

# Study of Autonomous Vehicles in Terms of Stages along with Technologies and Possibility of Implementation in Thailand

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**Abstract**— The replacement of traditional vehicles by autonomous vehicles are inevitable. Therefore, it is vital to be prepared for the next big revolution. This paper consists of autonomy's levels of autonomous vehicle, associated along with technology requirements in distinct level, including sensors, in-vehicle technology, infrastructure, professionals' perspectives as support, and the possibility of implementation in Thailand. The implementation of autonomous vehicles will not be practical without the execution plans and the collaboration of related parties. Moreover, the benefits of autonomous vehicle brought to users and environment are concrete. Vice versa, barriers and concerns occurs along with the implementation of autonomous vehicle such as ethical issues, parking area and parking fee, knowledge, and economical feasibility would also be included.

**Keywords**—Autonomous vehicles, Thailand, infrastructure, expert perspective

## I. INTRODUCTION

Autonomous vehicles (AV) could change people's lives forever, not only in people who are using it, but also people's perception toward safety, and ethical issues.

In the initial stage, autonomous vehicles will offer as private purposes, not public purposes. Since public needs huge amount of prerequisite work before implementing autonomous vehicle. On the other, private household could purchase and experience without further concern. However, tradeoff between immediate experience and safety would have to be informed to the public.

Autonomous vehicles are divided into 5 levels, starting from non-autonomous to fully autonomous that does not require human intervention. In Thailand, there are only the first 3 levels that are offered to the public as private vehicles. However, infrastructure still needs improvement and renovation in Thailand in order to maximize the safety level to both pedestrians and autonomous vehicle users.

## II. LITERATURE REVIEWS

Technology requirements of autonomous vehicles depends on a particular level of autonomy. With the increase in level, the system becomes more complex and expensive

along with the intensive complexity of infrastructure. Implementing autonomous vehicles provides many benefits, but also has many barriers at the beginning.

### A. Levels

Autonomous vehicles categorized into 5 levels of autonomous. Reference [1], with the first level of driver assistance, the vehicle could assist humans by emergency brake, decelerating/accelerating through autonomous, as well as adaptive cruise control. Second level, partial autonomous, drivers could now take their hand off the steering wheel and pedals off the foot. However, drivers would have to stay alert and monitor surrounding at all times, and able to take over the vehicle if asked for. Third level, the vehicle can monitor the surrounding without human need, but drivers are still needed to intervene if asked for. Fourth level, vehicles could drive safely, even driver does not intervene to take over even it asked for. The vehicle could park and pull up safely until driver take back the control. Fifth level, vehicle can perform all drivers could do with no restriction.

Table1: The levels of autonomous vehicles along with features

Autonomous Level	Features	Vehicle Examples
Level 1	Cruise control, lane keep technology, emergency brake	• KIA Stinger GT
Level 2	Control both steering and accelerating/decelerating	• Tesla model 3 • Cadillac CT5
Level 3	Environmental detection, able to "make decisions for themselves"	• Audi A8
Level 4	Intervene without human interaction in most circumstances	• Waymo (small scale experiment in Arizona) • Volvo (still under development with Baidu)
Level 5	No need of steering wheel, acceleration/braking.	-

### B. Associated Technology of Vehicles

- Sensors  
Autonomous vehicle composed of three common sensors to capture, to detect and to recognize the object

surrounded which are visible-light cameras (VLC), light detection and ranging (LiDAR), and radar. Each sensor has unique in functions, capacities, and limitations. Therefore, all three sensors should be combined since one sensor is able to offset the weakness of another.

Visible-light cameras (VLC) uses to capture images and collect visible light through image sensor then transmit to electrical signal. Signal is sent to on-board computer where AI-based algorithms will classify objects [2]. VLC performance is reduced by atmospheric conditions such as low-light environment, in adverse weather, heat wave, on slick surfaces, and speed of vehicle travel can be a factor as well. The number of VLC in automated vehicle can be customized based on the preference of manufacture [3].

Light detection and ranging (LiDAR) uses scanning lasers to estimate distances to surface by using the laser to hit environment object and bounce back to a photodetector then provide three-dimension image of the environment. LiDAR is able to use in no/low light conditions but still ineffective in adverse weather and when road surfaces are reflective. LiDAR is useful for medium and long-range detection because LiDAR was put on vehicle's rooftop which mean LiDAR was obstructed by vehicle itself. Therefore, when pedestrians or animal first become visible at close range can be endangered. Moreover, LiDAR are struggled to determine non-grounded object as well. Reference [3] said the optimal number of LiDAR to install in autonomous vehicle is 3 or 4.

Radar uses radio waves to estimate distance and detect objects. This type of sensor can be used in darkness and adverse weather but has poor resolution therefore, radar has difficulty to distinguish pedestrians, especially children. Refer simply to the reference number, as in [3]-there should be 5 or more radar sensors on automated vehicle.

- *In-Vehicle Technology*

Driver State Assessment (DSA) could monitor driver's eye gaze, degree of head rotation, and eye blink in real time analysis, by looking at the driver's face and associated with image processing algorithm which is essential to autonomous vehicles [4]. Since automation itself promotes the development of drowsiness due to the change of the role from active interactor to passive observer [5]. Moreover, in-vehicle navigation systems (IVNSs) is also important because having advanced navigation systems can reduce visual processing, reduce navigational errors, and improving overall driving performance of the driver. Reference [6], Health Monitoring System has become one of the most significant systems in autonomous vehicle where system is able to check the health of driver such as heart rate, blood-oxygen level, and blood pressure. In addition, autonomous vehicle also needs advanced collision notification systems (ACNSs) to find the location of users and send to emergency service.

### C. Associated Technology of Infrastructure

- *Infrastructure Support*

During the first two levels of autonomous, no advance infrastructure is prerequisite. However, the remaining three levels of autonomous vehicles must have advance infrastructure development and changes. Among those infrastructure, 5G technology is the most vital

component has to be implemented prior of the level 3 autonomous and further.

5G can help the autonomous vehicles to reduce emissions up to 90 percent, cut travel time by 40 percent and save \$22,000 annually. By using the fast fiber connection, the 5G is able to create a hub of database center that every autonomous vehicle cut connect to it to ensure the maximum safety as possible. Also, 5G tower can assist autonomous vehicle in finding the best route to avoid congestion [7]. 5G has the connection speed of 100 times of 4G. Therefore, the processing speed of 5G is greater than the human reflection.

Roadside Sensor is hugely important in developing countries such as Thailand and Southeast Asia countries. Jaywalkers and reverse drivers play an important aspect in roadside sensor. With the assistant of roadside sensors, autonomous vehicles could get notified by the sensor that violation of traffic law enforcement occur right ahead, and how the autonomous vehicle should cope with it. Which, ultimately could reduce the accidental rate.

Machine Readable Sign able autonomous vehicles to read the sign not by camera, but by the code that embedded in the sign. With the embedded code readable sign slot in the signage. Autonomous vehicles could fully capture the details inside it. Unlike traditional camera used capture, which the information can be distorted by austere weather [7].

Most of the accidents caused by autonomous vehicles nowadays are caused by Lidar ineffectiveness. Therefore, it is critical for urban planner to install lane marking, these can be manufactured out of cold plastic to make Lidar work easier at night and in nasty weather conditions [7].

Refer simply to the reference number, as in [8]-Autonomous vehicles could reduce the gap between cars when compared to traditional vehicle. Along with greater reaction than human. The congestion situation in the city would reduce. Therefore, it is better to invest on autonomous vehicles than highway construction project. Since autonomous could reduce the gap between cars which ultimately increase the capacity of the highway.

Table2: Infrastructure and its benefits and contributions

Infrastructure	Benefits/Contributions
5G Tower	<ul style="list-style-type: none"> <li>• Reduce congestion</li> <li>• Faster decision making than human</li> </ul>
Roadside Sensor	<ul style="list-style-type: none"> <li>• Detect jaywalkers and reverse drivers, which will notify autonomous vehicle before hand.</li> </ul>
Machine Readable Sign	<ul style="list-style-type: none"> <li>• Increase accuracy of reading details</li> <li>• Would not distort by austere weather</li> </ul>
Lane Marking	<ul style="list-style-type: none"> <li>• Increase effectiveness of Lidar</li> <li>• Keep vehicle on track better</li> </ul>

## III. BENEFITS OF IMPLEMENTING AUTONOMOUS VEHICLES

### A. Increase in Safety

Studies have found that over 90 percent of road accidents can be attributed to human errors [9]. A vast majority of collisions happen as a result of the driver's errors

or omissions. The elimination of human error through the adoption of autonomous vehicles is anticipated to markedly reduce the number of accidents, with some experts putting the reduction as high as 90 percent [9]. According to the World Health Organization, car accidents lead to fatality of around 1.25 million people [10]. Therefore, autonomous vehicles could greatly reduce death rate from road accidents. Being better than humans is the low bar, so the 5G technology is essential to the development of autonomous vehicles since its decision making is faster than human judgement.

#### B. Reduce Congestion and Greenhouse Gases

Since autonomous vehicles possibly lower the gap between vehicles and vehicles, and also the delay in responses, it could make the congestion level goes down and also reduce the reaction time of humans. Moreover, with the combination of 5G, the congestion in the future would be hugely reduced. Autonomous vehicle car-sharing and ride-sharing will lead to significantly lower demand for private cars. Simulations that are performed for the city of Lisbon have proved that, while maintaining a highly efficient public transport system, there possibly be even 65 percent lower in the number of passenger cars in the streets at the peak traffic hours [9]. Autonomous vehicle will eliminate the violation of traffic regulation, in particular speed limits. Driving according to the imposed limits should make vehicle's driving speeds closer to the speed that ensures the lowest fuel consumption. Therefore, it is resulting in lower generation of Greenhouse Gases emissions. Most autonomous vehicles are almost certain to be electric, which will reduce harmful emissions which could reduce the cause of lung and heart diseases, and climate changing greenhouse gases [10]. Fewer vehicles in traffic means a significantly lower consumption of energy and resources for the production, which means a significant decrease in Greenhouse Gases emissions.

#### C. Create New Job Positions to Skilled Workers

There is a steady increase in posting jobs in the field of autonomous vehicles as well as the expectation of experts in slight increase in engineering-related positions, and other positions related to the integration of autonomous vehicles into society [9].

#### D. Assist Aging Driver

Aging population is a group of people who are faced with physical and mental disorder. In terms of age-related changes in sensory and motor function, all visual functions are deteriorated such as night vision, glare resistance, and visual scan. The muscular strength, speed of muscular contraction, and flexibility also decline which lead to delay responses to change. Moreover, age-related changes in cognitive function become a big issue. Since elderly people always encounter with low ability to divide attention and spatial cognition which affect navigation then aging people can get lost because of this disorder. In terms of memory, older adults face problems such as short-term memory and difficult to retrieve the information from long-term memory. Lastly, information processing and decision-making, speed of processing in adult become slower. Therefore, it is difficult for them to respond appropriately to quickly changing on the road. The system may not provide that much benefit to adult drivers because sometimes aging people believe themselves

more than the system because of their accumulated expertise and judgement cause them to second-guess their trust but if the provider can make the user trust the system, it will help them a lot. [6].

### IV. BARRIERS TO AUTONOMOUS VEHICLES IMPLEMENTATION

Barriers on autonomous vehicles has many aspects. Not only in terms of economically, but also on ethical issues. Reference [10], when autonomous vehicles on the ground, cyber-attack on hijack the vehicles and ethical dilemmas are 2 important elements users would have to considered.

Cost of Lidar is major problem of implementation of autonomous vehicles. Cost of Lidar is more expensive than other components of vehicles which made it a huge barrier in terms of economical [10].

Parking space and area is critical in the implementation of autonomous vehicles. Most road infrastructure in Thailand are not pedestrian friendly. Therefore, it is difficult to assign parking area for autonomous vehicles. Moreover, the parking area must be disabled and vulnerable friendly which made the road condition in Thailand more austere. Along with the cost of parking. If the measure cost of parking is inexpensive, the traffic jam condition might exacerbate, also right of other users will be offended. However, if the cost of parking is expensive, the advocate of replacement traditional vehicles by autonomous vehicle might be holding back.

Refer simply to the reference number, as in [11]-autonomous vehicles may provide less benefit than expected. In the first time of autonomous vehicle implementation, users may not use the device in a correct way, and may fail to derive safety benefits because users still lack of knowledge in using this type of vehicle. In part of senior drivers, they may reject the system if the system makes a high false alarm rate which means that the system cannot fulfill their needs.

### V. EXECUTION PLANS OF AUTONOMOUS VEHICLES IN THAILAND

According to the suggestion policy from Thailand Automotive Institute and associated departments, demand and supply are the main factor to contribute autonomous vehicles in Thailand. To implement autonomous vehicles, associated parties need to prepare many things such as infrastructure, security, laws, and safety concerns along with the plans to implement which includes:

#### Plan1: Compatible Between Vehicles

Allowing imported vehicles from foreign countries to use effectively with Thailand's environment. The thing that Thailand needs to consider in term of compatibility consist of infrastructure support, traffic laws, and security law to make sure that autonomous vehicles can work practically with this certain environment.

#### Plan2: Implementing HD Map

In the case of the map, HD map is one of the fundamental facilities in to prepare for the autonomous vehicle implementation. At the beginning, the HD map should be prepared to be used in the motorway which is a good condition road. Accordingly, there should be the collaboration between government and private sectors to

build the HD map, and also create its business value as an incentive to develop.

Plan3: Vehicle to Everything and Intelligent Transportation System

Autonomous vehicles are about connecting things between vehicles and everything (Vehicle to everything) to promote safety, proficiency, and convenience. The connections will include the connection between many vehicles, and the connection between vehicle and infrastructure, e.g. traffic light, road ride sensors, traffic light center, and etc. Moreover, compatible with Intelligent Transportation System of Thailand is necessary and essential. Therefore, the preparation of 5G has to be in place as a tool of connection.

Plan4: Global Network Satellite System (GNSS)

Global Network Satellite System (GNSS) will be the major role to identify the precise position to autonomous vehicles and mass transportation system. Base station is needed to be expanded around Thailand with the assistance of Geo-Informatics and Space Technology Development Agency (GISTDA). Additionally, setting more sufficient stations for the usage, and also launch the regulation and standard to be with autonomous vehicles and mass transportation system is critical.

Plan5: Data Security

Autonomous vehicles are connected with outside environment where data can be transmitted easily. Therefore, all of the data need a high quality of protection to avoid hacking which can ruin the system. However, all data must be kept and can retrieve when needed such as in accidental situation. All of these force government to enact new legislation about data security that is kept in cloud or server, and also in-vehicle.

Plan6: Rules and Regulations Related with Public Use of Autonomous Vehicles

Before implementing autonomous vehicles, many laws have to be revised or legislate. To regulate the use and road accident victims from using autonomous vehicles, for example, Land Traffic Act, Vehicle Act, Highway Act, Road Accident Victims Protection Act, Civil and criminal law, and other related laws with the experts from many aspects, including law, social, and engineering to collaboratively legislate and revise the laws. [14]

## VI. PERSPECTIVE OF ASSOCIATED PARTIES IN THAILAND

Mr. Somchai Lertsutiwong, a chief executive officer at AIS which is mobile phone operator in Thailand. Mr. Somchai said 5G need approximately 2 more years to develop even though the government said Thailand will have 5G within next year because hasty implementation of 5G will possibly disrupt the experience of users and overall consistency of signal [12].

Thailand government along with private sector Airovr, and Siri Ventures, would be starting experiment of autonomous Tuk Tuk in Bangkok. Moreover, Thai government is advocating and providing incentives to vehicles that consume electricity as power sources. Reference [13], Therefore, Tuk Tuk is chosen as an experiment because 3-wheelers are more energy efficient than 4 wheelers. Moreover, 3-wheelers have smaller and cheaper parts, which is suitable for Thailand's hot weather condition.

With the Tuk Tuk experiment covering for 6 months, it is optimism with the future development of 15 seats autonomous vehicles that would be manufactured by Thai government and local auto makers [13].

According to the interview with the director of the Office of Road Safety Audit, Department of Rural Roads, the initial step to make autonomous vehicles possible in Thailand is to have the supportive infrastructure. The rural roads are under the authorization of the Department of Rural Roads, with the distances of 47,500 kilometers under control. The Department of Rural Roads is currently collecting the data of rural roads from image processing by using lasers. The infrastructure has to be informative and support autonomous vehicles in many ways, including signs and roads. In case of signs, Radio-Frequency Identification (RFID) tags have to be embedded in the signs to emit the signal to vehicles. However, Radio-Frequency Identification (RFID) tags have a limitation in which it is not able to operate effectively in long distances. Department of Highways is under developing machine-readable signage. Subject to the roads, in the level 1 to 3 of autonomous vehicles, road should be "Self-explaining" where infrastructures on the road are able to signal the vehicles what action should be taken, and the vehicles are required to read the information by itself. Moreover, in level 4 and 5, self-explaining is not enough, roads need to be "Forgiving" which means roads must not make people to be injured or into the dead. There are many ways to avoid people from damage, such as building a barrier on the road-side to avoid collision between vehicles, and expanding the road-size enable vehicles to have more space to evade the objects and pedestrians

The president in Electric Vehicle Association of Thailand (EVAT) said autonomous vehicles and electric vehicles should be developed simultaneously. According to the president's perspective, private vehicle would first be implemented in Thailand, since public sector would have to go through a huge amount of official procedures which normally would takes decades to permit.

As the interview from Dr. Pasan Kulvanit, Department of Science Service, who is an expert in terms of autonomous vehicle, said that there are three possible scenarios when implementing the autonomous vehicle. First, it is to make the autonomous vehicle outstanding that infrastructure does not need further upgrades. Second, building a good infrastructure making autonomous vehicle does not need outstanding performance. Lastly, it is about balancing both parties. As Dr. Pasan states, Thailand probably will go toward the balance direction. Furthermore, Department of Science is currently developing level 3 autonomous vehicle, cooperated with Sansiri group (one of the huge real estate company companies in Thailand) to launch residence village only autonomous vehicle and hope to launch in small scale initially, then expand to bigger scale. There is a project on the topic of supporting the development and application of next-generation automation that was launched a few years ago. The project was formed by the collaboration of the Ministry of Transport and Ministry of Science and Technology, and other associated departments to develop the autonomous vehicles in Thailand. Speaking to the autonomous vehicle levels launched in Thailand, the vehicle levels that are commonly used is level 1 to 2. However, the individual vehicle that has been tested is

available in level 3. Department of Science Service is doing research on trends of technology, and searching for Thai private sectors to jointly develop the level 3 vehicle in a closed system (e.g. university area, village, and etc.) in which trying to enable vehicle drive in reliable basis with speed of below 30 kilometers per hour.

Table3: The experts and required options

Doctor/Organization	Require Options
Department of Rural Road	<ul style="list-style-type: none"> <li>Develop outstanding performance on both infrastructure and autonomous vehicle.</li> </ul>
President of Electric Vehicle Association of Thailand(EVAT)	<ul style="list-style-type: none"> <li>Simultaneous development of electric vehicles and autonomous vehicles.</li> </ul>
Doctor Pasan Kulvanit	<ul style="list-style-type: none"> <li>Develop purely in “outstanding” infrastructure</li> <li>Develop purely in “outstanding” autonomous vehicle</li> <li>Develop simultaneously, but do not require particular outstanding party.</li> </ul>

## VII. DISCUSSION AND CONCLUSION

The evidence of autonomous vehicle benefits has been concrete in many countries. Autonomous vehicles not only improve the environment as a whole, but also provide better safety compared to traditional vehicles towards both pedestrians and drivers. Moreover, implementation of autonomous vehicles could reduce the congestion level on the street due to the integration of 5G technology. Most importantly, autonomous vehicles could handle the reduction of overall accident rate on the road, and control the emission of greenhouse gases that are hazardous to people and the environment. However, implementation of autonomous vehicle requires policy makers to enact new legislation act and consider issues such as imported cars and data protection. Imported cars must be compatible with local vehicle conditions and infrastructure. Additionally, the data that is kept in the car must be confidential. Moreover, the data should prevent hackers to extract the data in which all of these needs government policy makers to act and response. Therefore, the possibility of implementation of autonomous vehicle in Thailand currently is low. Not only in terms of budget constraint, but also in terms of hardware and software which all of these require long-term preparation.

## ACKNOWLEDGMENT

We would like to express our gratitude to our advisor Dr. Veeris Ammarapala for guidance and support in our project. We also have to give our special thanks to the director of the Office of Road Safety Audit, Department of Rural Roads, and the president of Electric Vehicle Association of Thailand(EVAT) for the interview and assistance. Without their kind guidance and advice, we would not be able to accomplish this work.

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