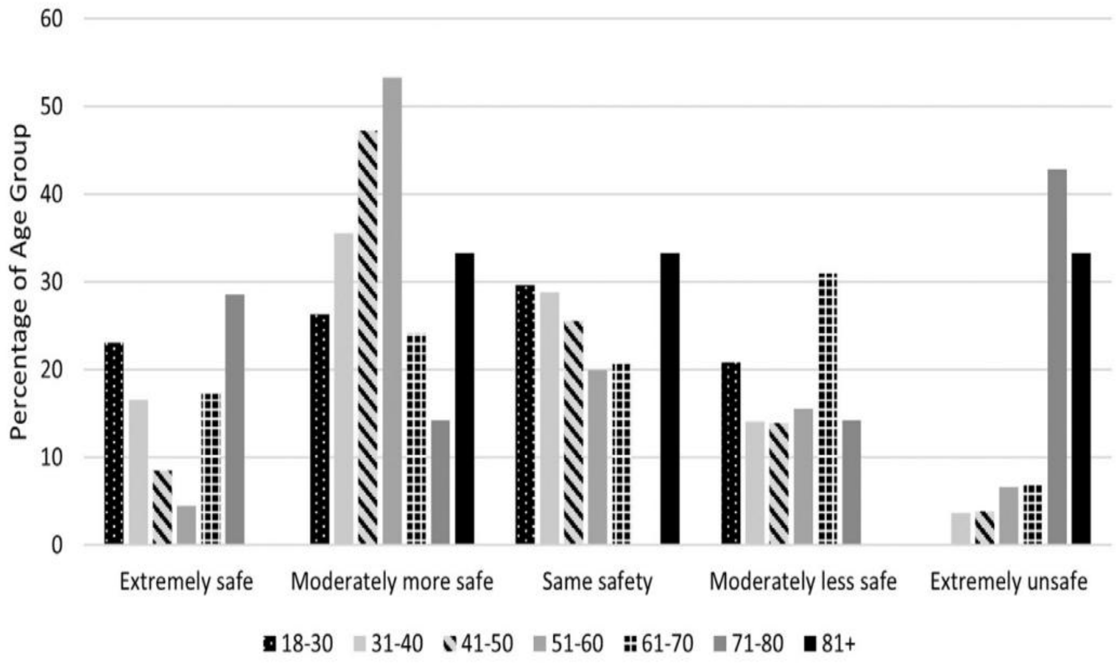


Fig.5: Perceived safety as per Age group, here old age groups tend to view AV less safe than traditional vehicle. Whereas an age group of 30-50 perceive AV as much safer [5].

Research done so far shows that safety related risk may arise from less careful conduct of driver, road occupants, system error, crash algorithm, due to which life or death situation compromises during accidents which are inevitable. The non-successful finishing in causal chain events in 95% of crash/collisions Is due to driver's error. These crashes occur due to negligence from drivers end, and it is categorised as below- [5].

1. Perceiving-non recognising hazards
2. Predicting-misapprehending behaviour of another vehicles
3. Planning -Lack of decision making on traffic law obedience.
4. Execution/performances-inappropriate vehicle control
5. Incapacitation-incapacitated driving. (Drinking alcohol etc.)

These must be overcome by autonomous vehicles to avoid crashing enhance safety features need to be improved more[13]. Hence negligent human like errors need to be avoided to maximise the safety.

3. Automotive Industrial trends

3.1 Featuring trends in automotive industry[18].

1. AV's- self driving feature in vehicles which has minimised the need of human driver.
2. Vehicle connectivity-vehicle connectivity solution which comes with tamper proof digital identity that discriminates from other vehicles in connectivity.
3. Electrification-solution to preserve fossil fuel depletion, increased greenhouse gas emission and ham due to pollution caused by gases which are emitting, noises etc.
4. shared mobility-basically focuses on collaborative mobility as an alternate to owning conventional vehicle.
5. AI-It is a technology that guides AV cars, manage fleets, assist drivers to enhance safety, improves vehicle inspection or insurance. In automotive industry, accelerating the production rate and reducing cost.
6. Big data and analytics-basically a newly emerging companies focusing on this to support automotive manufacturers, for streamlining operation and maximising their margins.
7. Human machine interfaces (HMI)-defines how, when and what all aspects of car user can control.
8. Blockchain-it incorporates vehicle data sharing over a secured network for linkages and collaborative mobility solutions.
9. IOT-this basically features vehicle and infrastructure elements. Technologies enhances road safety, traffic congestion and minimizes pollution etc.

3.2 Contribution to global economy: [18][36].

Autonomous vehicles will directly impact in 2 areas: -

1. **Industrial development-**industrial cluster forms as OEM plants are neighboured by component manufacturers provisions including steel plant glass manufacturers used car retailers, servicing shops and transportation service providers.
2. **People development-**1 motor vehicle for 5 people. Automobile increases quantity of life to increase mobility, comfort, and safety example in US there is one car for 1.25 citizens.

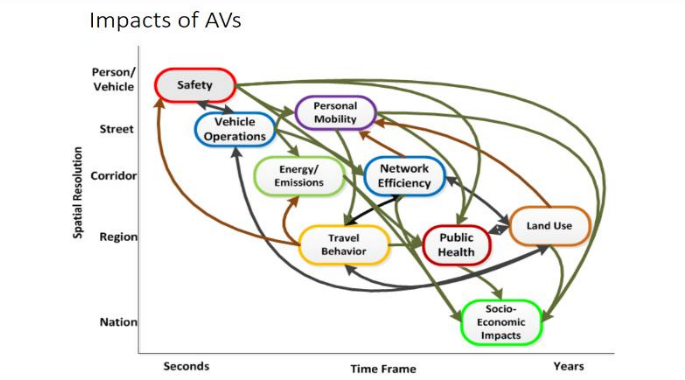


Fig.6: Impacts of AVs on different areas with the passing years [18].

1. **Society -** AVs have capability to impact society in upcoming years considering the positive front crashing of vehicles will get reduced and travelling time can become effective which would give huge benefits to society. Those who are specially challenged can get a greater benefit from a visa for travelling purpose.[37].
2. **Economy-** AVs can upgrade and access to mobility, especially for middle classes as cost transportation will decrease; and estimations were made stating that the cost will be cheaper than traditional vehicles.
3. **Safety-** The growth in AV technology will have a remarkable impact on safety with the potential to reduce mishaps which may occur due to sudden crashes prevent from injuries and save lives.
4. **Energy Emission-** Positive impact will be that it reduces GHG emission, can allocate to some factors like echo driving, eco-traffic signal, parking etc.

3.3 Modes & Levels of Autonomous Driving: [15].

Standard 3016 outlined by SAE describes 6 distinct levels of AVdriving-

1. No automation- In this case, human driver is responsible for performing or driving related action items manually. Example- control on steering come acceleration, braking etc.
2. Driver assistance- with an anticipation that the remaining activities which are performed while driving will be carried out by a driver itself, the vehicle had been featured with a single automated system with the driver assistance. Example-steering control, acceleration or deceleration
3. Partial automation- we will perform steering control, acceleration, deceleration, however driver can monitor the same and can take the control anytime.

4. Conditional automation-vehicle can detect hindrances if any and still can perform most driving tasks. Though, human intervene and take the control when in driving phase.
5. High automation- Vehicle can perform driving aspects. Geofencing is required. Still human can override whenever he feels to.
6. Full automation- without human intervention vehicle can perform the entire driving tasks.

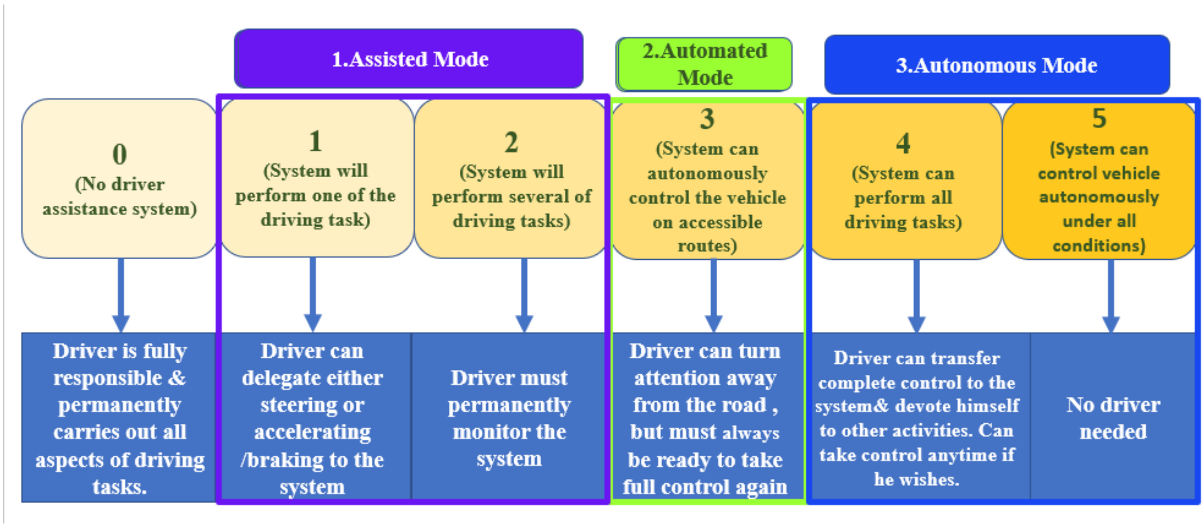


Fig.7: -Modes & Levels of Autonomous Driving from human intervention phase to No human intervention phase [15]**.**

4.Features &Components[16].

4.1 Safety equipment’s used in vehicles:[16].

- Two-fold frontline airbags.
- Anti-Lock Braking System (ABS) and electronic brake-force distribution (EBFD)
- Cornering stability control
- Rear parking sensor
- Seat belt pretensioner
- Speed sensing door lock
- Impact sensing door lock
- Panic braking signal
- Reinforced B-pillar
- ISOFIX-Child seat anchors

Table 3:-Features in Sensorsto avoid collision , pedestrian and cyclist detection, and complements vision-based camera-sensing systems.[16][14][25][27][2].

Factors	Camera	LIDAR	RADAR	Fusion
Range	~	~	Y	Y
Resolution	Y	~	x	Y
Distance Accuracy	~	Y	Y	Y
Velocity	~	x	Y	Y
Colour perception e.g.. Traffic light	Y	x	x	Y
Object Detection	~	Y	Y	Y
Object Classification	Y	~	x	Y
Lane Detection	Y	x	x	Y
Obstacle edge detection	Y	Y	x	Y
Illumination conditions	x	Y	Y	Y
Weather conditions	x	~	Y	Y

The “Y” indicates sensor- being operated effectively under the factor. The “~” indicates sensor- performance logically well under the specific factor. The ‘x’ indicates sensor- Not operating well under specific factor comparative to other sensors [16][14][25][27][2].

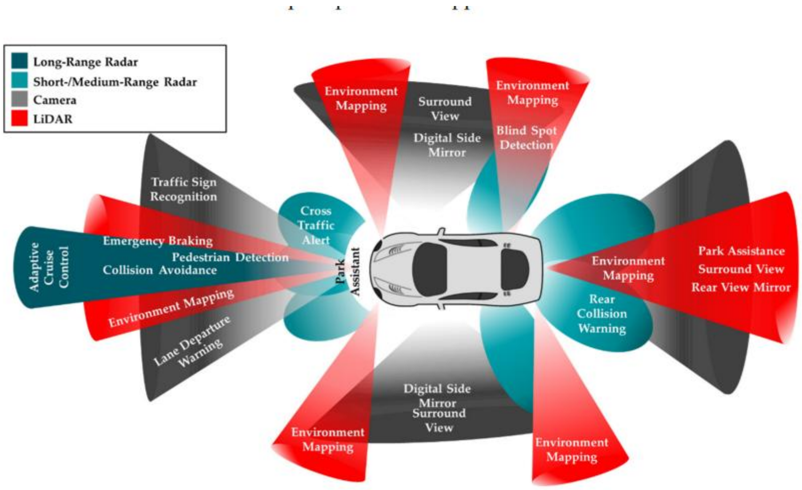


Fig. 8: Types & positioning of sensors configured in vehicle where multiple targets&sources are coupled which supports medium &long-rangecommunication [25][33]**.**

5.Modification in safety measures: -

From all the pre-existing trends in AI's, HMI is one of the features that considers the scope of my study where human and machine/vehicle interaction will be the most significant aspect. there are 3 existing numerous features in vehicle that too for vehicle safety. Considering drivers safety in semi auto drive vehicles some features need to be enhanced and this feature must involve some more frequent, continuous, or interactive session between driver and vehicle.[32].

The recent studies in AVs have tremendously increased out of which the major focus was on eHMI

The presence of eHMI on AV can speed up the driver's interpretation about passive purpose of an AV and have the capability to evaluate AV-driver communicative action in vague traffic situations. For defending this, a field experiment was lead which aimed to shed light on how drivers overcome a vague traffic circumstance when experiencing an AVs in the existence of a submissive intended signal AV with eHMI or not AV without eHMI.[29][32].

A survey had been performed with traffic conflict scenario with two opposing vehicles commanded to perform a left turn at 4-way junction, at the similar point in time. Around 40 participants were allocated into two groups experiencing either an AV with eHMI or an AV without eHMI. To inspect for uniformity across two groups, both groups also faced a conventional vehicle. Outcomes manifested that the two groups executed exactly same during an experience with a CV. Amid experiences with AV, however, participants dealt with the eHMI maintained higher speed before the AV and finished their maneuver expeditiously than when were not provided with eHMI. In addition to that, participants offered with eHMI rated higher their capability to judge the AV intention before coming to a full-stop than those offered without eHMI [29].

5.1 DM for autonomous vehicles-

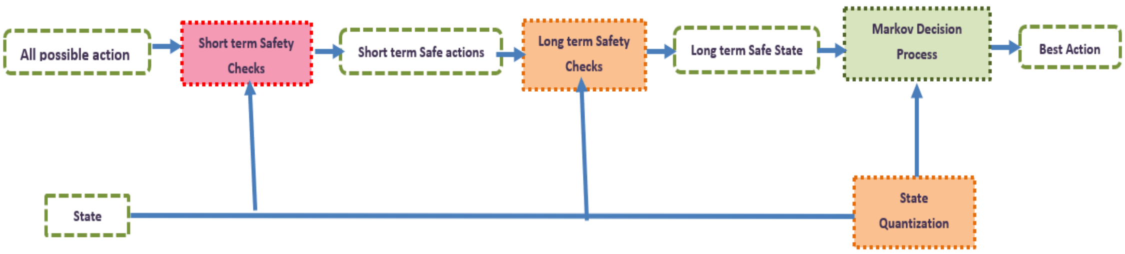


Fig. 9: -Decision maker architecture (DM), depicting different components and sequential flow of information.[3].

All actions are specified by combination of updated speed and lateral maneuver. Lateral maneuver were specified in 3 categories [3].

LCL- change of lane to the left
LK-lane keeping as it is
LCR- change of lane to the right
The speed maneuver is categorised as-

1. Increased speed
2. Maintained speed
3. Reduced speed

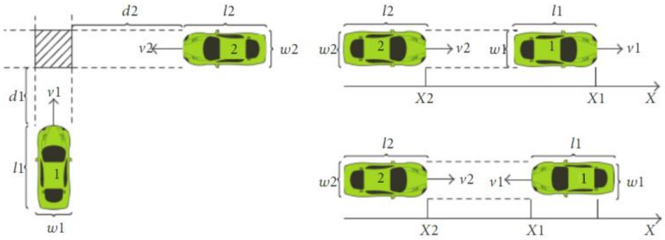
Table3: - Nine possible activities with combination of lateral maneuver and updated speed.[3].

Updated Speed	**Lateral maneuver**		
Accelerate	LCLa	LKa	LCRa
Maintained Speed	LCLm	LKm	LCRm
Reduced speed	LCLr	LKr	LCRr

5.2 Markov action process:

Measurement of safety means time to collision as introduced by Hayward. DM action selected based on 2 stages- **safe action and best safe action.** Time to collision (TTC) is one of the common safety measures that specifies time until the collision occurs given a constant approaching and velocity for both vehicles. If TTC is higher situation will be safer. TTC is ranged between O and 15 seconds which is considered limited values [12].

$$\mathrm{TTC} = \begin{cases} \dfrac{d_2}{v_2} & \text{if } \dfrac{d_1}{v_1} < \dfrac{d_2}{v_2} < \dfrac{d_1 + l_1 + w_2}{v_1} \text{ (side)} \\ \dfrac{d_1}{v_1} & \text{if } \dfrac{d_2}{v_2} < \dfrac{d_1}{v_1} < \dfrac{d_2 + l_2 + w_1}{v_2} \text{ (side)} \\ \dfrac{X_1 - X_2 - l_1}{v_2 - v_1} & \text{if } v_2 > v_1 \text{ (rear end)} \\ \dfrac{X_1 - X_2}{v_1 + v_2} & \text{(head on)}, \end{cases}$$



Here,

d1, d2-distances to conflict areas

v1, v2-vehicle speeds

l1, l2- vehicle length

w1, w2- vehicle width

X2, X1- vehicle position

Safety is checked in 2 stages-

1. Short term safety- Measured by considering TTC with single time step.
2. Long term safety-only verified for actions which can be considered safe for short term. This party is considered as threshold on TTC.

MKV(Markov decision process);Sutton and Barto [1998] described with 4-tuple (S, A, T, R), where S: set of states, A:set of actions, T : S ×A×S → [0, 1], such that s∈S T(s, a, s) = 1 for all s ∈ S and a ∈ A, is depicting the probabilistic transition of state, comprising of action identified in time step. This equation is illustrated by the transition function T (s, a, s) = Pr – s (k + 1) = s | s(k) = s, a(k) = a , (4) where k ∈ N. T(s, a, s) : probability that the state at time step k + 1 is s if, at time step k, a: action taken in states. R: S × A → R is a function showing instant result for considering an action, when in state [6].

$$safety = 15 - \sqrt{\frac{1}{n}\Sigma_{i=1}^{n}(15 - TTC(i))^2},$$ [6].

$\mathbf{x}_i = [x_i, y_i, v_i, \theta_i, l_i, h_i, w_i]^\top \in \mathbb{R}^7$; one-step ahead prediction in the safety check, due to computational delay

$\mathbf{X} = [\mathbf{x}_e, \mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_{n_v}] \in \mathbb{X} = \mathbb{R}^{7\times(n_v+1)}$; Computed TTC

Algorithm: Safety computations [6].

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Input:
$\mathbf{X}$: State
a_{prev}: Previous action

$A_{short} \leftarrow \emptyset$
$A_{long} \leftarrow \emptyset$
$a^* \leftarrow LK_c$
$\mathbf{X} \leftarrow f(\mathbf{X}, a_{prev})$
for all $a \in A$ **do**
  if $TTC(X, a) \geqslant 1.5s$ **then**
    add a to A_{short}
  end if
end for
for all $a \in A_{short}$ **do**
  if $TTC(X, a) \geqslant 1.5s \wedge a \in LCL_* \wedge \forall i \in \{1, \ldots, n_v\} : l_i = l_e + 1 \Rightarrow x_i \notin [x_e, x_e + 30]$ **then**
    add a to A_{long}
  else if $TTC(X, a) \geqslant 1.5s \wedge a \in LCR_* \wedge \forall i \in \{1, \ldots, n_v\} : l_i = l_e - 1 \Rightarrow x_i \notin [x_e, x_e + 30]$ **then**
    add a to A_{long}
  end if
end for
$a^* \leftarrow \mathrm{argmax}_{a \in A_{long}} TTC(X, a)$

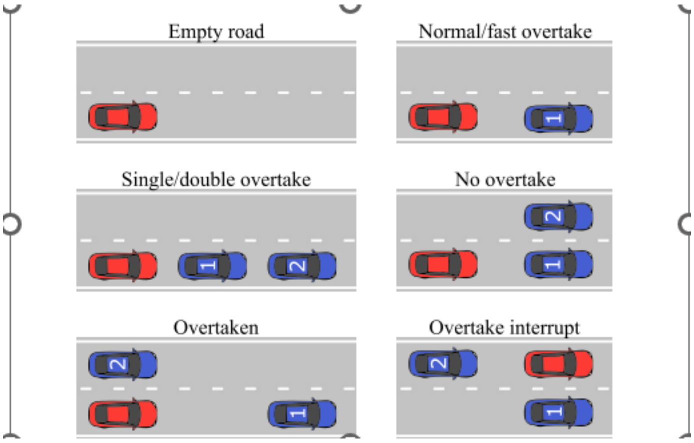
Table4: Behaviour of vehicle on road in different situations, based on safety norms [6].

Scenario name	Description	Expected behaviour	Rule based			2 stages		
			Safety	dtrav	nLC	Safety	dtrav	nLC
Vacant road	no obstacle vehicles	maintaining speed and lane keeping	15.00	777	0	15.00	779	0
Casual overtake	a slower vehicle before the ego vehicle	overtaking the slower vehicle	12.91	777	2	13.14	781	2
Quick overtake	a slightly slower vehicle before the ego vehicle	lane keeping and decelerating	13.32	765	2	13.31	743	0
double overtake	2 slower vehicles in front of the ego vehicle, close together	overtaking both vehicles at once	9.93	724	4	11.38	730	2
Single overtake	2 slower vehicles in front of the ego	overtaking both vehicles	12.06	779	4	10.51	699	3

	vehicle, for apart	separately							
no overtake	2 slower vehicles on different lanes in front of ego vehicle	lane keeping on either lane	10.05	654	1	11.68	646	0
overtaken	the same as normal overtake, with faster vehicle on left lane	waiting before overtaking	12.00	773	2	11.71	711	2
Interrupt Overtake	the ego vehicle is left of a vehicle, with faster vehicle behind	accelerate to promote safety	9.37	668	1	12.15	702	1

Initial position of vehicle. Ego Vehicle -Red

Obstacle-Blue



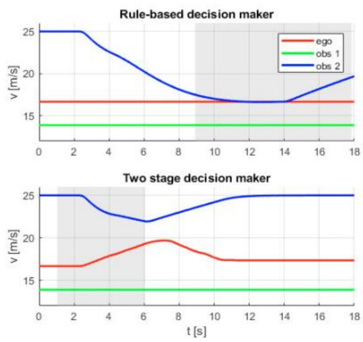


Fig. 10: Top view of vehicle behaviour on road with statistical illustration

grey background depicts LCR [6].

5.3 Governing strategies for autonomous vehicles basically focusing on 5 classifications of risks:- Safety, accountability, Privacy, Cybersecurity, and Industrial risks [10].

Almost 90% of vehicle accident are caused due to error which may be caused by person negligence (NHTSA,2015; Smith,2013; Sunet al.,2016). Promoting of autonomous vehicle can eliminate major source of accidents nearby surpassing person drivers in perception, making any decision, executing the same. However, these autonomous vehicles have introduced issues which basically occur due to negligent behaviour of drivers, passengers, and pedestrians. In case study by Collingwood, 2017; Douma & Palodichuk, 2012) and Littman (2017); It was highlighted that vehicle occupants have reduced the usage of seat belt; pedestrians have also become slightly less vigilant feeling safer. It was made clear that elimination of human error does not signify the discarding of machines. With the growth in technologies probability of occurrence of any kind of error which are technical can compromise vehicle safety. One incident where there was a fatal crash which occurred in 2016 with Tesla autopilot's call and unpredictable machine perception (Banks, Plant, & Stanton, 2018) add highlighted the incompetence of autonomous vehicle technologies to avoid such incidents.

Table5: Governing strategies & guide for policymakers based on AVs[10,21]

Strategy	Definitions
Unresponsive	This strategy indicates that the government had neither established nor had indicated its desire to establish safety standards which can be followed during testing of AVs.
Precautionary response	Under this strategy the main name is to avoid risk by adopting preventive action. To avoid the risk prohibiting the option of innovative technology is one such way. This strategy basically comprises of risk minimisation.
Authorized Strategy	Authorities takes applicable steps to control the risk by implementing formal policies and regulations. Some conventional methods of assessing risk are being considered to anticipate and manage risks.
Toleration Strategy	In various situations policymakers ensures that the performance of the system as well as the organization is vigorous to risk. Policymakers also makes progressive plans to mitigate possible consequences by developing alternative strategies.
Compliance& Modification strategy	This strategy enhances the capability of system and organization. It lays more emphasis on improvement of system performance in response to shocks.For the betterment of systems performance policymakers considers risks as discussionfor opportunity rather

	than a threat which should be ignore, hidden, monitored or tolerated.

NHTSA has defined a Vehicle Performance guideline for those organizations who are associated in "manufacturing, designing, supplying, testing, selling, operating, or deploying" AVs in US (NHTSA, 2017). Though NHTSA has intended to impose this proposal in future, at present it urges organizations to facilitate voluntary safety assessment that states adherence to the guideline, that incorporates all mandatory requirements on systems safety like detailing safety plans and design repetitions for addressing AV failures (NHTSA,2017). Being a "leading regulation body" (Stone; 2018) NHTSA allows states to impose newly defined standards on AVs only in case they are "similar" to whatsoever is authorized by federal law (H.R.3388, 2017)[10].

Both the US and UK adapted a slightly control-oriented strategy/plans though they are quite cautious and avoids imposing regulations that are too rigid, to have an extremely tolerable stance on safety of an AV, to give an adequate territory for innovations (CCAV,2016, Kang, 2016)[10].

Similarly, NTC which is Australia's regulatory body has published non-obligatory guidelines where more significance is laid on managing access to AVs, and it holds a commercial deployment of Auto drive vehicles (ADV's) as an endless goal, no regulations had been established yet to approve 6 A. TAEIHAGH and H. S. M. LIM establishment, and it will still be taken into consideration based on cases (NTC,2016) [10].

Government of China has also adopted a light control-oriented strategy to measure and tackle all safety risks while adopting some precautionary measures to avoid exposure of AVs to practical road conditions. An individual person is very much needed to be in the vehicle with the hands placed on the steering wheel, and AVs cannot be tested under actual road conditions until the government formulates a framework for granting road test exemptions (KPMG,2018, West,2016).

In Europe, permission for AV testing has been lawfully granted, but due to differences in culture the Europe is stricter comparative to the US, as Europe emphasizes on safeguarding citizens from risks which is basically arising from existing and upcoming technologies while the US focuses on the "race for revolution transformation and advancement" (Nicola, Behrmann, & Mawad,2018).

To regulate safety in AV testing Singapore and Japan have begun amending their laws and illustrating control-oriented strategy. The law exhibited by Singapore now acknowledges that a vehicle need not to have a person driver (RTAB, 2017) and the new rules to be created on AV trials by Minister for Transport, regulating standard guidelines for AV designs, and obtain the records from AV trials.

In early 2017 even Japan had drafted laws and regulations for AV testing that essentially needs person driver carrying driving licence in vehicle, acceptance from police, AV test vehicles with clear labelling and testers to be well prepared for applying brakes in any circumstances (Kyodo,2017) [10].

Table 6: Adopted governing strategies[10].

Risk Categories				
Countries	**Safety**	**Liability**	**Privacy**	**Cyber security**
US	slightly controllable	Unresponsive	controllable	controllable
UK	slightly controllable	Bearing	slightly controllable	Adapted
Australia	slightly controllable, adaptation	slightly controllable	slightly controllable, adaptation	Unresponsive
EU	slightly controllable	Unresponsive	controllable	slightly controllable
Germany	controllable	slightly controllable, control	slightly controllable, controllable	Unresponsive
China	prevention, slightly controllable	Unresponsive	controllable	controllable
Singapore	controllable	slightly controllable	controllable	controllable, adapted

Japan	prevention	slightly controllable	controllable	Unresponsive
South Korea	Unresponsive	Unresponsive	slightly controllable	Unresponsive

6. Structural Mechanism of AV[26][27].

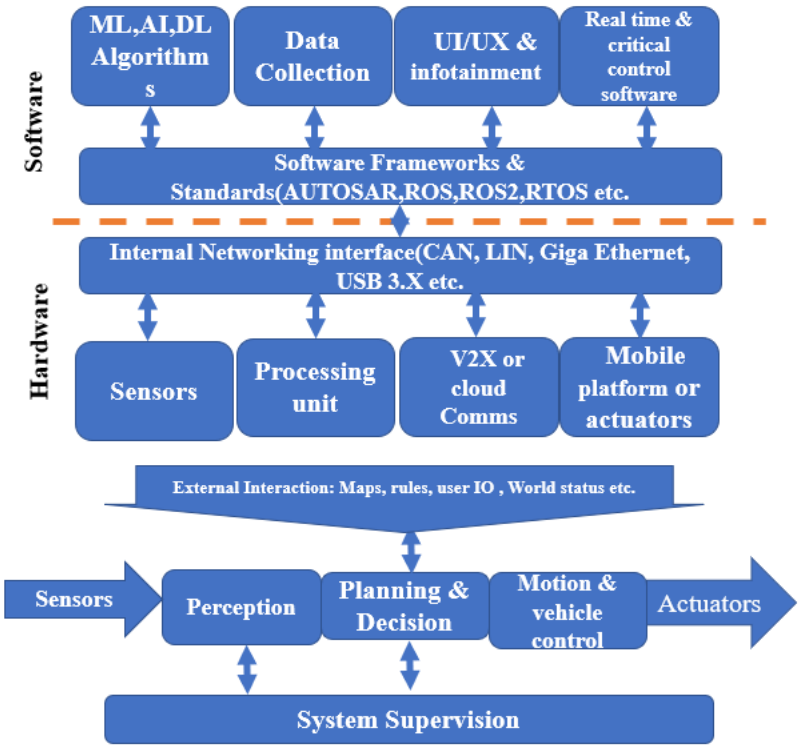


Fig. 11: Software & Hardware Technical/Functional architecture of an autonomous vehicle[26][27]**.**

Description: -

Technical view

Hardware and Software depicted above describes functional view of an AV driving architecture and every individual component has its own aspects which gets embedded in the system.

AVs provided with multiple sensors for internal as well as external monitoring of vehicles and surrounding by human drivers. multiple ECU's to be used for extracting data has been replaced by GPU's and FPGA's having multiple cores which extracts end process the data from sensor and this overall platform is being specified under heterogeneous computing. External data gets extracted from V2X communication and Internet.[9] The hardware is nothing but the vehicle where the operation or behaviour of system has its dependability over the application and terrain where system function. Internal interface for connectivity involves 2 different bands[26][27].

High Band-USB 3.X, gigabyte ethernet

Low Band- CAN, LIN Networks

With the upgradation and advancement in AV technology, vehicle has now become a supercomputer running on route. This vehicle comprises of real time monitoring system which includes framework, different modules libraries that supports ML, AI & DL algorithm.[26][27].

Now a days in the automotive industry to standardise the architecture of an ECU, and system design framework AUTOSAR has become a Bible for all automotive industry which outlines the guidelines related to software and its framework. ROS (robot operating system) also runs in a well-established framework of software which provides all basic and dependable tools and libraries which involves accessible implementation for navigation, motion control algorithm, perception etc[26][27][30].

Functional view

Avs comprises of logical blocks which describes the information flow, data collection to control vehicles, and monitoring of system etc. So, basically these blocks cover perception, planning and decision motion and configuration of system for vehicle control of actuators and monitoring [26][27].

Sensors in AV- Sensor detects the events which are ongoing in the surrounding, for quantitative measurement. Smart sensors are those which collects & transfers the data without human intervention and are interrelated with system. Non-Smart sensors are those which needs human intervention for collecting & transferring data [31].There are 2 types of sensors[2][9].

1. proprioceptive sensor- senses states of vehicles like global navigation satellite system, ecoders, inertial navigation system.
2. Exteroceptive sensors- monitors the environment and its surroundings which features terrains and external objects. Ex. camera, RADAR, LIDAR etc.

In planning and decision states, which ones on receiving external information of travel mission whether it is long term or short-term plan capture the data and activate the navigation. Autonomous emergency breaking is one of the examples of this behaviour. [34].
Motion and configuration of system for control and monitoring relates the generated trajectory which considers configuration, geometry, and limitation. To control or stop the movement of vehicles this stage involves all the expected safety features as commanding involves operation of high priority.[34].

Monitoring considers supervision of system which involves both the hardware and software aspects. ISO 26262 standard has outlined all the guidelines which are standardised for road vehicle safety and automotive industry has adapted and must adhere to all these stated guidelines to prioritise and guarantee the safety of people environment and property. The document involves a full product development life cycle by model which explains all the possible hazards falls risk severity and controlling measures. The guidelines document covers the entire product development life cycle from requirement elicitation to designing & further to validation and product release. This ISO 26262 to adhere to ASPICE guidelines from quality and management perspectives which captures the entire vehicle life cycle from development to testing, verification and validation state. Also serves the purpose of consumers to receive a quality product [22].

7. Challenges in Autonomous Vehicles

Autonomous vehicles are promoted so that it will create a future with effortless driving. Companies claim that it will reduce almost 95% of risk of accidents and crashes. Autonomous vehicles connectivity with its neighbouring vehicle almost reduced the crashes but cannot still assure safety in absence of network linkage /connectivity. After consolidating theoretical models, empirical data, still it can be observed that we cannot avoid such scenarios and this hazardous scenario can certainly happen with high probability [1].

7.1 Pre-crash scenarios

Three crash causes were investigated to capture many views that causes driving on roads a biggest challenge: (a) Obstructing Vehicles, passer-by (remote vehicle location), (b) Traffic disobedience (assuming traffic rule-disobeyed), (c) Projecting Unreliability (inaccurate prediction of vehicle activity based on previous inspections and monitoring). In all these instances, it isobserved that it is not possible to assure safety in worst casesin absence of network linkage. We also provide some estimates for the probability of a crash in such scenarios[28].

Fig. 12: 3 scenarios prior- crash[3].

Illustration of pre-crash cases with obstructing passer-by: AV (in yellow) is obstructed by stopped or moving vehicle (in blue). There are few challenges which affects automobile industries: -

1. Worldwide shortage of semiconductors
2. increased commodity prices
3. electrical vehicle segment
4. upcoming BSVI phase 2 regulations.

Crash rates were surveyed & predicted results were statistically depicted (crashes per year) for vehicles which are conventional & those which are autonomous. Calculations were done using equation and are illustrated in below figure. The outcome of the illustration states that the decrease in crash rate was around 12% [3].

$$Ln(Crashes) = 1.09 \times Ln(Conflicts) - 0.98$$

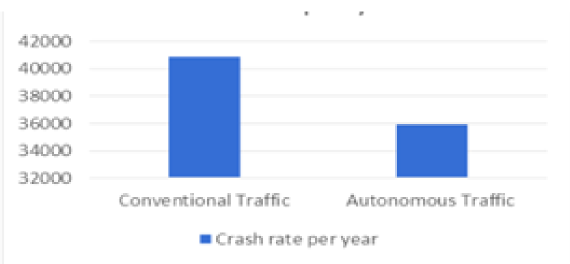


Fig13: Crash rates in AVs and Conventional vehicle scenario with decrease in the crash rate of around 12% [3].

Research done so far confirms that risks which are associated with AV may emerges from the slight careful conduct of vehicle occupiers and road occupiers, system fault, shortage of rule, dash algorithms which results in severe crashes that regulates life or death circumstances throughout unavoidable mishaps. Safety execution may enhance over time if the people agree on extensive establishment, that will permit AVs to enhance more real-world driving cases.[20]. The below depicted coordination strategy address the cross disciplinary concerns of engineering which ensures safety.

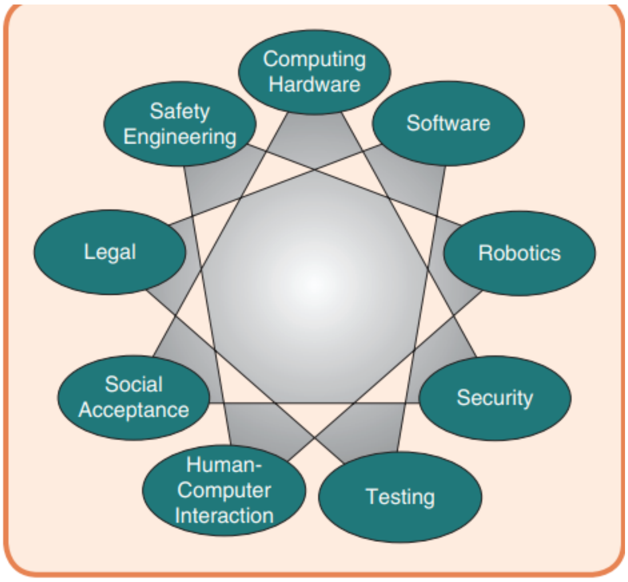


Fig14: - Inter-disciplinary approach for Safety considering all the aspects which needs coordination to ensure safety[20].

To ensure safety of fully autonomous vehicle it requires multifaceted approach in all tiers of functional scaling from hardware fault tolerance to ML cooperative with human driving vehicles, authenticating system to operating in highly disorganized environment and so on. However, above all the immense challenge in establishing full design, rollout procedure that merges all safety aspects in unified approach. this concern also includes non-functional aspects with respect to expenses, risks, ethical inspection. One biggest threat to autonomous vehicle is due to cyber-attacks which impacts the security and reliability of system [24].

8. Challenges to autonomous vehicles in field of testing:[19].

ISO 26262 V-model process sets framework that specified each type of testing based on the design or requirements document. The research paper which describes Autonomous Vehicle Testing and

Validation also identifies 5 major challenges in testing according to be model for autonomous vehicle

1. Driver out of loop
2. Complex requirements
3. Nondeterministic algorithm
4. Inductive learning algorithm
5. Failed operation system

SAE works in concerning all aspects of injury caused and mitigation associated with transport system. This includes safety mechanism, injury response, tolerance, impact with objective of developing restraining vehicle and infrastructure environment, which is successful from safety aspects for passengers, riders, occupants etc [19][23].

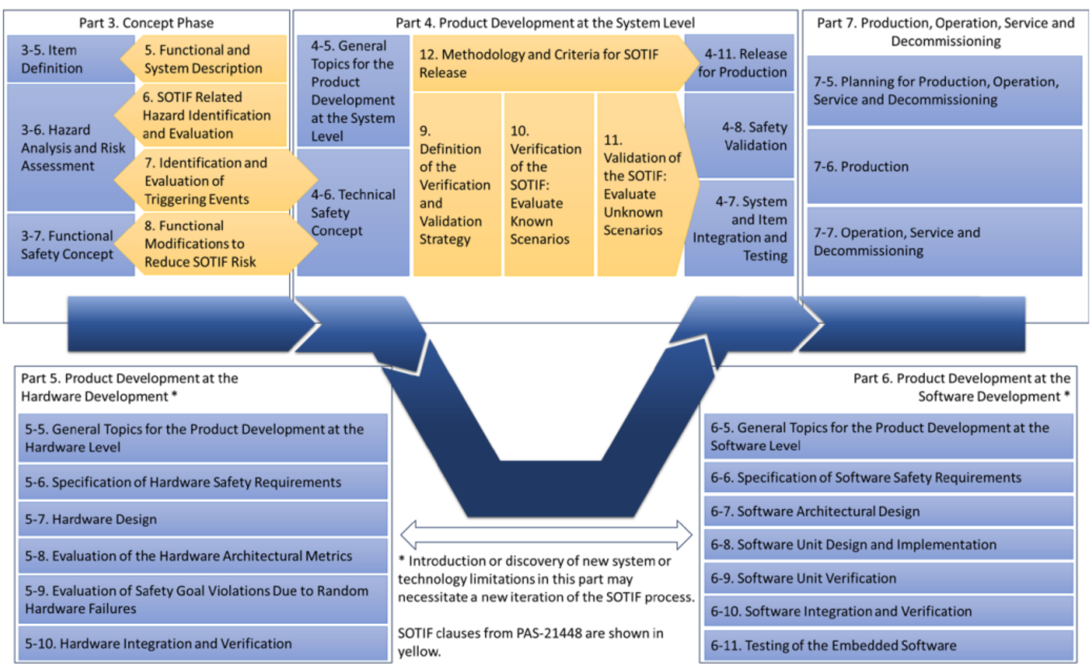


Fig. 15: V Model of vehicle safety[19,23].

Conclusion: -

An investigation done by us so far justifies that there can be numerous medical assistance that can be used to maintain drivers' safety and chances of accidental deaths to be reduced up to negligible.

All possible scenarios for safety operation of vehicle have been examined in initial segment of this study. Till now safety has been taken into consideration on basis of categories which are identified under- safety, accountability, privacy, industry influence. All safety aspects for vehicle/driver can be achieved by introducing additional safety features in the autonomous vehicle. Some features need to be enhanced which can specifically ensure safety of driver & the passengers inside the vehicle. Also, to avoid sudden mishap of accidents due to unidentified speed breaker/bumpers is proposed for safety purpose. Further, considering few more safety aspects to be introduced in future, a sensing device to detect occurrence of any sudden explosion in vehicle is proposed. The increasing demand of 4 wheelers across the globe has a tremendous impact on economy of the country. Hence, above mentioned features can be introduced in vehicle to make it smarter, convenient & interactive with the driver.

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