2 Days, 13th International Conference on Recent trends in Engineering Science and Management (ICRTESM-18)
Vedant College of Engineering & Technology, Bundi, Rajasthan (India)
21st -22nd January 2018, www.conferenceworld.in ISBN: 978-93-86171-93-1

Technology & Testing Methods used in Autonomous Cars

Prince Amera[1], Dr. Brajesh Tripathi[2], Dr. K. B. Rana[3]

[1,2,3]Department of Mechanical Engineering,
Rajasthan Technical University, Kota (India)

ABSTRACT

Now a days, driving is very critical to the peoples as there rapid increasing in vehicle traffic. On the other hand as traffic increases the possibilities of accidents also increases result people scares to travel. Most of the people like physically handicapped, having blur vision, children's and due to age factor they don't dare to drive the vehicle.

In new generation of cars the system becomes so advance that it is moving from mechanical to the electric and electronic system technologies as it reduce the human efforts. In this report, we show about the technologies used in cars and how they can change the strategy of driving so that people can trust. Trusting of people accelerates the development which is also safe, quick, low cost and reliable to the people. Even these technologies reduce all the human inputs nearly up to 99.00 %. So we are discussing about the vehicle which made autonomous from automated by using various technologies, classification of vehicles, description of technologies, how they works and how human input and the possibilities of accidents reduced.

On the second hand, it is also necessary to review the people about the methodologies of testing of these vehicles. In this we learn about the vehicle testing related methods, vehicle functional testing and the system validation approach. At last we discussed about the conclusion and the future aspects of autonomous vehicles.

Keywords: Automobile, Autonomous, Safety, Technology, Testing

I. INTRODUCTION

Autonomous means Self Governance, Autonomous Vehicle which drives by itself. It is the next revolution of automotive industry and have impact reaches most aspects of our lives, like it has lower mobility cost as it increases the efficiency, consumes lower energy resource i.e., renewable sources which helps to reduce the emissions, gives personal freedom for those who currently cannot drive because of age, blindness, fear of traffic accidents and fatalities which increasing day by day or by other reasons. Some technologies are already used in cars and the development is continued but still people don't know about them and they fear to adopt it, reason lack of trust. Many systems are evolved in India, but as of 2018 no cars are permitted on public roads were fully autonomous as people requires vehicles which is ready to take control at any time.[1]

The goal of this paper is to bring attention towards these great advances which currently used in automotive field and to adopt this crucial and highly beneficial technology without any misconceptions. Driver error is the most common cause of accidents due to lack of decision, response and attention during driving and when the

human brain is replace by technologies it naturally improves the driving as they have faster response to take decision.

An autonomous vehicle also called Un-manned grounded vehicle, a robotic vehicle that designed to travel between destinations without human operations. It is well qualified and fully capable to sense the environment and to navigate itself without any human input, only the destinations from origin are to be set by human.

An Autonomous cars use a variety of techniques to detect their surrounding such as Radar, Laser Lights, Global Positioning System (GPS), Computer Vision and Advanced Driver Assistance Systems (ADAS) and several sensors. These control systems interprets the sensory information to identify obstacles, gives navigation paths and relevant signage, as well as they allow for taking decisions. They are capable to analyze the sensory data to distinguish between other cars moving on the road which is useful to eliminate accidents and they make plan for choosing another path to reach the desired locations in less time as possible which is a great advantage for human. Furthermore, as the great precision of automatic systems available in vehicle they could improve traffic flow, increases highway capacity and reduce the traffic jams.

An autonomous car not only moves freely without any communication connection to the cloud or other vehicles. They are interconnected with Vehicle-To-Vehicle (V2V) for better approach to reach in case of emergency also, Vehicle-to-Infrastructure (V2I) for upcoming traffic signals, Vehicle-To-Network (V2N) for traffic queues nearly up to 5 kilometers ahead and Vehicle-To-Pedestrians (V2P) for people walk away. These interconnections are necessary to make the car more advances and it makes the people trustworthy to adopt it. [2]

After the buildup of these cars, system safety and testing is the next challenge for autonomous driving and to assured it, they must be highly précised and accurate to the surrounding models. Hence the testing process is done to cope with this in such a way that they should be able to take the decisions in different modes of failure and when the dangerous situations of the real world are happened. There are many approaches which we are going to discussed for driving test of vehicle. These methods are very useful to test the scenarios and it is enough sufficient to make the vehicle legal in the country after fulfill the needs of autonomous drive. In the world, Nevada, US became the first jurisdiction in year of 2011, which is allowed to use the self-driving cars on public roadways. Also several companies are developing and done the testing on it include Google, Volvo, Volkswagen, BMW, Ford, Mercedes Benz, Audi and many of them get the positive results as a single accident is occurred during one of the infrequent occasion is arrived when a human is driving. After the repetitions of testing, at last another test of over 1000 miles was completed successively without any human instruction. Finally the commuters are allowed to do other things while travelling such as working, reading or sleeping.

In this report, I review about the car technologies and how they make it fully autonomous. Also I review about the existing test methods of autonomous driving, functioning, verification and validation. It will be helpful for safe and quick reproducible testing at low cost and accelerates the future development.

II. AUTONOMOUS CARS

In this section, we are discussing about the technologies used in vehicle which makes it fully autonomous, all these technologies are interconnected to the monitoring device it collects the sensory data and interprets it. First of all, **LIDAR** (Light Detection and Ranging) called "Heart of the system" a sensing technology located on the roof of vehicle, put the laser in every direction and calculate the time it takes for the light to bounce back which measures the distance between the car and object, repetition of this occurs by doing so it creates a 3D map of the car's surrounding, its range is up to 60 meters. It is necessary to understand the environment for the system so it takes the decision about where to move or stop. When the map is created by LIDAR it correlates with GPS receiver which tracks the altitude and location of system. After this second technology, called **AGVS** (Automated Guided Vehicle System)[3] is located on the dashboard of the car; it helps to guide the occupant and to navigate the vehicle automatically. The map is pre-installed in memory of monitor and by using GPS (global positioning system) vehicle knows the traffic flow, highway capacity, time to travel the distance and which one path is better to drive. Only the origin and destination is to be select by the occupant and then the decision is taken by the fully autonomous vehicle automatically. Even when the car is empty, we can call the car by android or by other predefined gadgets to system at any place to receive us. This could be possible when the navigation is provided to the system. We discussed that the vehicle knows it's surrounding by using LIDAR and the path is followed by the prediction using AGVS navigation system.

Now the major query is arrived that how the vehicle moves on desired path with or without occupants without any human input, how the vehicle maintains the speed or stop when the obstacle is come in front of it, how the vehicle keep itself on the lane, how the vehicle stabilize itself during motion on non-uniform paths, how the vehicle park itself at parking spot or places after it drops the occupants and at last "Is the autonomous car is safe for human being ? " when it moves in the real world. These queries are solved when remaining technologies is described.

The third one technology is called **ACC** (Adaptive Cruise Control) system[4] which helps to vehicle move on desired path chosen by AGVS system and it does not only moves the car constantly, it increases and decreases the speed of car, automatically re-accelerates when the vehicle is stop and maintains the proper distance in same lane to avoid collision. The distance is set by cruise control switch in manual but in fully autonomous it is already preset. Technology behind this is LIDAR, sensors located around vehicle (nearly up to 12 or more), cameras- connected to monitor. Vehicle moves when the LIDAR sends the information to the monitor to accelerate the vehicle when the path is cleared and the throttle sensor controls the throttling/actuator device which is responsible for engine rpm; more the throttle angle is more the vehicle achieves speed, when the obstacle arrives it sends the message to slow down or to stop the vehicle and then brakes are applied.

At the same time when the vehicle gets acceleration, the fourth technology called **LKS** (Lane Keeping System) is participated. This is a mechanism which is designed to keep the vehicle on lane by detecting the line markings on the road surface so the vehicle doesn't tends to move outside. The device used is very high tech protected Laser or Infrared Sensor or camera to detect the markings mounted on the top of windshield or at both sides of bumper. They send the virtual image of road to the monitor to analyze and after it recognize to steer the vehicle

and also to take the turn, turning radius is given by this system; this simulation of data and command is done in microseconds. In partial autonomous vehicle, LDWS (Lane Departure Warning System) is used in place of LKS, as it is designed to warn the driver when the vehicle moves out of its lane in different ways. Like when your car leaves your lane, system will give you warning signal usually an audible sound with flashing lights to get your attention, if still you did not take any action then another signal of vibration on steering wheel and on driver seat is occurs and at last when no response is given by you in time the safety system is activated and brakes are applied automatically to stop the car itself.

When the vehicle moves, takes turn or achieves top speed it is necessary to consider the problems of directional instability, drifting, under/over steer of vehicle also rollover effects, yawing effects and other side or wind forces (gust) which leads to loss of control; to avoid this the another fifth technology called **ESC** (Electronic Stability Control) an active vehicle safety system is activated simultaneously with other technologies during driving.

ESC works with the traction control system as driving safety system when the vehicle shows a tendency to leave the driver's intended path i.e., under/over steer or exceed a lateral acceleration threshold, the system intervenes by selectively applying appropriate brakes to get better align of vehicle and in fully autonomous it assist the vehicle to maintain itself. Behind this on wheel is speed sensor, on steering angle sensor and on center of vehicle the rotational sensor is used to analyze the motion of vehicle in stability control system. The movements is recorded by these sensors and the data is send to the monitor for analyze then monitor monitoring the actuators by sending the interpreted data to stabilize the vehicle.

Note – ESC take the charge of monitoring side-to-side motion around a vertical axis, whereas Traction control takes the charge of monitoring front-to-back motion. If the traction control system detects wheel slippage, the ESC sensor will pick up the direction of slide. Another side when there is a difference found between steering wheel angle and the direction of car sliding, then ESC activated to work with traction control system in such a way that it engage the Anti-Lock Brake System at the proper wheel/wheels and it control the throttle to reduce the speed of the vehicle.

Generally, a car might take five seconds to decelerate from speed 100 kilometer per hour under ideal conditions, but nowadays we need to stop spinning of vehicle within a second or less than a second. To achieve this, the next technology called **ABS** (Anti-Lock Braking System) [5] is used; it monitors the speed of each wheel to detect locking and reduces the stopping distance to avoid collision. Hence ability of stopping the vehicle is improved.

In Partial Autonomous Vehicle or Manual Driving when sudden brakes are applied it will release the brake pressure for a moment and then provides the optimum brake to each wheel. This process repeated several times in short duration of time, also it enhances the steering control during sudden stops as vehicle is steer easily at high speeds. In Fully Autonomous Vehicle, when the obstacle is come in front of car which is detected by LIDAR, the controller sends the command to release the braking pressure it is done by pump, when the pressure is released (via brake line) to the valves (implemented on wheel hub) they opened and force exerts on the spinning wheel which causes vehicle to stop. Here, monitor decides the breaking force i.e., either it slows down the vehicle or to stop vehicle, depending on the surrounding of vehicle as sensors senses at all times.

Note – Occupants inside vehicle feels pulsing when the ABS is in operation; this comes due to rapid closing and opening of valves. Some ABS systems can cycle up to 15 times per second.

At last when occupant reached at destination they must be sincere about "If vehicle should be fully autonomous then where and how the vehicle is parked?"

To overcome from this situation the another technology called **APGS** (Advance Parking Guidance System) is used to guide the vehicle at parallel parking places (At the corner of roads) or to park the vehicle at parking spots like in Lexus LS 460 L. In partial autonomous vehicle, the driver has to find the parking space using AGVS in navigation screen to tell the vehicle where it should go this is to be chosen in parallel parking place. In fully autonomous vehicle, no need to find the parking place it find itself and parked at the parking spot by using advance technology includes AGVS, GPS, IR, surrounding Cameras etc.. Vehicle needs space to park up to 10 feet or longer than the car. Occupant also parks the vehicle at their own place they only need to set their parking place in their navigation system so that vehicle knows the parking. At last occupant only calls the vehicle by predefine gadgets when he wants drive.

Finally, from beginning to end we discussed about autonomous driving by this we committed that autonomous driving is safe and it is able to tell us about any ethical problem or any technical obstacles if comes during driving then for occupants safety the **Airbags**[6] are implemented on the dashboard and on the doors of car which keeps driver safe even when vehicle collides. Airbags are used to reduce injuries as they prevent the chest and head of occupants occurs from collision. It is simple and clever because bags are inflated (due to chemical explosion causes release of harmless gas, this inflates the bag at speed of approximately 300 kilometers per hour which is very faster comparing with car crash speed) and then deflated by holes at edge when occupant pushed against the bag. Also for safe drive purpose in autonomous cars, **Adaptive High Beam** and **Automotive Night Vision System**[7] is in built to project high/mid/low beam of headlights or dippers automatically when the intensity of light if come in front of vehicle during night drive and the night vision system is used for better view for occupants it uses IR, Laser, etc..

III. TESTING METHODS

Before autonomous drive it's necessary to test the autonomous vehicle for safe drive as all vehicles should be eligible for crash test. In this section, we discuss about driving testing related methods, testing of functional system and last method of evolution testing.[2]

Note - "loop" is a computer language command which is used for repeating cyclic process and "simulation" means testing of program to gain a desired action or behavior.

First step, millions of line codes, equations and algorithms are used and tested by using different software's by this software testing is done. Then it is implemented in the hardware namely installation chips, arduinos, controllers and in memory of computer, this step is further tested to observe the working of system actuators, sensors or vehicle components it called as simulation test. Both steps are repeated many times so named as "X-in the loop" where X refers to either software or hardware. In short form they called SIL and HIL. X-in the loop is responsible for receiving or sending the data from surrounding of vehicle to the monitor of vehicle to perform

 ISBN: 978-93-86171-93-1

action and vice-versa. After implementation of equipment a single autonomous vehicle is prepared for testing and when it is done perfectly they are connected to another vehicle to create communication cloud like V2I, V2V, V2P, V2N etc. this is the third step and last step is done when the vehicle driving test is performed successfully with or without obstacles and then in real traffic.

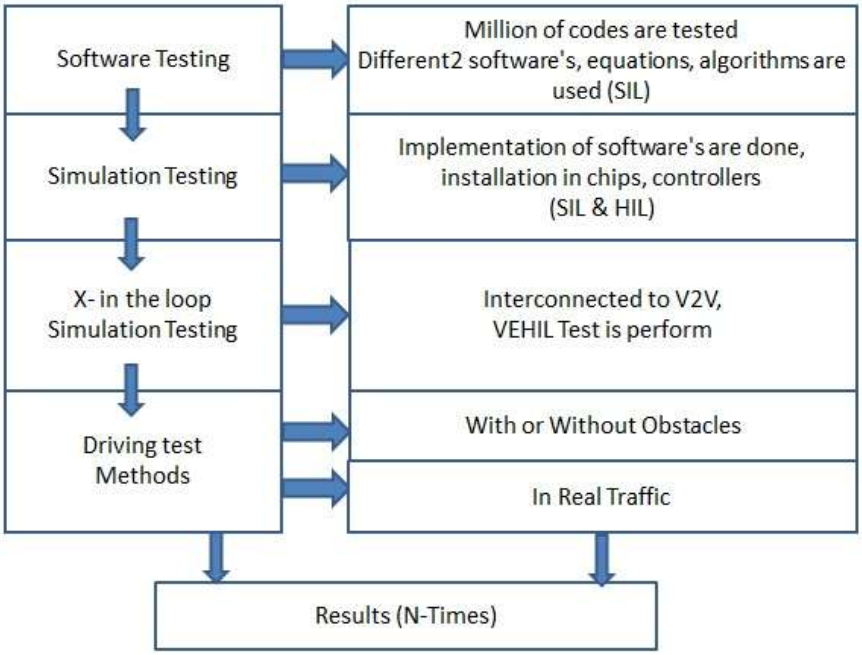

Fig 1 – Testing Related Methods Flow Diagram

After creating the communication cloud between vehicles the testing of functions is done to check the model of an autonomous vehicle which depends on the driver behavior, sensor and actuator followed by this autonomous system model. It consist the Perception, Decision and Action Layer. Now a day, advanced and new technologies, such as adaptation and learning, the existing test/validation methods are insufficient. These new challenges require considering established technologies like formal verification it is done when models data are compared with the real data to evaluate or compare the performance by both datasets with the help of statistical characteristics.

The first step of the functioning test is perception layer which is responsible for the acquisition of all data comes from environment through vision or radar or all other sensors used near actuators. After it they merge to a unique fusion map. By physical tests, software test or HIL simulation test, both the various sensors and environment perception layer are tested. The assessment criteria are obtained, including the state and errors of the posture and localization, the detected pedestrians, lanes, traffic signals and lights, other vehicle and other related elements. When the perception layer of the autonomous car is completed the data is transferred to the system where it takes the decision “What to do?” The ability to take these decisions is pre-installed to the system according to the situations of real environment. The n cases of situations are pre-setted to the module so that it cannot be confused to take it. Further optimizing this data acquisition it interprets all the incoming data to

 ISBN: 978-93-86171-93-1

generate a reasonable output to the Action Layer. The Situational Assessment are defined to the chip in categories of short and long term planners; they should influence each other to avoid short term decisions which do not accomplish the overall goal. Artificial Intelligence algorithms are commonly used in the Decision Layer mainly due to the highly non-linear behavior of real environment such as Neural Networks, Machine Learning, etc. Majority to take decision is like to vary the speed or to stop whenever any obstacle is come in the front of car. Many of the vehicles are able to overtake the car even they decide to move continue after the vehicle stopped like during intersection of roads, and following the traffic signals, it avoid the collision. The driving system reaction characteristics are used for indicators, including reaction time and operating correctness etc. After taking decision this navigation layer function test is done by driving test and simulating. It performs the higher level of tasks related to driving such as controlling the global objectives, trajectory planning, efficiency and commodity, taking into account the driving conditions. The Path planning error is used for assessment criteria; evaluate the capability of the algorithms to avoid collisions with other objects, at any time.

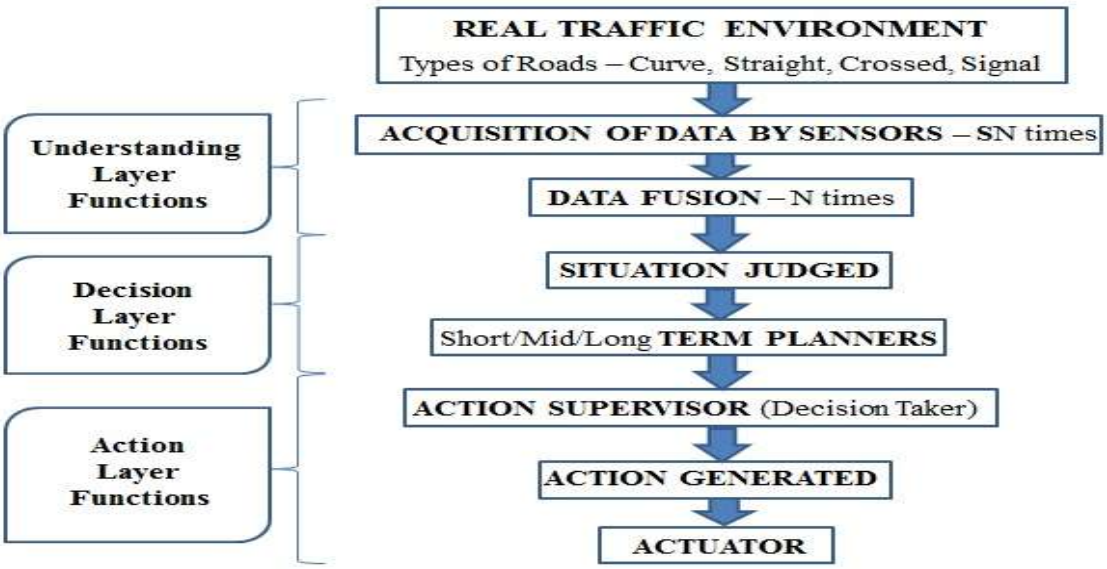

Fig 2 - Functional Flow Testing

At last, Action layer test is done. Sensors like actuators are tested about their response and how they behaves after they receive the command from decision layer via navigation system to take the action by supervisor, it sets up the abstract decision into set points to be fed by the actuators controllers. The action generator denotes the system controllers and performs the low-level actions in the actuators, also monitoring the feedback variables to further process the new actuating variables. The control level is the lowest level, i.e. the physical control of the vehicle, i.e. the sensors and actuators of the driver's model. It is evaluated by test drive or simulation ways. The vehicle trajectory deviation, acceleration and jitter are used to evaluate this module.

 ISBN: 978-93-86171-93-1

For the validation of the autonomous vehicle system various steps are taken the simplest approach is to allow the vehicle to complete the specified task at different level of complexities so it has to become more ability to avoid the errors of system, failure of decision, taking the proper navigation and avoidance of collision. It can be done by tremendous algorithms evaluation. By analyzing autonomous driving functions, lists of simple function test cases are selected and assembled into different testing processes, which are further abstracted as driving tasks sets. By analyzing specific driving tasks sets, autonomous driving functions can be evaluated. Autonomous driving tasks tests are carried out under different simulation or real environments. By a formal evaluation process, including tests design, recording and evaluation and completion verification, all driving tasks completion are finally evaluated with different task complexity property and different environment complexities.

Based on these autonomous driving testing practices and other related works, we summed up an Autonomous Vehicle evolutionary design and testing comprehensive flow.

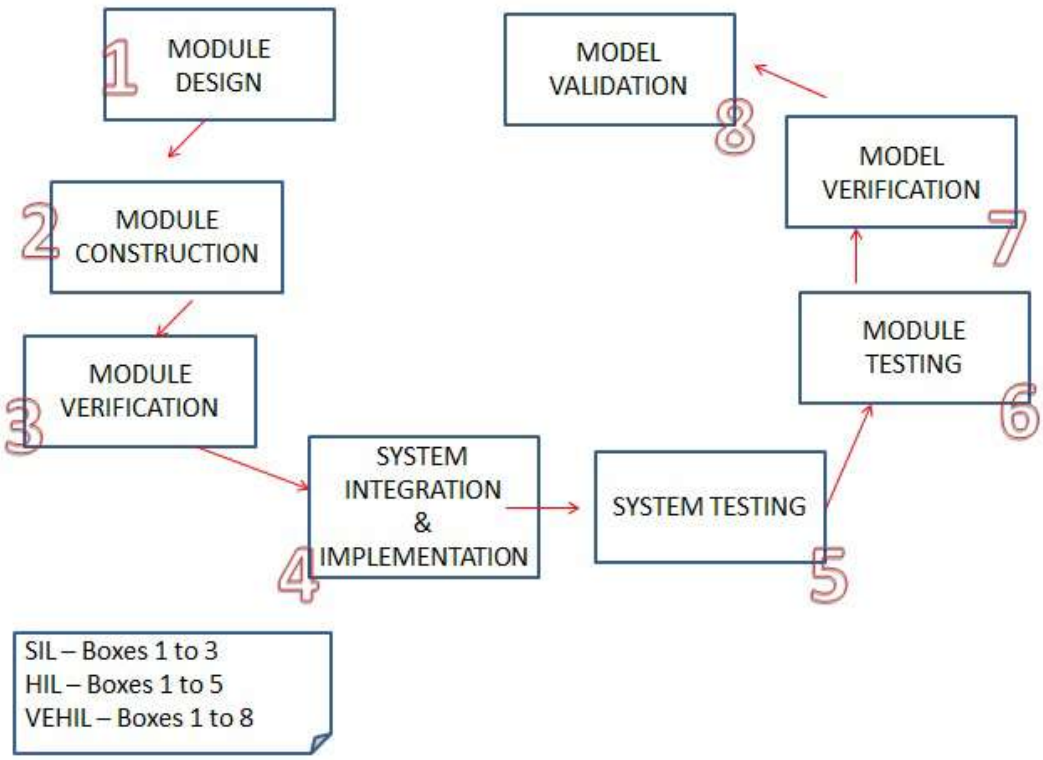

Fig 3 – Vehicle Design and Validation Flow

Finally, when these testing methods are successfully done the flow of testing in real traffic taking several cases are to be held after the succession of these tests its validation is completed.

 ISBN: 978-93-86171-93-1

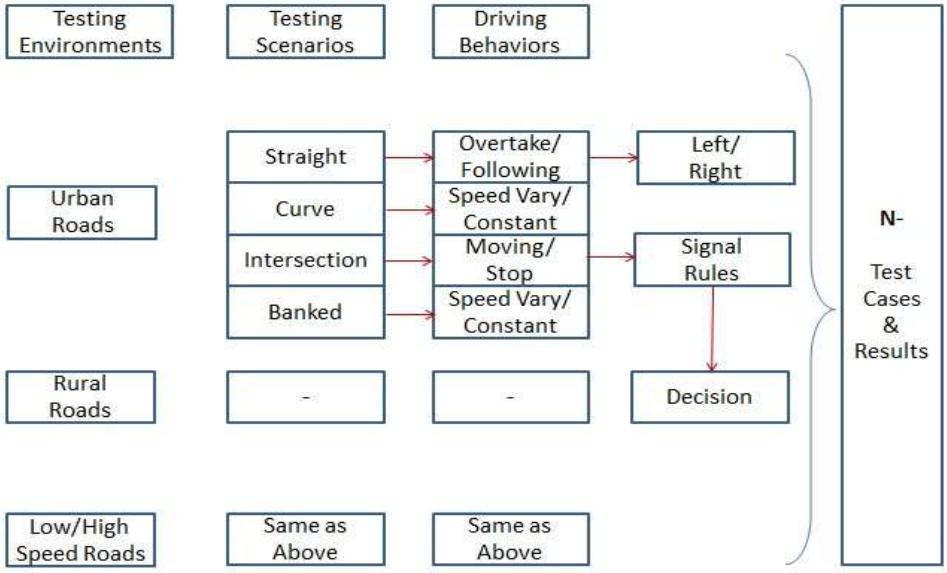

Fig 4 - Real Time Testing Cases & Techniques

IV. CONCLUSION AND FUTURE ASPECTS

If the sensors of the car are the eyes, the processing unit is the brain. Processors take all the data collected by the sensors and turn it into actual driving. We might think that machines would naturally be better at driving than humans, with faster responses, automatic decision-making, and an infinite amount of attention and stamina. However, cars still need to "learn" how to drive because it's an offline process. The following technologies could provide moderate to high benefits to older drivers like lane departure warning, forward collision warning, parking assist systems, navigation assistance and adaptive cruise control system only if proper training is provided to human to operate it. We conclude that they are too early in development to be able to assess the benefits for older drivers. Many of these technologies are available today in vehicles, while some of the technologies are under development and are expected to be available in the near future. Also we conclude that the autonomous vehicle is still in the infancy stage. There is a considerable road to travel before maturity, implementation, and mass-market release are achieved. The path is still problematic, facing several challenges. Perception of the environment remains the biggest challenge to reliable, smooth, and safe driving. There is a long list of research questions covering a wide scope that will need to be addressed and answered, including but not limited to customer acceptance, societal impacts, communication technologies, ethical issues, planning, standards, and policy. Software challenges such as system security and integrity have also emerged as serious issues to be addressed. These in turn have a number of policy implications including the challenge for policymakers to streamline and regulate many diverse vehicles with different operating constraints. It is also of paramount importance for policymakers to ensure that drivers understand these vehicles' capabilities and can operate them safely. One of the challenges ahead is to connect several intelligent vehicles to each other. In this report, we shed light on transport related themes that are directly or indirectly and positively and negatively

affected by emerging autonomous vehicle technology. Examples are land use, safety, vehicle-kilometer-traveled, parking, variation of demand, and fuel consumption.

In the near future, autonomous vehicle will be an indispensable part of modern transport systems. Furthermore, in light of such rapid changes in intelligent transportation systems, the education system must without question, align itself with these emerging technologies. Traffic engineering schools must reform their curricula to ensure that they cover more diverse subjects including communication technologies, software development, electrical engineering, and environmental and energy sustainability.

V. ACKNOWLEDGEMENT

I offer my sincerest gratitude to my guide Dr. Brajesh Tripathi, who has supported me from the preliminary to the concluding level with his patience and knowledge. I encouraged by my sister Mrs. Shraddha Srivastava, without her this report would not have been completed.

BIBLIOGRAPHY

[1] Autonomous car. (2018, January 17). In *Wikipedia, The Free Encyclopedia*. Retrieved 09:58, January 18, 2018

[2] Huang, WuLing, et al. "Autonomous vehicles testing methods review." Intelligent Transportation Systems (ITSC), 2016 IEEE 19th International Conference on. IEEE, 2016.

[3] Trepagnier, Paul Gerard, et al. "Navigation and control system for autonomous vehicles." U.S. Patent No. 8,050,863. 1 Nov. 2011.

[4] Karim Nice "How Cruise Control Systems Work" 15 January 2001.

[5] Karim Nice "How Anti-Lock Brakes Work" 23 August 2000.

[6] Marshall Brain "How Airbags Work" 1 April 2000.

[7] BMW Night-Vision Available in the 5 and 6 series as of March, Worldcarfans.com. 2006-01-08