

# Deployment of Autonomous Vehicles to Support Emergency Response During Crisis

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## ABSTRACT

Emergency response services face massive pressure during global crises, such as COVID-19. The food supply logistics sector is one of the pressures that impacted the emergency response services, due to crisis restrictions. A regulatory framework to deploy autonomous vehicles, in any nominated country, has been presented to boost the food supply logistics as an emergency response to critical situations to serve isolated areas. This framework resulted in three steps to deploy AVs in the nominated country, which are evaluating their legislation, modifying their existing regulations accordingly, and ensuring the full deployment of the innovative technology. This is done by minimising person-to-person contact during the transportation and distribution phase. In conclusion, fully autonomous vehicles can help lift the pressure from the emergency response teams in the food supply transportation and distribution phase to meet the basic living requirements for human needs during global crises.

## Keywords

Autonomous vehicles, emergency, food, COVID-19.

## INTRODUCTION

The Coronavirus, or Covid-19, is considered a crisis of public health. It results in significant life loss and human suffering globally, which examines our ability to respond to emergencies (Majdúchová, 2021). The pandemic also created a massive social, economic, and financial shock in the twenty-first century after the 2008 Global Financial Crisis (Gurría, 2020). COVID-19 has become a dangerous epidemic, with millions of cases detected globally. Over 100 nations implemented either a full or partial lockdown to combat the COVID-19 outbreak, impacting billions of humans, and industries (Reinstadler et al., 2021).

The World Health Organisation (WHO) declared the virus to be a pandemic disease in March 2020, indicating that most countries in the world will experience the crisis of the uncontrolled deadly virus outbreak (Singh & Singh, 2020). At the same time, the virus was first conducted in late 2019 in Wuhan, China. Since then, the breakout of the virus has spread quickly around the world. Therefore, social distance and isolation policies have been implemented or advocated globally to restrict disease spread, reduce the pressure on the healthcare sector, and decrease total death (Bargain & Aminjonov, 2020). However, these policies have created a massive disruption to many other sectors, including food supply chain logistics (Barman et al., 2021).

All aspects of the food supply chain have experienced disruptions because of the crisis outbreak, including transportation and logistics, food processing, agricultural productivity, and final demand (Chari et al., 2022). Different products have faced interruptions at different stages of the supply chain, and not all professions and products have been affected in the same way (OECD, 2020). Due to transportation and mobility restrictions, food supplies from rural regions no longer reach consumer centres in urban and peri-urban areas. In addition, food delivery to consumption centres was restricted due to lockdowns and anxiety of exposure to the virus (Nchanji et al., 2021).

Farmers also have been restricted from producing, harvesting, and selling their products locally and globally, due to border closures, trade and transport restrictions, and confinement measures (ILO & IFAD, 2020). Besides, millions of self-employed and waged agricultural workers who are accountable for feeding the world frequently experience high levels of working poverty, hunger, and bad health as it is the main source of their income in such a critical situation. As a result, this will increase the pressure on the food supply emergency services to respond to the food shortages globally.

For instance, the food distribution trucks in France have declined by 60 per cent due to virus limitations, which used to be 30 per cent before the virus outbreak (Aday & Aday, 2020). In addition, the European nations increased their demand for fresh bread and vegetables by 76 per cent and 52 per cent, respectively, in the week after the COVID-19 pandemic was announced (Barman et al., 2021). This results in an obvious problem that faces the food supply chain transportation and distribution worldwide. This problem needs to be addressed perfectly to solve the food supply chain emergency response issues during a crisis. Therefore, this study aims to improve the food supply emergency response by deploying Autonomous Vehicle (AV) technology to enhance the transportation and distribution processes during critical situations.

## LITERATURE REVIEW

The transition to automation is happening quickly. In Australia, the Royal Automobile Club (RAC) examined the first autonomous bus in Western Australia, and the Australian Driverless Vehicle Initiative has published a timeframe that predicts accelerated prototype trialing and policy reforms for the remainder of this decade to pave the way for subsequent public acceptance and adoption of AVs, in 2016 (Pettigrew et al., 2018). The Queen stated in her 2016 State Opening of Parliament speech that the United Kingdom will be “at the forefront of technology for new forms of transport, including autonomous and electric vehicles” (Cabinet Office, 2016). The Institute of Electrical and Electronics Engineers (IEEE) predicted that 75 per cent of vehicles will be completely automated by 2040 (Read, 2012). The jobs of commercial truck drivers are predicted to be impacted by 50 to 70 per cent by self-driving vehicles in Europe and the United States, by 2030 (Baratta, 2021).

Driverless cars, known as AVs, can travel to various places with a high response rate to traffic signals and avoid obstacles on the road without requiring driver engagement (Xing et al., 2021). The engagement of AVs has many advantages for social, economic, and the environment. It is expected to improve road capacity and traffic flow by 100 per cent and 20 per cent, respectively, to save fuel, time, and money. Also, a 60 per cent reduction in CO<sub>2</sub> is expected (Goldin, 2018). According to a study at the University of Illinois at Urbana-Champaign, as low as 5 per cent of engagement of self-driving cars might solve the traffic jams caused by stop-and-go behavior. This, in turn, will not only save individuals time, but will also cut the amount of time their automobiles are on the road, and lowering emissions (Stern et al., 2018).

The advantages of AVs are generally recognised, but questions remain regarding the deployment of their range, risks, and unforeseen effects (Taeiagh & Lim, 2019). Therefore, this section will tackle the safety, liability, and cybersecurity implementation of AVs from different governmental approaches to be deployed in any nominated country. Each implication also will be assisted against the five AV-related governing strategy types to maximise end-user benefits and minimise AV risks, as will be explained in Table 1 below. It is worth mentioning that the AV has different levels to assist the driver. At the same time, the highest level exempts the human driver, as will be explained in the next paragraph.

**Table 1: AV-related governing strategy types (Li et al., 2018; Li et al., 2021)**

Respondents	Position Year of experience
ADAPTATION-ORIENTED	The goal of this technique is to increase the system's or organisation's capacity for adaptation. It places a strong focus on accepting uncertainty and enhancing how well it responds to disruptions. It incorporates elements of " co-decision, shared accountability, and forward-looking planning "(Li et al., 2018). It is like the resilience and adaptive resilience methodologies put out by Nair and Howlett, and Walker et al. (2016; 2012)
TOLERATION-ORIENTED STRATEGY	The strategy's goal is to tolerate risk. In other mines, the person who makes the choices does part of the operational tasks to inspire the company to perform effectively in a steady transition atmosphere. It also relates to the understanding of various researchers' resilience, which refers to a business or sector that is resilient to a wide range of new threats and changes (Nair & Howlett, 2016).

CONTROL-ORIENTED STRATEGY	This technique relies on previous risk assessments since it anticipates that academic knowledge will lessen uncertainties, and it's crucial to comply with government policies. It seeks to mitigate known sub-optimal risks, and it is desired to achieve a favourable risk assessment by consistent risk estimation (Krieger, 2013).
PREVENTION-ORIENTED STRATEGY	The decision-makers defensive strategy of reducing risk using innovative technology (Li et al., 2018). For highly anticipated situations, a prevention-oriented approach is a good option. However, because of its slower response time, it makes policy insensible.
NO RESPONSE	There is nothing the decision-maker can do to determine the dangers. It may happen because the individual making these selections is not aware of what innovation technology might lead to (Walker et al., 2010).

### AV Levels

Advanced AVs can sense the surrounding environment by relying more on technology to take over human driving duties and actions (Ma et al., 2020). The vehicle can also navigate from point to point with a high response rate to traffic signals and avoid road hazards without any human-driver interactions (Litman, 2017). Consequently, the Society of Automotive Engineers (SAE) has published the SAE international standards J3016 designed to define the six levels of AVs, from the lowest level (non-computerised vehicles) and progressing to the highest level (Fully computerised vehicles) (© SAE International from SAE J3016™, 2021), as explained in Figure 1 below.

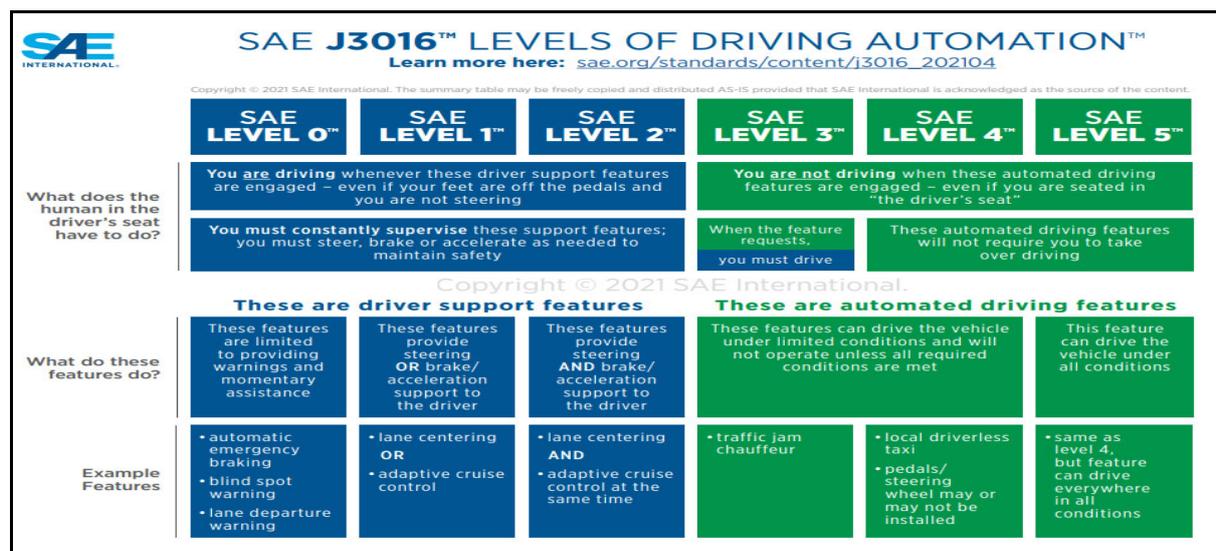


Figure 1: Autonomous Vehicles levels (© SAE International from SAE J3016™, 2021)

### Safety Implications

In the modern day, vehicles are a necessary component of land transportation since they greatly enhance the comfort and activity of human existence. However, extensive studies revealed that human error globally accounts for more than 90 per cent of vehicle collisions. (Chen et al., 2019; Shetty et al., 2021). By integrating AV technology into the transportation system, automobile accidents caused by human decision-making can be reduced or even avoided, potentially saving more lives on the road. As a result, several nations have begun to implement innovative AV deployment techniques while also paying close attention to overall vehicle safety.

The United States has adopted the controlled-oriented strategy to control the AV-associated risks that follow the standards of SAE and International Standards Organisations (ISO) (NHTSA, 2016). The United Kingdom has adopted the same techniques, depending on the established transport regulations with feedback from private and public sectors, encouraging and attracting businesses and investors by enabling actual public road trials for AVs (Department for Transport, 2019). Similar to the United States, Australia has selected the same strategy to

embrace AV safety testing within the country's current transportation rules, working with the Transport Infrastructure Council to set up a safety assurance system to examine all AV stages on open streets (NTC, 2017a). Australian National Transport Commission aims to adopt an oriented strategy through feedback collection from stakeholder groups concentrating on this technology and exploring opportunities to mitigate risks, rather than focusing on ignored, suppressed, or controlled risk strategies (NTC, 2017b).

Additionally, the Chinese government has adopted a similar technique for deploying AVs under government transportation norms and regulations (KPMG International, 2018; West, 2016). Furthermore, the European government requires obtaining authorisation and adhering to start the controlled strategy to test AV technology (Nicola et al., 2018). Furthermore, the Singaporean government has adopted a controlled-oriented strategy (Government of Singapore, 2017). However, the government of Japanese considered the prevention-oriented strategy as they emphasised a displayed label on the vehicle, consent from the police department, and a person to operate the vehicle with an appropriate license (Kyodo, 2017). However, no response has been shown by the South Korean government to the safety implication (West, 2016). Finally, the New Zealand government has authorised Autonomous vehicle experiments on public roads without any limitations, whereas the transport regulations remain in place since the Land Transport Act of 1998, which require upgrades (Ministry of Transport, 2020a).

### Liability Implications

The AV collisions have created great doubt and confusion about liability implications (Fagnant & Kockelman, 2015). Because fully automated vehicle driving involves no human instruction while needed for lower levels, which creates more liability uncertainty over who is accountable for the accident, such as the software designer, component maker, manufacturer, or car owner (Collingwood, 2017). Therefore, Event Data Recorder (EDR) has been strongly proposed to distinguish the specific malfunction that triggered the accident from real human driving (Martinesco et al., 2019). The EDR will record the vehicle journey and all tasks performed in Automated Driving Systems (ADSs) to allocate liability concerns to the responsibility part which will accept complete responsibility for it. Because AV liability issues remain complex; various governments have adopted different approaches to managing these risks.

The Accident Compensation Corporation (ACC), known as No-Fault Compensation Scheme (NFCS), has been deployed by some countries to handle any road collision losses for any victim involved in an accident without referring to or suing the main suspect (Schellekens, 2018). Therefore, the victim should seek compensation and rehabilitation under this scheme. The collision scheme is already established in many regions such as Sweden, Quebec, New Zealand, and Israel (Van Uytsel, 2019). Moreover, the Act prohibits anybody from suing a manufacturer for personal injuries or death caused by a defective product (MBIE, 2022). As a result of this scheme, the vehicle manufacturer and parts will be protected against any claims regarding personal injury, which will encourage the deployment of AVs. However, the manufacturer will be liable for any physical damage under the product liability.

Product liability Act focuses on the low quality of services or items businesses provide to their customers. Customers can also obtain a refund, repair, or exchange if they acquire a faulty product or experience unsatisfactory service (Consumer NZ, n.d.). The MBIE (2019) mentioned that the main purpose of the Consumer Guarantees Act is imposing liability under the manufacturer's responsibility due to the significant control and influence over their product quality. However, the distributor or supplier will account for responsibility if the product is manufactured overseas. Therefore, the Act will hold the manufacturers fully liable for their product quality while exempting them from personal injuries under the no-fault compensation scheme.

Many countries have followed different liability strategy approaches for deploying AVs. For instance, most United States have taken their initial step toward a controlled-oriented approach after their ignorance of liability implications (NHTSA, 2016). In contrast, the United Kingdom has taken a toleration-oriented approach to clarify insurance and liability risks for AV deployment (Centre for Connected & Autonomous Vehicles, 2017). Besides, the UK transportation agency intends to install EDR in AVs to clarify the liability issues and distinguish human blames from manufacturing defects when the AV manages the journey (Centre for Connected & Autonomous Vehicles, 2017, p. 15; TRL, 2019). Similarly, Germany has updated their transportation legislation to tackle AV liability concerns with an initial step toward a control approach (White & Case LLP, 2017). Also, Germany implemented EDR in all AVs using the same approach as the UK (Wacket et al., 2017).

Japan, Singapore, and Australia have also made their initial moves towards a controlled-oriented approach to limit liability issues related to AV (NTC, 2017b; Taihagh & Lim, 2019). However, no response has been shown from South Korea and China (Alawadhi et al., 2020), along with Europe (Patti, 2019). New Zealand showed great concern about assigning liability issues to AV, where a review of the liability legislation is

required if the vehicles are utilised for personal purposes (Cunningham et al., 2018).

### Cybersecurity Implications

Cyber risk is the dangerous threats of monetary, corruption, financial, debt, or disruption to companies as they are concerned about hacking their sensitive information system (Sheehan et al., 2019). Therefore, the cybersecurity system works as a defined line for any electronic device to secure the end-user data from cyberattacks. Every technology that relies on the internet to transfer information is at risk, as it could lead to serious life threats by hackers.

In order to evaluate the vehicle route via sharing data about the transportation system, such as Vehicle to Infrastructure (V2I) or Vehicle to Vehicle (V2V), the car must be connected to the internet. Additionally, losing communication due to a cyberattack or Denial of Service (DoS) network failure might pose serious risks to the safety of passengers as well as the surroundings, especially for critical applications that require a lower latency for their network (Weimerskirch & Dominic, 2018). Hackers may hack and control the vehicle through wireless connections like Bluetooth, keyless systems, or other connections since the AV is connected to the surroundings through the internet (Lee, 2017).

According to Shankland (2019), the 5G is a novel answer to AV cyber threats. It represents the effectiveness of AVs in terms of liability because the vehicle relies on a robust data interchange during any trip to act quickly to prevent any danger or accident by recognising the effective approach to overcome any upcoming circumstance. Furthermore, by integrating a 5G network in AV, the vehicle will be remotely operated by an authorised control centre to respond quickly to any emergency circumstance (Mutzenich et al., 2021).

Many governments, including the United States, Singapore, China, and the EU, have used a controlled-oriented approach to determine the associated AV cyber risk (Chen et al., 2020). As a result, they have adopted a voluntary guide to demonstrate the hazards linked with AV cybersecurity and to protect users' confidential information. The United Kingdom has taken a step toward an adaptive-oriented strategy to manage AV cybersecurity risks, as mentioned by HM Government (2017). Whereas Germany, Japan, and Australia showed no response to this implication (ERTRAC, 2015), along with South Korea (KLRI, 2018). In December 2021, the New Zealand Privacy Act was revised to emphasise the confidentiality of end-user data and privacy to cover the advanced AV cybersecurity risks (Ministry of Transport, 2020b).

### METHODOLOGY

The study's main objectives are to understand and define the implementation of Autonomous Vehicle (AV) technology in any nominated country. However, the world implementation level for AV is still in the early stages due to the limited information on young technology. To meet this objective, a semi-structured interview experimental research was carried out with experienced AV practitioners. The interview includes 9 semi-structured questions intended to allow participants to freely discuss their opinions based on their area of expertise throughout the interview meeting, which lasted around 60 to 90 minutes. The interview questionnaires were prepared based on the current literature review and thematically analysed by the previous section to maximise the technology benefits and minimise its risks.

Based on the AV information, the NZ Transport Agency (NZTA) which is heavily involved in the AV trial phase in New Zealand, and the New Zealand Ministry of Transport, 5 official firms were selected for this study based on their area of experience. Invitation emails were issued to the 9 organisations to participate in this research, but only 5 responded and consented to cooperate. During the interview, they provide their consent to the interview session. To maintain confidentiality protocols, all interviewees' identities were suppressed, and each interviewee was allocated a code. Participants for this study's interview came from the middle and upper managerial levels. Table 2 below illustrates the information of the participants.

**Table 2: Interviews information**

Respondents	Position	Year of experience
participant 1	Senior Policy Advisor	19
participant 2	Senior Transportation Manager	16
participant 3	Manager Targeted Investment	7
participant 4	Academic Professor	18
participant 5	Electrical Engineer	8

The questionnaires that occurred in qualitative research to ensure the validity of the information are about the number of samples. According to Sandelowski (1995), defining a sufficient sample size is subjective; certain studies require a sample size of 5, while others require more than 5 based on their study philosophy. Creswell and Creswell (2017) also suggested 5 to 25 respondents for a qualitative study, which highlights the researcher's efforts to understand the various positions of humans as social players and to comprehend their reality depending on their experiences. Moreover, AV technology is still new, and few countries have adopted this technology making it challenging to obtain more data related to this study.

According to Patton (1990), interpreting data in a qualitative method is a big concern for researchers. This is because qualitative data is mostly made up of words, which might have various interpretations and contribute to incorrect interpretations. Therefore, NVivo software 1.3 was used to conduct a thematic analysis and develop a pattern matching the literature for better understanding.

The interviewees were from the Ministry of Transport, Accident Compensation Corporation, NZ Transport Agency, IT experts, universities, and electric car manufacturers. The research's main objective is to boost food supply chain logistics and transportation during a crisis as an emergency response to serve isolated areas. Due to time and financial limitations, the interview data was conducted only in New Zealand.

## DATA ANALYSES

This section aims to analyse the data that have been collected during the interviews to support the AV implementation process. Also, the data will be analysed on NVivo software to present thematic patterns on the adoption of AVs to mitigate food supply chain shortages during a crisis. The following sections present respondents' perceptions of safety, liability, and cybersecurity implications.

### Safety Implications

- Awareness level: All participants in this research agreed that global awareness is low. Participants 1 and 4 emphasise the low level of awareness about this technology. Participants 2, 3, and 5 support advertising to better understand AV levels and functions. As a result, there is an urgent need to raise awareness through commercials, public events, and a data-driven strategy.
- AV risk approach: To manage the associated risks of deploying AVs, 60 per cent of the interviewees supported an adoption strategy for liability and safety implications. A controlled-approach strategy showed 80 per cent agreement to manage cybersecurity risks associated with AV deployments.

### Liability Implications

- ACC/NFCS; It is recognised as unique and the most significant key driver for deploying AVs globally to support the AV liability issue. Approximately 80 per cent of interviewees strongly agreed that the programme is highly appealing to vehicle companies looking to test and trial their technology on public roads and under current transportation regulations. However, participants 1 and 4 noted that the programme is not a significant motivator for investments and investors worldwide. Also, they will not sacrifice the locals' lives to test any technology. All interviewees also highlighted that the system would enhance AV liability by lowering the insurance required to operate the vehicle.
- Event Data Recorder: the EDR plays an essential role in supporting the AV liability implication to determine the fault that led to the collision. All participants emphasise the need for vehicle manufacturers to learn and improve the technology. Participant 2 noted the important role of algorithm process and image in the AV, which will be less effective in the future when technology improves. Finally, participants 3 and 5 strongly support the EDR only if it complies with the Privacy Act of the nominated country and does not exploit the government's ability to investigate vehicle owners. All the interviewees strongly agreed on this device and illustrated its benefits and how it could improve AV liabilities to be deployed worldwide.
- Local legislation: All participants in this research agreed and supported the same method of amending current legislation and adapting certain international regulations to allow AV deployment in the nominated country. They had a smeller point of view about the mixed approach strategy to review and understand the international strategy due to the lack of information about AV as a new technology with many associated risks. Importantly, consolidate some international regulations to standardise the most critical component for the AV by manufacturers, to make the deployment of AVs easier in any country. After that, reform some of the country's legislation and adopt some international legislation to suit the



program will support the deployment phase by lowering insurance costs and encouraging manufacturers to test and evaluate this enormous technology in real life.

3. Cybersecurity perspective: the controlled-oriented strategy is highly suggested due to the massive worries about cyber-attack risks. Also, the hackers could take over the vehicle control, which will make the rider and surroundings life-threatening. Besides, the cyber-attack can be managed by a trusted source like the traffic control room. However, involving a third party like the vehicle manufacturer to authorise the controller is highly recommended to minimise the government's influence and maximise transparency.

**REGULATORY FRAMEWORK**

Along with the previous literature, discussions, and analysis of expert perceptions, it is highly recommended for each country to consider the following steps to partially change, upgrade, or reform their existing legislation to fit the new technology in their regulations to enhance food supply during emergencies.

- A. First step: due to the lack of information on AV, each country is encouraged to review the international approach to sense and evaluate their position regarding their existing legislation.
- B. Second step: modify the existing regulations to merge some of the international legislations. It is highly recommended to consolidate some international approaches and techniques to minimise the mistakes and efforts required for each stage to be developed individually by every country.
- C. Final step: A complete revision of the legislation to ensure the innovative technology has been deployed and fully covered under the nominated country rules or it might require final amendments.

The following framework has been drawn upon the summary of the discussions in the previous sections. Therefore, it is strongly advised that the Transportation Agency in the nominated country follow the procedures outlined below.

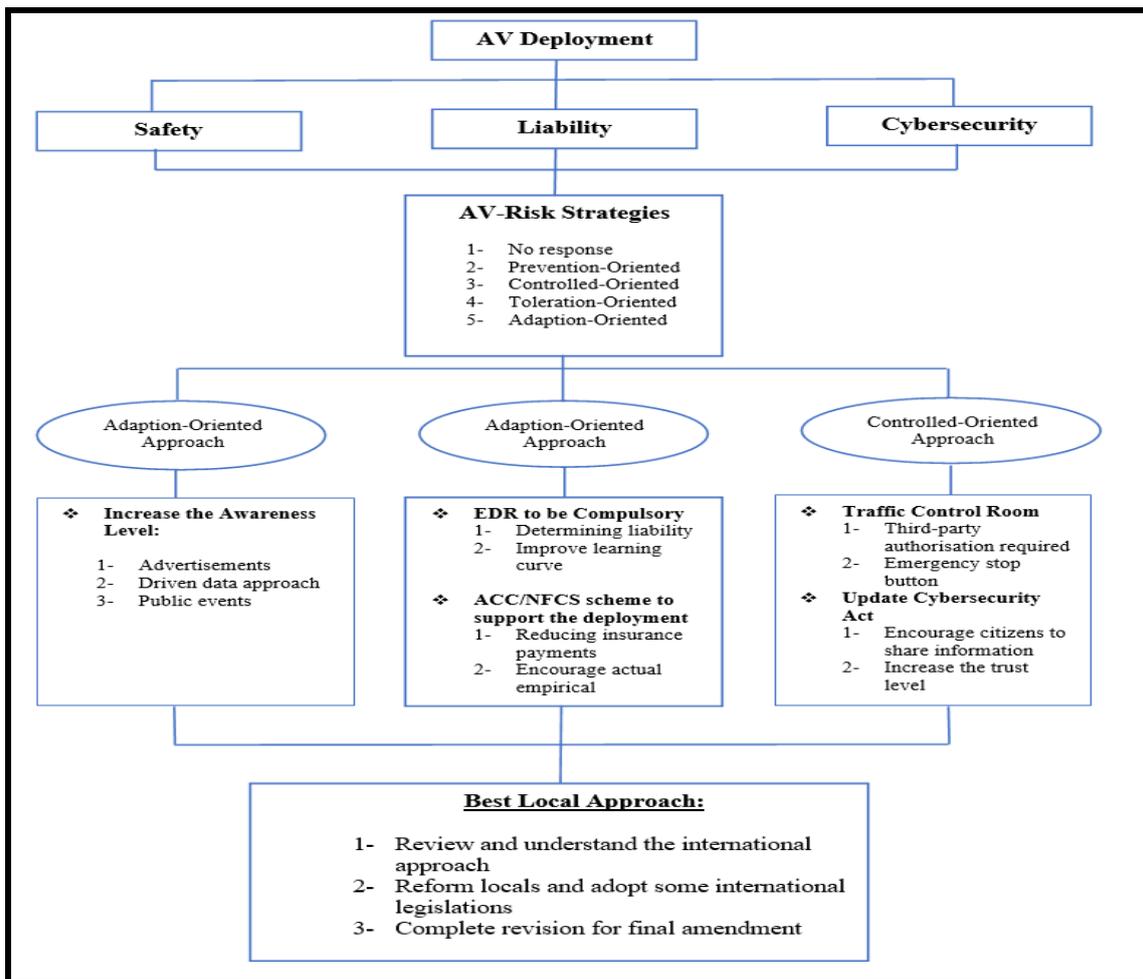


Figure 3: Regulatory Framework to Deploy AVs globally.

## CONCLUSION

Crisis struck the world without notice like COVID-19, which led to massive disruption and restrictions in most sectors, including essential industries, such as the food supply chain. Due to the Coronavirus crisis restrictions, a 60 per cent reduction faced the food distribution tracks in France (Aday & Aday, 2020). As a result, during the crisis, the emergency response team faced massive pressure along the way to meet the basic living requirements for their citizens under world restrictions and countries' lockdowns.

Therefore, this research presents a comprehensive framework to deploy fully autonomous vehicles to boost the food supply chain during crises and serve isolated areas while minimising person-to-person contact. It also aims to improve the emergency response system worldwide and prepare for future unexpected situations.

Following the procedures outlined in the proposed framework is highly recommended to reflect the enormous support and collaboration to the emergency response system and aid the food supply chain transportation and distribution during crises like COVID-19. Besides, minimising personal contact to manage the outbreak of the deadly virus. Due to the study limitation, more interviews are needed that samples from different regions and an empirical trial of the framework to confirm its benefits and advantages.

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