

Facilitating the deployment of highly and fully automated vehicles in road traffic along the Asian Highway Network

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Abbreviations:

Abbreviation	Full Name
AADT	Average annual daily traffic
ADAS	Advanced driver assistance systems
ADS	Automated driving system
AL	Automatization level (of an automated vehicle)
ATMS	Automated traffic management systems
BRI	Belt and Road Initiative
CITS	Cooperative intelligent transport systems
CEN	Comité Européen de Normalisation (Committee of European standards)
CT	Committee of Transport of Kazakhstan
DRT	Directorate of Road Transport of Kazakhstan
EAEU	Eurasian Economic Union
ERA-GLONASS	State Automated Information System in Russian Federation
ETSI	European Telecommunications Standards Institute
FOC	Fibre optical cable
FSUE	Federal State Unitary Enterprise (a legal form of state-owned company)
GOST	National standard in Russian Federation
GPRS	General Packet Radio Service
HFAV	Highly and fully automated vehicles (both trucks and cars)
ICT	Information and Communication Technologies
ISO	International Organisation for Standardisation
ITC	International Transport Corridor
ITS	Intelligent transport system
LTE	Long-term evolution (wireless broadband communication standard)
MIID	Ministry of Industry and Infrastructure Development of Kazakhstan
ODD	Operational design domain
OICA	Organisation Internationale des Constructeurs d'Automobiles
V2C	Vehicle to cloud
V2I	Vehicle to infrastructure
V2V	Vehicle to vehicle
V2X	Vehicle to everything

0. Executive Summary

This report assesses the current connectivity status along the Asian Highway 9 (the AH route 9 or the West Europe – West China International Transport Corridor) identifying policy, infrastructure and technology gaps and challenges for seamless international connectivity for highly- and fully automated road vehicles (HFAV) in China, Kazakhstan and the Russian Federation (the target countries).

In addition to the feasibility analysis, the report also offers possible directions for future development and use of HFAV along the AH route 9 in the target countries in terms of policies and regulations, road infrastructure, smart transport systems and onboard vehicle devices.

This report consists of five Chapters organised in the following way:

- Chapter 1 introduces the purpose and the scope of the Study;
- Chapter 2 presents basic backgrounds for the existing technologies in ITS and autonomous driving covering the definitions and concepts of automated vehicles, connected vehicles, cooperative-ITS and smart cities;
- Chapter 3 discusses the general technical and operational conditions for the use of HFAV along the AH route 9 in the target countries, including current status and development plans for their physical and smart infrastructures, representative R&D initiatives and application experiences of automated vehicles, as well as legal and regulatory frameworks and challenges;
- Chapter 4 summarises key findings of the Study and provides policy recommendations to help to streamline the deployment of HFAV along the AH route 9 in the target countries; and
- Chapter 5 concludes the report.

The report has been prepared by the Secretariat based on inputs of individual consultants and national experts engaged by UNESCAP in 2020-2021.

1. Introduction

1.1. Overview of the AH Route 9

The Asian Highway 9 (AH route 9) is a land route connecting Chinese seaport Lianyungang with Saint Petersburg, the “north capital” and seaport of the Russian Federation, across the territories of China, Kazakhstan and the Russian Federation.



Figure 1. AH9 route: Intergovernmental Agreement on Asian Highway Network, Annex I

The total length of the AH route 9 is 8,445 km of which 2,233 km run through the territory of the Russian Federation, 2,787 km through Kazakhstan, and 3,425 km through China.

The route represents a continental alternative to the Trans-Siberian Railway and the maritime traffic through the Suez Canal aiming to reduce the travel time from 45 days required for sea freight shipping and 14 days for freight transport along the Trans-Siberian Railway to 10 days by road.

In China, the route is known as “the Lianyungang–Khorgas Expressway” (Lianhuo Expressway, G30) whereas in Kazakhstan and in the Russian Federation it is referred to as “the West Europe – West China International Road Corridor”. It encompasses several core national highways across the target countries as it traverses their national boundaries and huge territories.

The scope of analysis of the study will give particular focus to highly and fully automated vehicles (HFAV) and smart transport systems along the AH route 9.

1.2. Rationale, Purpose and Scope of the Study

The use of highly and fully automated vehicles (HFAV) and smart transport systems (also referred to as ITS) can significantly reduce the economic, social and environmental costs of passenger and freight transport, while enhancing its overall quality and resilience. Although this potential contribution is widely acknowledged, their implementation in Asia and the Pacific in general, and in the target countries in particular, is lagging behind due to various factors, including low awareness of the role of smart transport systems, limited capacity for implementation and a lack of regional cooperation, hindering the exchange of best practices and experiences.

The use of highly and fully automated vehicles on international road corridors will depend on the progress made by countries in implementing smart transport technologies at the national level. At the same time, highly and fully automated vehicles for international transport will depend on achieving a common understanding at the regional level of the principles of using smart transport systems, as well as on the willingness and ability of countries to jointly address issues related to transport infrastructure and operational needs along highways or at border crossings. As the implementation of any emerging technologies must come with relevant laws and policies, the development of the autonomous vehicle industry is also inseparable from the support of the legal system.

This Study has been launched by ESCAP with the purpose to facilitate the deployment of highly and fully automated vehicles in road traffic along the AH route 9 within the territories of China, Kazakhstan, and the Russian Federation, and assist other countries of the region by sharing lessons learnt and knowledge accumulated to date to increase the common understanding and awareness of current initiatives, challenges and advantages related with the introduction of HFAV in road traffic at national, regional and global levels.

In this regard, the scope of the Study includes collection and analysis of available information and data on the AH route 9 within the target countries and in a broader regional context to assess potential operability of HFAV along the AH route 9. Respectively, the research subjects of the Study include: (i) current status and development plans for road infrastructure and smart systems along the AH route 9 within the territories of the target countries; (ii) ongoing and planned national initiatives related to the development and introduction of HFAV in road traffic; and (iii) availability and usage of ITS and other smart technologies along the AH route 9 which can support smart HFAV operation.

Based on the findings of the Study, the overall adequacy of the existing infrastructure and operational connectivity was assessed and existing conditions and gaps of technologies and infrastructure were identified.

The subject of the Study is highly relevant to support the efforts of the target countries in developing their smart infrastructure in line with the global trends that would allow a seamless operation of automated freight road vehicles along the AH route 9 in the future. In this sense, improving the sustainability performance of international road transport by using highly or fully automated vehicles, can contribute to the delivery of the region's sustainable development agenda.

2. Existing Technologies in Smart Transport Systems

2.1. Overview of Existing Concepts

The spotlight on Automated Vehicles (AVs) has increased in recent years as technologies quickly grow closer to achieving the goal of driverless vehicles operating on public roadways. To begin to address the status of highly and fully AVs from selected countries along the Asia Highway (AH) routes, three interconnected concepts are first defined that have been mostly discussed in recent years –AVs, Connected Vehicles (CVs) and Cooperative-Intelligent Transport Systems (C-ITS) and smart cities.

2.1.1. Automated Vehicles (AVs)

Automated, autonomous, or self-driving vehicles are defined by the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) as “those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode.” For the sake of standardization, clarity, and consistency, the Society of Automotive Engineers (SAE) outlined international definitions for levels of automation. These definitions divide vehicles into levels based on “who does what and when.” The higher the level, the more automated the vehicle: The higher the level, the more automated is the vehicle, as shown on Figure 2 and discussed in detail below.

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in “the driver's seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?	These are driver support features			These are automated driving features		
	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

Figure 2. SAE J3016™ levels of automation.¹

- **Level 0: No Automation.** The human driver does all the driving. The driver is in complete and sole control of the primary vehicle controls—brake, steering, throttle, and motive power—at all times.

¹ Retrieved from SAE web-site: [https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic#:~:text=The%20J3016%20standard%20defines%20six,%2Dvehicle%20\(AV\)%20capabilities](https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic#:~:text=The%20J3016%20standard%20defines%20six,%2Dvehicle%20(AV)%20capabilities) (last accessed on 8 February 2021).

- **Level 1: Function-Specific Automation.** Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than human reaction. An Advanced Driver Assistance System (ADAS) on the vehicle can assist the human driver with either steering or braking/accelerating.
- **Level 2: Combined Function Automation.** This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. For example, adaptive cruise control in combination with lane centring is a combined function. An ADAS on the vehicle can control both steering and braking/accelerating under some circumstances. The human driver must continue to pay full attention (“monitor the driving environment”) at all times and perform the rest of the driving tasks.
- **Level 3: Limited Self-Driving Automation.** Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions to an Automated Driving System (ADS) under certain traffic or environmental conditions. The human driver must be available for occasional control and be ready to take back control (with adequate transition time) whenever the ADS requests the human driver to do so. The driver can rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. In all other circumstances, the human driver performs the driving tasks.
- **Level 4: Full Self-Driving Automation.** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. Vehicles with level 4 automation may also be referred to as AVs. An ADS on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances. The human need not pay attention in those circumstances.
- **Level 5:** An ADS on the vehicle can do all the driving in all circumstances. The human occupants are just passengers and need never be involved in driving.²

AVs use satellite positioning systems and various sensors (i.e. radar, ultrasonic, infrared, laser, etc.) to detect and process the surrounding environment.³ These sensors interpret information to find appropriate paths considering obstacles and traffic signage by using wireless networks, digital maps, automated controls in vehicles, and information and communication technology.⁴ Because AVs are technology-intensive, many private automobile manufacturers and Internet-oriented technology companies are also actively driving toward research and development.

AVs have existed primarily as prototypes but have recently become commercially available and many cities are amending the legislations to permit automated driving on roadways. While the leading countries in Intelligent Transport Systems (ITS) are working to develop such vehicles, some cities have already made noteworthy progress.⁵ Vehicles with limited automated driving functions are already available on the market (SAE Levels 1 and 2),⁶ while some Level 3 vehicles are commercially

² Available from http://autocaat.org/Technologies/Connected_and_Automated_Vehicles/

³ ESCAP, Review of developments in transport in Asia and The Pacific (Bangkok, 2017).

⁴ ESCAP, Policy Framework for the Use and Deployment of Intelligent Transport Systems in Asia and the Pacific – Study Report (Bangkok, 2018).

⁵ Wang, X., 2016. ITS development and deployment in China. EGM on Asian Highway. Intelligent Transportation Systems Center. Available from

http://www.unescap.org/sites/default/files/3.1%20China_Mr.%20Xiaoqing%20Wang.pdf, accessed 3 February 2017

⁶ See the details at http://autocaat.org/Technologies/Automated_and_Connected_Vehicles/

available in certain leading ITS countries. More and more countries are testing Levels 3 and 4 vehicles should appear on the market in the early 2020's.⁷

2.1.2. Connected Vehicles (CVs) & Cooperative-Intelligent Transport Systems (C-ITS)

Connected Vehicles (CVs)

CV technologies function within a Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) data communications environment, supporting numerous applications to improve roadway safety, mobility, and environmental impacts.

The infrastructure-based component and vehicle-based component of these applications may be developed by different stakeholders:

- Infrastructure-based components are expected to be developed by the state and local agencies responsible for building and maintaining the roadway infrastructure and their contractors.
- Vehicle-based components are expected to be developed by vehicle manufacturers, their primary suppliers, and aftermarket system suppliers.

CVs use any number of different communication technologies to communicate with the driver, other cars on the road (V2V), roadside infrastructure (V2I), and the “Cloud” (V2C). This technology can be used to not only improve vehicle safety, but also to improve vehicle efficiency and commute times. Performance requirements encourage synchronized and consistent exchange of data between both infrastructure and vehicle application components in order to best capture the attention of the driver without confusion.

a. Vehicle-to-Infrastructure (V2I)

Vehicle-to-Infrastructure (V2I) is the next generation of ITS and C-ITS. State and local agencies are likely to install V2I infrastructure integrated with or alongside existing ITS equipment. Because of this, the majority of V2I deployments may qualify for similar government-aid programmes as ITS deployments, if the deploying agency meets certain eligibility requirements. Examples of V2I Safety Applications are:⁸

- Curve Speed Warning (CSW): alerts drivers of an upcoming curve and provides a warning when the vehicle's current speed may be too high to safely traverse upcoming curves.
- Red Light Violation Warning (RLVW): alerts drivers of an upcoming signalized intersection and provides a warning when they may violate an upcoming red light based on their speeds and proximity to a signalized intersection.
- Reduced Speed Zone Warning with Lane Closure (RSZW/LC): alerts drivers of an upcoming reduced speed zone and/or changed roadway configuration. Provides a warning to drivers when exceeding speed limits in reduced speed zones and, given lane level accuracy, warns of

⁷ European Commission, On the road to automated mobility. Available at https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/com20180283_en.pdf.

⁸ See Executive Summary U.S. Department of Transportation, Office of the Assistant Secretary for Research and Technology Intelligent Transportation Systems Joint Program Office V2I Safety Application Performance Requirements – Volume 1), available from: <https://rosap.ntl.bts.gov/view/dot/3592> (last accessed in October 2021).

changed roadway configurations. Reduced speed zones may include school zones, work zones, and populated areas.

- Spot Weather Information Warning – Reduced Speed (SWIW-RS): uses standalone weather systems to alert drivers of inclement weather conditions (i.e., fog, wind, adverse surface conditions, etc.) that may impact travel conditions and provides a warning if a driver should slow down through the impacted weather zone.
- Spot Weather Information Warning – Diversion (SWIW-D): uses standalone weather systems to alert drivers of roadway closures related to inclement weather conditions (i.e., fog, wind, adverse surface conditions, etc.). Alerts the driver when the vehicle approaches a weather-related road closure and advises an alternate route in advance of the diversion point.
- Stop Sign Gap Assist (SSGA): informs drivers at stop-controlled intersections of unsafe gaps due to approaching cross-traffic.

b. Vehicle-to-Vehicle (V2V)

Vehicle-to-Vehicle (V2V) communication is a crash avoidance technology that relies on the exchange of information between nearby vehicles to potentially warn drivers about dangerous situations that could lead to a crash. V2V communication enables vehicles to wirelessly exchange information about their speed, location, and direction all while maintaining anonymity of the driver and vehicle. The technology behind V2V communication allows vehicles to broadcast and receive omni-directional messages (up to 10 times per second), creating a 360-degree “awareness” of other vehicles as well as traffic, terrain, and weather in its proximity. V2V messages have a range of approximately 300 meters, which exceeds the capabilities of systems with ultrasonic sensors, cameras, and radar – in some cases, by nearly twice the distance, allowing more time to warn drivers. V2V communication extends and enhances available crash avoidance systems to detect potential crash threats as they develop. The technology can then employ visual, tactile, and/or audible alerts, enabling drivers to take advance action to avoid crashes. For example, V2V could help warn a driver that a vehicle up ahead is braking and they need to slow down, or let a driver know that it’s not safe to proceed through an intersection because another car (yet unseen by the driver) is quickly approaching. V2V communication technology can increase the performance of vehicle safety systems and help save lives.

This technology can be comprised of several innovations, such as:

- **V2V messages** can “see” around corners or “through” other vehicles addressing, for example, scenarios such as those where an oncoming vehicle emerges from behind a truck, or perhaps from a blind alley, detecting the threat much earlier than radar or camera sensors. Additionally, V2V technology can also be combined existing radar and cameras to provide even greater benefits than either approach alone. This combined approach could also augment system accuracy, encouraging the introduction of AVs on roads and highways.
- **Dedicated Short-Range Communications (DSRC)** can enable a number of safety “applications” that help drivers with different aspects of driving, such as warning of stopped vehicles in the road ahead, vehicles speeding unexpectedly through intersections, vehicles in blind spots, etc. DSRC are two-way, wireless communications permitting secure and fast messaging needed for safety applications, where “short range” is approximately 300 meters depending on the surrounding environment. These communications are emitted in a 75 MHz band of the 5.9 GHz spectrum for use by ITS vehicle safety and mobility applications. This

band affords a relatively clean operating environment with very few preexisting users, allowing for a relatively unimpeded and interference-free communication zone. DSRC-based devices can be installed directly in vehicles when originally manufactured, after initial manufacture via an “aftermarket” installation, or could potentially be carried into vehicles by drivers in the form of a handheld device (even as a function on a smart phone).

- **Basic Safety Message (BSM)** is exchanged between vehicles and contains vehicle dynamics information such as headway, speed, and location. BSMs are updated and broadcasted up to 10 times per second to surrounding vehicles. The information is received by the other vehicles equipped with V2V devices and processed to determine collision threats. If necessary, a warning could be issued to drivers to take appropriate action to avoid an imminent crash.

V2V can enhance the capabilities of other on-board systems and enable warnings that might not otherwise be available without V2V. Potential applications of V2V technology include:

- **Intersection Movement Assist (IMA)** warns the driver when it is not safe to enter an intersection because of an increased potential for colliding with one or more vehicles.
- **Left Turn Assist (LTA)** warns the driver when there is strong probability they will collide with an oncoming vehicle when making a left turn. This is especially critical when the driver’s line-of-sight is blocked by a vehicle also making a left turn from the opposite direction.
- **Emergency Electronic Brake Light (EEBL)** warns the driver to be prepared to act when a V2V-equipped vehicle traveling in the same direction but not in the driver’s line-of-sight decelerates quickly. V2V would allow the driver to “see through” vehicles (particularly in poor weather conditions) to learn if traffic ahead may be coming to an abrupt stop.
- **Forward Collision Warning (FCW)** warns the driver of the risk of an impending rear-end collision with a vehicle ahead in traffic in the same lane and direction of travel.
- **Blind Spot Warning (BSW)** notifies the driver that a vehicle in an adjacent lane is positioned in the driver’s “blind spot” zone.
- **Lane Change Warning (LCW)** warns the driver when making a lane change that another vehicle is present in or approaching the “blind-spot” zone.
- **Do-Not-Pass Warning (DNPW)** warns the driver that it is not safe to pass a slower-moving vehicle when vehicles are approaching from the opposite direction.

Security system design is based on the mature and successfully applied Public Key Infrastructure (PKI). PKI is widely used in our daily lives, most commonly found in banking and credit card transactions. However, the system envisioned for V2V is unique in that it involves machine-to-machine PKI which improves some of the vulnerabilities associated with other PKI systems. PKI for V2V communication will require a Security Credentials Management System (SCMS) that issues, distributes, and revokes security credentials for devices operating in the system to ensure V2V messages can be trusted and to protect the privacy of users. Devices will then need to have valid certificates in order to communicate. Occasionally, devices will need to securely receive new certificates via a communications network, which facilitates two-way encrypted communications between an SCMS and a device (and, potentially, roadside infrastructure).

The current proposed design for V2V systems employs a very high level of security and is compliant with the latest standards to support deployment of V2V technologies in a manner that safeguards the system from unauthorized access. It is actively engaged with security experts to ensure comprehensive security prior to system implementation. The V2V system will not collect, broadcast, or share personal information between vehicles, nor does it permit tracking of specific drivers or their vehicles. V2V-enabled vehicles only exchange generic and anonymized safety information. The system is designed with several layers of security and privacy protection to ensure that drivers can rely on messages sent from other vehicles and that authorities and vehicle manufacturers can identify defective V2V equipment without collecting or using any personal information about specific vehicles or drivers.⁹

c. Vehicle-to-Cloud (V2C)

With the emergence of connected “infotainment” systems (connected navigation, social media, music streaming, and in-car Wi-Fi) and accompanying automotive application frameworks, more advanced vehicle connectivity platforms and cloud capabilities are required. It also requires broadband cellular connectivity, initially 3G, but now increasingly 4G, and with 5G based services. Additionally, Over-the-Air (OTA) is quickly becoming a key vehicle lifecycle management tool as well as an enabler of analytics and big data approaches. Finally, with CVs increasingly communicating, interacting, and engaging with other connected industries such as energy, transportation, and smart homes, the cloud is quickly becoming a key technology to enable cars to connect with the wider Internet of Everything (IoE).¹⁰

d. Vehicle-to-Pedestrian (V2P)

Vehicle-to-Pedestrian (V2P) detection systems can be implemented in vehicles, within infrastructure, or with pedestrians themselves to provide warnings between drivers and pedestrians. In-vehicle warning systems are becoming more and more commonplace (e.g., blind spot warning, forward collision warning), with even more advanced warning systems on the way (e.g., intersection movement assist, left turn assist). In-vehicle warnings of pedestrians will also help increase roadway safety. Handheld devices for pedestrians are perhaps the simplest and most apparent warning system for pedestrian.

A mobile accessible pedestrian signal system is a V2P application that enables an automated call from a visually impaired pedestrian’s smart phone to the traffic signal. Additionally, drivers attempting to make a turn are alerted to the presence of a pedestrian in the crosswalk. Pedestrian in signalized crosswalk warning (transit) is a similar application that warns transit bus operators when pedestrians are in the crosswalk of a signalized intersection on the bus’s route. In terms of automated technologies, some stakeholders have been researching pedestrian crash avoidance and mitigation systems that can automatically brake to avoid striking a pedestrian (in both intersection and mid-block conditions). These systems could potentially address up to 46 per cent of pedestrian crashes. Technologies that notify both vehicles and pedestrians of potential collisions could be enhanced with infrastructure communication. A pedestrian device that communicates with various infrastructure components has the potential to more accurately interpret and predict pedestrian movement than a pedestrian device that only communicates with vehicles within a short range.¹¹

⁹ Available from http://autocaat.org/Technologies/Connected_and_Automated_Vehicles/

¹⁰ Ibid

¹¹ Available from http://autocaat.org/Technologies/Connected_and_Automated_Vehicles/

Cooperative-ITS (C-ITS)

Cooperative-Intelligent Transport Systems (C-ITS) is an advanced stage of ITS that utilizes V2V and V2I technologies and can operate in multimodal and international contexts. These technologies rely on three major components— vehicular on-board units, infrastructure roadside units, and a central managerial system.¹² C-ITS advances transport systems as it capitalizes on the latest enhancements and additional services that result from interlinking systems.¹³

Modern transport systems are continuously evolving together to accurately respond to users' various demands, sometimes referred to as a "Complex Adaptive System of Systems".¹⁴ The "Concept of Operations" is an innovation method to effectively manage the ever-growing complex system of systems.¹⁵ This concept proposes a modular and open design of ITS applications that can easily be connected in order to create a full ITS network.¹⁶ Currently, most ITS work in silos. Even though one ITS application is an integrated system with various technologies, each individual ITS application is not easily integrated into other ITS applications. Some ITS applications are combined through a control centre but are limited in response times to external needs (e.g. disaster or emergency events). Standardization is necessary to achieve full interoperability among ITS applications, which will improve resiliency against user's demands.

2.1.3. Smart Cities

Growing urbanization is causing cities to rethink how to increase the sustainability of cities while providing adequate infrastructure and services for growing populations. Redesigning infrastructure is essential to adapt cities to evolving social needs and growing economic competition. Citizens also have higher expectations for quality of life and public authorities must provide efficient transport systems with seamless connectivity while meeting environmental challenges through technology enhancements and capabilities.

Deployment of ITS on a global scale has propagated promising opportunities to transform socioeconomic life. According to the United Nations Economic Commission for Europe, "ITS is not only an innovative transport technology. It is a new way of living, a new business approach, and overall, a new culture for all players. Every portion of the transport sector of the future will be a receiver and a sender of information. Mega-cities will no longer be about how much to expand infrastructure to serve the continuous increase in population, but rather how to make the most use of the existing infrastructure to better serve more people".¹⁷

Smart city status has become a common vision among cities in recent years. The concept of a smart city does not compete with the efforts already done to improve economic, environmental, and social sustainability; instead, a smart city can support these progresses already underway. Although each

¹² Available from https://ec.europa.eu/transport/themes/its/c-its_en, accessed 3 March 2017.

¹³ Ministry of Land, Infrastructure and Transport, undated. ITS National Plan 2020 (2nd ver.), Republic of Korea.

¹⁴ Johnson, B., and A. Hernandez, 2016. Exploring Engineered Complex Adaptive Systems of Systems. Elsevier B.V. Available from <http://www.sciencedirect.com/science/article/pii/S1877050916324656>, accessed 8 April 2017.

¹⁵ Chokesomritpol, P., and M. B. Regmi, 2016. Next-generation Intelligent Transport System (ITS): concept of operations. United Nations Economic and Social Commission for Asia and the Pacific, Transport Division, unpublished.

¹⁶ Available from https://ec.europa.eu/transport/themes/its/c-its_en, accessed 3 March 2017.

¹⁷ United Nations Economic Commission for Europe, 2012. Intelligent Transport Systems (ITS) for Sustainable Mobility. Geneva, Switzerland.

city has different emphases according to the future goals, the core concept is to benefit from smart technologies (i.e. ICT). The World Bank¹⁸ outlines two targets of a smart city:

- “A technology-intensive city, with sensors everywhere and highly efficient public services, thanks to information that is gathered in real time by thousands of interconnected devices. (For example, trash cans have sensors that indicate when they are full, and trash collectors follow a specific route based on this information.) All buildings are “intelligent”, with smart meters and energy saving systems, and transport is painless.”
- “A city that cultivates a better relationship between citizens and governments—leveraged by available technology. They rely on feedback from citizens to help improve service delivery and creating mechanisms to gather this information. For example, citizens are more active in managing their neighbourhoods. Open government data is used by civil society to co-create smart phone applications (or an SMS service), e.g. to report a full trash can, and trash collectors can accommodate their routes based on this information.”

Smart cities gain full situational awareness from sensors scattered throughout a city, communicated through wireless networks, shared with relevant agencies and analysed to understand and take proper actions in a city.¹⁹ Smart city technologies can also prevent traffic and climate situations in advance, anticipate tasks based on modelled patterns, and eventually, optimize asset operations.²⁰ Smart cities bring more benefits through the digitalization, centralization, and interconnectedness of transport systems. Additionally, environmentally friendly transport modes, such as electric vehicles, AVs and personal rapid transit, can be operated through a combination of intelligent traffic signal operations and smart infrastructure.²¹ After all, an eco-friendly transport environment is a product of the reduction of associated negative externalities in smart cities.

2.1.4. Infrastructure Required for Operation

Automated Vehicles (AVs)

The infrastructure required for the operation of AVs involves integrating cameras, radar, lidar (image sensing), satellite navigation systems, computer vision, and other technologies that can detect the traffic environment and its changes. Using this information, the manipulation of the vehicle mechanisms then follows so that direct human operation of the vehicle can be minimized.²²

Cooperative-Intelligent Transport Systems (C-ITS) & Connected Vehicles (CVs)

C-ITS allows CVs to communicate with each other, roadside infrastructure and other wireless services. They involve sharing real-time information about the surrounding environment with other vehicles, infrastructure, and access devices, allowing for enhanced mobility and safety. The infrastructure elements include mobile data networks, wireless technologies (including Wi-Fi), DSRC and radio frequencies, to enable the creation of a connected vehicle network of Vehicle-to-Everything (V2X) communication.²³ Connections to mobile data networks via phone towers enable V2X

¹⁸ Available from <http://www.worldbank.org/en/topic/ict/brief/smart-cities>, accessed 4 April 2017.

¹⁹ Available from <http://readinessguide.smartcitiescouncil.com/>, accessed 2 April 2017.

²⁰ Ibid

²¹ Ibid

²² National Association of Counties, ‘Connected and Automated Vehicles Toolkit: A Primer for Counties’, 2019, h https://www.naco.org/sites/default/files/documents/2019%20CAV%20Toolkit%20Four%20Pager_09.5.19%20v2_FIN_AL_1.pdf.

²³ National Association of Counties, ‘Connected and Automated Vehicles Toolkit: A Primer for Counties’, 2019, h

communication over large distances to disseminate information such as traffic delays, rapid braking, slippery road conditions and distances between vehicles travelling in the same direction. DSRC technology accessed through built-in DSRC car units is effective for distances up to 1 km to determine when a conflict is likely, based on comparing a car's own location, direction and speed with other vehicles.²⁴

Smart Cities

Infrastructure involved in the creation of a smart city is the result of combining physical infrastructure relating to transport, energy, water, and waste with digital infrastructure involving ICT such as IoT, sensors, networks, BIM/GIS, Big Data & Machine Learning.²⁵ The infrastructure elements for the operation of a smart city involve the deployment of a network of static cameras, sensors and actuators located throughout the urban area together with mobile devices. Within the transport ecosystem, these elements are facilitated through an integrated cloud platform that connects vehicles, people, infrastructure and logistic partners with access to their data typically via wireless mobile devices. In addition to access to real time data on traffic conditions, occupancy of parking spaces, location of vehicles; the smart city network offers other services such as air/water quality information, the structural health of bridges, roads, or buildings, and the location and status of city resources, police officers, or healthcare facilities.^{26,27}

2.2. Specific Status of Countries along the AH 9 Route

2.2.1. The Russian Federation

The Russian Federation is exploring several ITS projects that have the potential to relate to the Europe-West China smart transport corridor. One such project is an ITS corridor with Finland with the ultimate goal of using similar technologies to create a full-service international transport corridor for connected and automated vehicles from Europe to China.²⁸ The corridor consists of two parts:

- CARAVAN – an innovative project of Russian Federal Road Agency (Rosavtodor) which is aimed to create digital infrastructure on federal roads for common, connected and self-driving vehicles, using technologies of C-ITS, V2V, V2I, and V2X. The vision of the project is to create international smart transport corridors with service continuity across borders.
- CAVLANE – the Connected Automated Vehicle Lane Consortia, was initiated by the Finnish Ministry of transport together with a few private companies from Finland and the Russian Federation. The objective of CAVLANE is to create new services, products, and standards for

https://www.naco.org/sites/default/files/documents/2019%20CAV%20Toolkit%20Four%20Pager_09.5.19%20v2_FIN_AL_1.pdf.

²⁴ Centre for Road Safety, 'Connected Vehicles', New South Wales, November 2021, <https://roadsafety.transport.nsw.gov.au/research/roadsafetytechnology/cits/index.html>

²⁵ Mavoco, Smart City – Combining physical and digital infrastructure, 2021, <https://www.mavoco.com/smart-city-infrastructure/>.

²⁶ S. P. Mohanty, U. Choppali and E. Kougianos, "Everything you wanted to know about smart cities: The Internet of things is the backbone," in IEEE Consumer Electronics Magazine, vol. 5, no. 3, pp. 60-70, July 2016, doi: 10.1109/MCE.2016.2556879,

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7539244&isnumber=7539234>.

²⁷ Cassandras, C.G, Smart Cities as Cyber-Physical Social Systems. Engineering, 2. 156-158, 2016, www.sciencedirect.com/science/article/pii/S2095809916309420.

²⁸ Available from: Vladimir Kryuchkov, Co-deployment of fiber optic cables for cross-border connectivity along the highway routes in Russian Federation, presentation for UN ESCAP, 2018.

crossing borders. New intelligent services increase road safety, improve mobility and logistics, boost businesses, and create markets for new innovations.

The CAVLANE/CARAVAN smart route, which originates in Finland's largest cities and runs via Helsinki through the border with the Russian Federation to Saint Petersburg, Moscow, and Kazan to the border with Kazakhstan and China. The project tests cross-border interoperability of different relevant international standards and directives for communication, C-ITS, automatic driving, platoon driving, use of fibre-optic cables for cross-border and custom procedures, information of travellers, and road users about traffic and weather conditions, traffic jams and queues at the cross-border points, road-side services, road works and accidents, navigation and selecting detour routes, etc.

In May 2018, the first demo test of automated trucks and self-driving vehicles within the CARAVAN\CAVLANE project was presented on the eve of opening the Crimea bridge. The road infrastructure was equipped with all necessary means to allow automated trucks and vehicles including real time high-precision vehicle positioning system, incident detection and recording system, measurement of traffic flows parameters, and a duplicate positioning system. The digital model of the road was created together with other additional digital services: protection of information flows of bus and registration of unauthorized impacts on control elements of automated vehicles and trucks, as well as identification of impact of false base stations of cellular communication systems on the road infrastructure and demonstration of the imposition of false GPS coordinates; modular platform for interaction of ITS and road users. The testing site deployed was an LTE standard cellular system, engineering communications, including fibre-optic cables. Two trucks, one shuttle bus and two cars were tested. The final aim of CARAVAN\CAVLANE consortia is to create a full-service international transport corridor for connected and automated vehicles from Europe to China.²⁹

In the Russian Federation, the truck manufacturer produced several prototypes of automated trucks and is developing the special programme for the platooning of automated trucks within the Russian Federation and along international transport corridors in cooperation with Federal Road Agency (Rosavtodor) and State company Avtodor (the federal operator of toll ways in the Russian Federation). Rosavtodor initiated the international programme, CARAVAN, together with Finnish Road Administration for creating C-ITS cross-borders transport corridor which connects Europe and Asia through the Russian Federation and Kazakhstan with China.

Russian telecom company is working on a special programme for the automated taxi in Moscow, Kazan, and other cities in the Russian Federation, Kazakhstan, Uzbekistan and Kyrgyzstan.

A few special programmes for AVs have been set in the Russian Federation on the Federal level: AutoNet, AutoData, Digital trucks and Digital truckers, led by National Technology Initiative.³⁰ On March 3, 2020, the Russian Ministry of Construction announced the urban digitalization index "IQ of cities" along with a rating of digitalization of Russian cities based on this index (based on 2018 data). Developed with Lomonosov Moscow State University, the index of digitalization of urban economy contains 47 indicators, covering ten areas, including smart city transport and infrastructure of communication networks. A total of 191 cities participated. Among the largest cities (population over 1 million people), the first places in the rating were taken by Moscow, Kazan, and St. Petersburg.³¹

²⁹ Available from: Vladimir Kryuchkov, Co-deployment of fiber optic cables for cross-border connectivity along the highway routes in Russian Federation, presentation for UN ESCAP, 2018.

³⁰ Available at <https://www.tadviser.ru/index.php/>

³¹ Available at <https://www.tadviser.ru/index.php/>

2.2.2. Kazakhstan

Kazakhstan also has several domestic ITS projects underway, particularly those among the 12 priority projects of the “Digital Kazakhstan” programme. High-quality transport and logistics infrastructure give a powerful impetus to economic development by increasing the connectivity of the country and reducing overhead costs for the delivery of goods. In order to obtain the maximum effect from the development of infrastructure of telecommunication networks, it is necessary to simultaneously develop the transport connectivity of the country both by developing all types of transport communication and reducing its costs, as well as by developing the infrastructure of forwarding and delivery of goods.

The main task of the digitalization of transport and logistics is to increase the volume of freight traffic. It is expected that the reduction in transit time will significantly increase the volume of cargo in all directions from China through Kazakhstan to Europe, Turkey, and Iran. The main effect will be obtained both through the transition to electronic document management and through the introduction of ITS, which will allow the increase of volume of cargo transport by providing high-quality and safe road infrastructure between the regions of Kazakhstan and international traffic. ITS will combine the functions of video surveillance, traffic management, driver notification of weather conditions, and electronic payment for transport services.

For the system integration of vehicles, infrastructure, users, and information technologies, ITS will be developed, consisting of sub-components with their phased implementation, including the automation of the collection of roadway tolls, a system of continuous dynamic weighing of transport vehicles installed on the main road transport corridors, and a traffic management system. All this makes it possible to inform drivers about roadway conditions, identify traffic violations, and to develop systems of analysis so that freight traffic can reliably move through the country of Kazakhstan.

Developing advanced transport infrastructure based on ITS will be part of the implementation of the Smart City concept in Kazakhstan.³² Smart City is an initiative to improve the efficiency of urban resources and services management and improve infrastructure through the introduction of innovative solutions to create a comfortable environment for citizens.³³ The “smartest” cities of Kazakhstan include Nur-Sultan in first place, Almaty in second, and Uralsk in third, as reported by the press release from the Ministry of digital development, innovation, and aerospace industry.³⁴ Employees of the Ministry evaluated the work on digitalization carried out by the regions. The study involved 14 regional centres and three cities of national significance. The assessment was based on the smart cities reference standard, which consists of 11 different areas and 80 indicators. They concerned digital initiatives including transport, telecommunication, and others.³⁵

The representative of the automotive brand predicted optimistic expectations for the appearance of driverless cars during the second international auto forum in Astana. During the forum, Iveco representative Lorenzo Bernardeli presented futuristic transport concepts with innovative solutions.

³² References: Analytical report of the Eurasian Economic Commission, "On the existing in the member States of the Eurasian Economic Union intelligent transport systems used in the field of road transport and road economy", Moscow, 2019. Analytical report of the Eurasian Economic Commission, <http://www.eurasiancommission.org> . State program “Digital Kazakhstan”, <https://www.digitalkz.kz> . State program "Development and integration of transport infrastructure of the Republic of Kazakhstan until 2020", approved by the decree of the President of the Republic of Kazakhstan dated January 13, 2014 No. 725, www.miid.gov.kz Kazakhstan presentation: www.alrt.kz ; www.astana.gov.kz ;www.24.kz

³³ Available at <https://egov.kz/cms/ru/smart-cities>

³⁴ Available at https://tengrinews.kz/kazakhstan_news/nazvanyi-samyie-umnyie-goroda-kazahstana-389334/

³⁵ Available at https://tengrinews.kz/kazakhstan_news/nazvanyi-samyie-umnyie-goroda-kazahstana-389334/

Iveco, part of CNH Industrial Corporation, demonstrates the active implementation of advanced technologies in commercial vehicles. In his speech, the speaker noted that the manufacturer adheres to the trend of switching from driver-controlled cars to self-driving cars, and also expressed hope that Kazakh colleagues will be able to follow the experience of the world.³⁶

2.2.3. China

Chinese car manufacturers are also participating in the development of AVs. Different tests of AVs have been running from Chongqing to Beijing on several expressway sections.³⁷ China expects smart cars with some automated functions will account for 50 per cent of new vehicles sold in the country by 2020, according to a blueprint released by the National Development and Reform Commission in January. This is part of the country's efforts to become a global power in smart car development and production by 2035.³⁸

AVs could, at some point, take over most of the automotive market in China. For instance, industry respondents to a survey indicate that passenger vehicles used for mobility services such as “robotaxis” will see a peak adoption rate of 62 per cent, followed by private premium vehicles (51 per cent) and private mass-market cars (38 per cent). Mobility services will lead due to the expected increase in AV usage (close to 24/7 operation) and lower labour costs (no drivers). The same rationale puts city buses at 69 per cent adoption and commercial vehicles at 67 per cent. AVs will likely shift a substantial share of the mobility market value away from products (that is, buying vehicles) and toward services (that is, paying for transportation per mile). This “Mobility-as-a-Service” (MaaS) transformation suggests dramatic changes ahead for vehicle sales volumes, business models, and the capabilities companies will need to thrive in this new environment. In China, fully AVs (SAE Level 4 and above) will see mass deployment in nine or ten years.³⁹

In China the main strategic plans of “National Strategy for Innovation and Development of Intelligent Vehicles” are:

- By 2020
 - Intelligent vehicles will account for 50 per cent of new cars in China;
 - Commercialization of middle and high-level intelligent vehicles will have been achieved;
 - 90 per cent of expressway and big city roadways have been covered with wireless telecommunication networks for vehicles.
- By 2025
 - Almost 100 per cent of new vehicles will be intelligent vehicles;
 - Scalable high-level intelligent vehicles will be on the market;
 - New generation wireless telecommunications network for vehicles (5G– V2X) will basically meet the needs to allow for the development of intelligent vehicles;
- By 2035

³⁶ https://www.inform.kz/ru/avtomobili-bespilotniki-poyavyatsya-v-kazahstane_a3005403

³⁷ Wang, X., 2016. ITS development and deployment in China. EGM on Asian Highway. Intelligent Transportation Systems Center. Available from http://www.unescap.org/sites/default/files/3.1%20China_Mr.%20Xiaoqing%20Wang.pdf, accessed 3 February 2017

³⁸ Available at <https://www.intelligenttransport.com/transport-news/70487/autonomous-technology-regulations-china/>.

³⁹ Available at <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-china-will-help-fuel-the-revolution-in-autonomous-vehicles#>

- Chinese standard intelligent vehicles will earn global reputation and China becomes a powerhouse of intelligent vehicles.⁴⁰

China is also determining opportunities in implementing C-ITS with cooperative systems for Highway Ramp Safety on the Beijing-Tianjin Expressway (2012), for example, and Technology Development on Vehicle and Road Cooperation (2011-2015).⁴¹

There are more than 300 cities and regions undergoing smart city planning in China. A total of 586 cities have built up intelligent centres of public security and traffic, among which 325 cities have set up intelligent dispatching platform that are based on geographical information systems. Four hundred and sixty-seven cities have implemented network control of traffic signals. There are 95,000 video monitoring nodes in China (including 25,000 highway monitoring nodes), among which there are 57,000 high-definition video monitoring nodes. Meanwhile, 280 cities feature a traffic video monitor platform.⁴²

Thus China, Kazakhstan, and the Russian Federation have all necessary foundations for developing the next generation transport route: speed highways equipped for automated and connected vehicles, smart cars and trucks to operate with each other and road infrastructure, and smart cities which all together will serve to the fastest, most safe and comfortable mobility of goods and people from the Asia-Pacific region to Europe and back. This will be the new AH 9, which is also known as Europe-Western China International transport corridor or Smart Silk Route.

2.3. Lessons Learned in Asia and the Pacific

Several other countries in the Asia and Pacific region have implemented ITS plans, testing facilities, and infrastructure. This section outlines a few examples of such countries.

2.3.1. Singapore

The Land Transport Authority in Singapore established the first test site for self-driving vehicle technologies and mobility concepts in 2015.⁴³ Singapore has also embarked a new phase of transformation of “Smart Nation”, developing their own vision of the city for the future. The Intelligent Transportation Society Singapore together with the Land Transport Authority developed an ITS strategic plan called Singapore Smart Mobility 2030.⁴⁴ This plan aims to create a more comprehensive and sustainable ITS ecosystem in Singapore by 2030. The goals of the plan are to improve quality of transport information, enhance travel experience with smarter interactivity, improve environment safety, and enable greener mobility. In Singapore, the Centre of Excellence for Testing and Research of Autonomous Vehicles recently developed a testbed for AVs. This facility is intended to support the development of test requirements and standards to deploy AVs in Singapore.

⁴⁰ References: UN ESCAP, Bangkok, 2017 – “Development of model Intelligent Transport Systems. Deployments for the Asian Highway network”, Paragraph 2.1.; China ITS-Country Study Report; China presentation; China Survey result. Mr. Xiaojing Wang, Director of China National ITS Centre, Chief Engineer of RION of Ministry of transport of China.

⁴¹ Available from <http://itsasia-pacific.com/pdf/WangXiaojing.pdf>, accessed 25 March 2017.

⁴² References: UN ESCAP, Bangkok, 2017 – “Development of model Intelligent Transport Systems. Deployments for the Asian Highway network”, Paragraph 2.1.; China ITS-Country Study Report; China presentation; China Survey result. Mr. Xiaojing Wang, Director of China National ITS Centre, Chief Engineer of RION of Ministry of transport of China.

⁴³ Land Transport Authority, 2017. Joint Release by the Land Transport Authority (LTA) & MOT - Self-driving Vehicles Will Transform Singapore’s Transport Landscape. Singapore. Available from <https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=e6dc5dff-8892-4f7f-9a3e-c89d29c0642c>, accessed 3 March 2017.

⁴⁴ Land Transport Authority, 2014. Smart Mobility 2030-ITS Strategic Plan for Singapore. Singapore.

Recently, a self-driving shuttle – spotlighted as the next-generation transport system in Singapore – underwent a variety of experiments, including obstacle recognition, linking with signal controllers, and providing the capability to cope with traffic conditions through vehicle-to-everything wireless communication. Beyond the testbed experiment, roadway demonstrations are underway in the One-north area that connects Biopolis, Fusionopolis, and Mediapolis. Its acceptance level of self-driving vehicles is relatively higher than that of other regions, as One-North has major research institutes and companies. To test AVs in this region, advanced infrastructure has been installed, including high-definition CCTVs, V2X communications (roadside units), and electronic high-definition maps. This promotes public and private sectors to test AVs in this area.⁴⁵

2.3.2. Australia

In Australia, vehicles with relatively high levels of automation, including self-parking systems or traffic jam assistance, are already commercially available.⁴⁶ The concept of connected and automated vehicles has attracted a lot of interest in Australia, with approximately 30 related pilots, trials and case studies having been conducted.⁴⁷ For example, connected and automated vehicle trials are being deployed and tested on the South East Queensland highway networks.⁴⁸ South Australia had the first on-road trials of driverless cars in 2015 and driverless shuttle buses were tested in Perth.⁴⁹ Australia's first driverless shuttle bus, "IntelliBus", has been tested in Perth, with a capacity of 11 people and maximum speed of 45km/h in controlled environments.

2.3.3. The Republic of Korea

The Republic of Korea is also a leading contributor in the development of ITS technologies, adopting the "National ITS Master Plan" in order to progress their ITS phases. The Government of the Republic of Korea defined 15 traffic safety services based on C-ITS and initiated pilot projects.⁵⁰ The objectives of the pilot projects are to test the performance of C-ITS, in line with the advancement of the self-driving system, to develop any related roadway or traffic regulations, and to support and promote the private sector in the C-ITS field. The Seoul Metropolitan Government and the Jeju Special Self-Governing Province are the locations selected for C-ITS pilot studies. For these pilot studies, C-ITS infrastructure will be deployed on 300 km of roadway in Jeju and 121 km of the bus rapid transit routes and urban expressways in Seoul. Furthermore, 500 commercial vehicles have received onboard units to promote C-ITS.⁵¹

The Republic of Korea has been interested in establishing smart cities for over ten years. The Ministry of Land, Infrastructure and Transport of the Republic of Korea is building a testbed, called K-City,⁵²

⁴⁵ Available from The Korea Transport Institute, "Overseas trip report: best practices in smart city and automated vehicle technologies" (2018). A. Quek, "Singapore Autonomous Vehicle Initiative (SAVI)", presentation 20th ITS World Congress, Singapore, 21–25 October 2019. Available at [https://www.itu.int/en/ITU-T/extcoop/cits/Documents/Workshop-201707-Singapore/010%20-%20Alan-Quek-Singapore%20Autonomous%20Vehicle%20Initiative%20\(SAVI\).pdf](https://www.itu.int/en/ITU-T/extcoop/cits/Documents/Workshop-201707-Singapore/010%20-%20Alan-Quek-Singapore%20Autonomous%20Vehicle%20Initiative%20(SAVI).pdf)

⁴⁶ Transport and Infrastructure Council, 2016. National Policy Framework for Land Transport Technology: Action Plan 2016-2019. Australia.

⁴⁷ See <https://dashboard.its-australia.com.au/>.

⁴⁸ See <https://cavs.transurban.com/trials/queensland/partial-automation>.

⁴⁹ Available from <http://thinkinghighways.com/>, accessed 1 April 2017.

⁵⁰ ITS Korea, Monthly ITS, vol.141 (February 2019).

⁵¹ The Korea Transport Institute and ITS Korea, "Study on C-ITS technologies status and domestic deployment strategies"

Available at: [www.prism.](http://www.prism.go.kr/homepage/origin/retrieveOriginDetail.do?cond_organ_id=1613000&research_id=1611000-201300022&pageIndex=1&leftMenuLevel=120)

[go.kr/homepage/origin/retrieveOriginDetail.do?cond_organ_id=1613000&research_id=1611000-201300022&pageIndex=1&leftMenuLevel=120](http://www.prism.go.kr/homepage/origin/retrieveOriginDetail.do?cond_organ_id=1613000&research_id=1611000-201300022&pageIndex=1&leftMenuLevel=120).

⁵² Republic of Korea, Ministry of Land, Infrastructure and Transport. Available at <http://www.molit.go.kr/portal.do>.

in which AVs could be tested on urban roadways.⁵³ By IESE Business School's Cities in Motion index (the Smartest Cities),⁵⁴ Seoul ranked 8th worldwide and 1st in Asia. Under the Master Plan for Ubiquitous City from 2009 to 2013 (previous concept for Smart City), the government invested around \$20 million. In August 2016, the Republic of Korea chose smart city projects as one of nine major national strategies and plans to invest around \$300 million to the development of smart city for five years (2017-2021).⁵⁵ Major components of smart city transport are smart parking, smart crosswalks, smart mobility, and smart infrastructure.

2.3.4. Greater Region

In Asia, a summit called Smart Cities Asia⁵⁶ is organized by the Knowledge Group from Malaysia, bringing together different stakeholders to discuss themes around the development of smart cities in the region. Main themes include smart development, smart ICT, smart mobility, smart citizens, smart energy, smart water, and waste management.

2.4. Lessons Learned from Other Regions

According to analysis from the Groupe Spéciale Mobile Association,⁵⁷ the market size for CVs is increasing—the global CV market was worth €39 billion in 2018, up from €13 billion in 2012.

Noticeably, collaborative work on CVs occurs around the globe; for example, the EU, USA, and Japan set up the forum “EU/US/JP Task Force” on CVs to exchange experience and information. Lists of applications which require the use of communications for both V2V and V2I have been created by the European Telecommunications Standards Institute “Basic Set of Applications” and the Connected Vehicle Reference Implementation Architecture (CVRIA), led by the United States Intelligent Transport Systems Joint Program Office.⁵⁸ In addition, a joint task force of the World Road Association-PIARC and the International Federation Automotive Engineering Societies has developed a report “The Connected Vehicle”⁵⁹ exploring the perspectives in the commercial and public sectors, and discussing issues and implementation factors.

2.4.1. Europe

The European Automotive Telecom Alliance (EATA) presented a roadmap for testing connected driving functionalities, including pilot projects and ongoing regulatory talks. Five EU countries (Belgium, France, Germany, the Netherlands, and Spain) joined in 2017, and other European countries are expected to join the project at a later stage. Another EATA's project (called CONCORDA) aims to enhance existing pilot projects' functionalities (automated highway chauffeur, truck platooning and automated collision avoidance).⁶⁰

⁵³ Republic of Korea, Ministry of Land, Infrastructure and Transport, Autonomous vehicle test bed, K-City. Available at <http://www.molit.go.kr/portal.do>.

⁵⁴ IESE Business School, 2016. IESE Cities in Motion Index. Madrid, Spain.

⁵⁵ National Assembly Research Service, 2016. Issue and Point. 1236th. Republic of Korea.

⁵⁶ Available from <http://www.smartcitiesasia.com/> (last accessed in April 2017)

⁵⁷ Groupe Spéciale Mobile Association, 2013. Connected Car Forecast: Global Connected Car Market to Grow Threefold Within Five Years. London, U.K.

⁵⁸ Available from <http://local.iteris.com/cvria/>, accessed 14 March 2017.

⁵⁹ Technical Committee B.2 Road Network Operations, 2012. The Connected Vehicle. PIARC Ref: 2012R02EN. Available from <http://www.piarc.org/en/order-library/13731-en-The%20connected%20vehicle.htm>, accessed 1 May 2017.

⁶⁰ Available from <http://www.acea.be/press-releases/article/connected-and-automated-driving-eata-presents-deployment-roadmaps-submits-pr>, accessed 2 May 2017.

In Europe, research projects on automated driving, called City Alternative Transport and CityMobil,⁶¹ were initiated. Germany introduced the concept of automated driving as an objective for 2020 in the Round Table organized by the Transport and Digital Infrastructure. The United Kingdom invested £33 million for the “driverless car” trials in four cities in 2014⁶² and completed the regulatory review called “the pathway to driverless cars”⁶³ in 2015.

Additionally, the European Commission supports the introduction and deployment of connected and automated mobility by developing policy initiatives, roadmaps and strategies, developing standards at the European level, co-funding research and innovation projects, and implementing infrastructure pilot projects.⁶⁴ In 2016, the European Commission members signed the “Declaration of Amsterdam on Cooperation in the Field of Connected and Automated Driving”⁶⁵ to establish shared objectives, a joint agenda, and proposed actions both for member States and the European Commission in the area of connected and automated driving.⁶⁶ In March 2017, 29 European countries signed a Letter of Intent committing to work together on large-scale testing and demonstrations for automated driving.⁶⁷ The letter addressed connectivity, spectrum, data, cyber security, and artificial intelligence for AV operation.⁶⁸ In September 2017, the Commissioners agreed to strengthen cross-border collaboration on AV testing, particularly new testing in Finland, Norway, and Sweden.⁶⁹

In Europe, projects were set up to prepare commercialization of C-ITS, Cooperative systems for Sustainable Mobility and Energy Efficiency (COSMO),⁷⁰ and Compass4D⁷¹ from 2013 to 2016 and reached an agreement that C-ITS must be installed by 2015 through the consortium with vehicle manufacturers (Car-2-Car Consortium).⁷²

In the United Kingdom, the Smart London Plan⁷³ has been established by the Greater London Authority aiming to “[utilize] the creative power of new technologies to serve London and improve Londoners’ lives”. Collaborative work is being conducted to support this plan and related summits share experiences and relevant information to better implement a digital city.

2.4.2. United States

⁶¹ Available from ERTRAC Task Force, 2015. Automated Driving Roadmap—Status: Final for Publication. Belgium.

⁶² United Kingdom Parliament, Evidence Check: “Driverless Cars”, Government Statement (undated).

⁶³ United Kingdom Department of Transport, Driverless Vehicles: Connected and Autonomous Technologies and Road Safety. Available at <https://www.gov.uk/government/publications/driverless-cars-in-the-uk-aregulatory-review> (accessed on 7 March 2017).

⁶⁴ European Commission, Connected and automated mobility in Europe. Available at <https://ec.europa.eu/digital-single-market/en/connected-and-automated-mobility-europe>.

⁶⁵ Amsterdam, Cooperation in the field of connected and automated driving. Available at <https://www.regjeringen.no/contentassets/ba7ab6e2a0e14e39baa77f5b76f59d14/2016-04-08-declaration-of-amsterdam---final1400661.pdf>

⁶⁶ European Commission, Cooperative, connected and automated mobility. Available at http://europa.eu/rapid/press-release_STATEMENT-17-3272_en.htm

⁶⁷ European Commission, Cooperative, connected and automated mobility. Available at <https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated>

⁶⁸ European Commission, Cooperative, connected and automated mobility. Available at http://europa.eu/rapid/press-release_STATEMENT-17-3272_en.htm.

⁶⁹ European Commission, Cooperative, connected and automated mobility. Available at <https://ec.europa.eu/digital-single-market/en/news/cooperative-connected-and-automated-mobility-stepping-efforts-frankfurt>.

⁷⁰ Franco, G., undated. Cooperative systems for sustainable mobility and energy efficiency. Competitiveness and Innovation Framework Program 2007-2013. Available from <http://ec.europa.eu/transport/sites/transport/files/themes/its/events/doc/2012-06-07-workshop/1.4-ict-psp-predeployment-cosmo.pdf>, accessed 24 April 2017.

⁷¹ Available from <http://www.compass4d.eu/> accessed 2 March 2017.

⁷² Available from <https://www.car-2-car.org/index.php?id=5>, accessed 2 March 2017.

⁷³ Greater London Authority, 2017. Smart London Plan.

In the United States, at least 41 states and Washington, D.C. have considered legislation related to AVs since 2012. Governors of 11 states have issued executive orders, while 29 states and Washington, D.C. have enacted legislation related to AVs.⁷⁴ In addition to the legislation, United States Department of Transportation (USDOT) is pursuing a variety of activities for AVs. In 2017, USDOT selected 10 proving ground pilot sites to encourage testing, validation, and information sharing of AV technologies.⁷⁵ In 2018, USDOT published *Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0)* to provide a framework and multimodal approach to the safe integration of AVs into the surface transport system.⁷⁶ Also in 2018, USDOT published a *Comprehensive Management Plan for Automated Vehicle Initiatives* to manage initiatives related to AVs within variously related administrations, such as NHTSA, Federal Highway Administration, the Federal Motor Carrier Safety Administration and the Federal Transit Administration.⁷⁷

In the United States, USDOT has leveraged about \$350 million in public and private funds for smart city and advanced transport technologies. In December 2015, the Smart City Challenge was launched and requested that mid-sized cities develop ideas for becoming a smart city including using data, applications, and technologies. The Challenge induced 78 applicant cities and USDOT committed up to \$40 million to one winning city.⁷⁸

2.5. Potential Benefits from Previous Studies

2.5.1. Safety Improvements

ITS technology is a life-saving innovation. Analysis only of two potential applications of V2V and V2I - “Intersection Movement Assist” (IMA) and “Left Turn Assist” (LTA), indicated there could be a 50-per cent average reduction in crashes, injuries, and fatalities for just these two applications. Of course, the addition of other V2V and V2I safety applications would save even more lives. Pedestrian crash avoidance and mitigation systems could potentially address up to 46 per cent of pedestrian crashes. Altogether, these applications could eventually prevent or reduce the severity of up to 80 per cent of non-alcohol-related crashes.⁷⁹

2.5.2. Economic Savings

Based on these and other trials, further potential benefits from connected and automated vehicles technologies can be noted. For example, in Australia estimated benefits of using C-ITS in South East Queensland range from \$A 575.7 million to \$A 3.95 billion from 2020 to 2050. In terms of fuel savings and emissions, C-ITS can save between \$A 448.3 million and \$A 298.2 million.⁸⁰ They also

⁷⁴ National Conference of State Legislatures, *Autonomous Vehicles*. Available at <http://www.ncsl.org/research/transportation/autonomous-vehicles-selfdriving-vehicles-enacted-legislation.aspx>.

⁷⁵ United States of America, Department of Transportation, *Automated vehicle proving grounds to encourage testing of new technologies*. Available at <https://www.transportation.gov/briefing-room/dot1717>.

⁷⁶ United States of America, Department of Transportation, *Development of automated vehicles*. Available at <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automatedvehicles/320711/preparing-future-transportationautomated-vehicle-30.pdf>.

⁷⁷ United States of America, Department of Transportation, *Comprehensive Management plan for automated vehicle initiatives*. Available at <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/317351/usdotcomprehensive-management-plan-automated-vehicleinitiatives.pdf>.

⁷⁸ Available from <https://www.transportation.gov/smartcity>, accessed 2 April 2017.

⁷⁹ Available from <https://rosap.nhtl.bts.gov/view/dot/3592>. Executive Summary U.S. Department of Transportation, Office of the Assistant Secretary for Research and Technology Intelligent Transportation Systems Joint Program Office V2I Safety Application Performance Requirements – Volume 1).

⁸⁰ Australia, Bureau of Infrastructure and Regional Development, “Costs and benefits of emerging transport technologies”, Research report 146 (Canberra, Commonwealth of Australia, 2017).

demonstrate an effective cost benefit ratio, ranging from 2.1 to 3.8 from 2020 to 2050.⁸¹ In the United States, 27 roadside units along with 75 miles of roadway were installed in a study to test the V2I applications for traffic signal timing and emergency vehicles. In addition, the USDOT had selected three sites to test CV technologies to improve vehicle and pedestrian safety as well as traffic flow. This was part of Phase 1 of Connected Vehicle Pilot Deployment Program, lasting up to 50 months. \$178.8 billion in societal benefits annually are expected if CV safety applications are deployed across the entire U.S. vehicle fleet.⁸² Estimates from an AV trial run in Victoria indicate a reduction of 27 million tonnes of greenhouse gas emissions, \$A706 million in health benefits, a 91 per cent increase in road efficiency, and a \$A 5 billion annual boost to economic growth.⁸³

2.5.3. Greenhouse Gas Reduction

In New South Wales, early results of the implementation of C-ITS for warning drivers indicate that using smart traffic signals with cooperative vehicles can potentially save up to 15 per cent in fuel consumption and corresponding emissions.⁸⁴ In the Republic of Korea, by 2020, the expansion of ITS is expected to enter into the second phase, or ITS 2.0, during which 30 per cent of roads are expected to be vehicle-to-everything based. In this phase, services such as bidirectional communication and cognitive functions will be provided on these roads, leading to an estimated reduction of 2.2 million tCO₂ per year.⁸⁵ The Ministry of Land, Infrastructure and Transport expects to reduce the annual traffic congestion cost by ₩800 billion, increase traffic speeds in the city centre by 30 per cent, and reduce traffic crashes by 46 per cent, as a result of the full utilization of the C-ITS on the roadways in the Republic of Korea.⁸⁶

ITS can save lives while saving money, time spent in traffic, and greenhouse gas emissions in the long run. It is important that countries collaborate when developing smart infrastructure to ensure a cohesive network that upholds the safety, economic, and environmental benefits of ITS.

⁸¹ M. Blogg, “Cooperative and automated vehicles in Queensland”, presentation at the 23rd ITS World Congress, Melbourne, Australia, 10–14 October 2016. Available at http://ibec-its.com/wp-content/uploads/sites/18/2016/11/IBEC-3_M.Blogg_Melbourne-2016.pdf

⁸² Cronin, B., undated. Connected Vehicle Benefits. Research, ITS Joint Program Office, U.S. Department of Transportation.

⁸³ KPMG, “Australia’s future transport and mobility; progress, policies and people” (2019). Available at <https://assets.kpmg/content/dam/kpmg/au/pdf/2019/australia-future-transport-and-mobility-report.pdf>

⁸⁴ In a statement at the IEEE Conference, Self-Driving Cars: Fiction or Reality?, held in Sidney, Australia, 30 October 2014, John Wall of the Centre for Road Safety, Transport for NSW, said “Cooperative vehicles receiving and transmitting information to smart traffic signals could potentially save up to 15 per cent in fuel consumption”. Retrieved from D. Maunsell, P. Tengutur, and J. Hogarth, “The new road to the future: realising the benefits of autonomous vehicles in Australia” (Accenture Digital, 2014). Available at https://www.accenture.com/_acnmedia/accenture/conversion-assets/dotcom/documents/local/en-gb/pdf_3/accenture-realising-benefits-autonomous-vehicles-australia.pdf.

⁸⁵ Available at: www.prism.go.kr/homepage/researchCommon/downloadResearchAttachFile.do?sessionId=3ED7CA847ADF54E649EFB2157250FD94.node02?work_key=001&file_type=CPR&seq_no=001&pdf_conv_yn=N&research_id=1613000-201700068.

⁸⁶ The Korea Transport Institute and ITS Korea, “Study on C-ITS technologies status and domestic deployment strategies” (2013). Available at: http://www.prism.go.kr/homepage/origin/retrieveOriginDetail.do?cond_organ_id=1613000&research_id=1611000-201300022&pageIndex=1&leftMenuLev el=120.

3. Country Feasibility Studies

3.1. China

3.1.1. Technical and Operational Condition of the AH route 9

The AH route 9 in China, also named the Lianyungang–Korgas Expressway (Lianhuo Expressway, G30), connects the cities of Lianyungang in Jiangsu and Korgas in Xinjiang, on the border with Kazakhstan. It is one of the longest expressways in China stretching across the country from the Yellow Sea on the east coast to the Kazakhstan border in the west, which passes through the provinces of Jiangsu, Anhui, Henan, Shaanxi, Gansu, and Xinjiang.

On November 18, 2017, the last reconstructed section of the G-218 Expressway in the Xinjiang Uygur Autonomous Region of China was opened for traffic. The new highway connects the border crossing of Kazakhstan with the main road G-30 - a highway that runs through 4,243 kilometres of flat China.

The AH route 9 plays an essential role in the Belt and Road Initiative, and it is also a very important link in the comprehensive national transport network of China. The AH route 9 largely overlaps with the Silk Road, which is seen as an important transportation artery in the Silk Road Economic Belt. According to the “14th Five-Year Plan (2021-2025) for the National Economic and Social Development and the Long-Range Objectives Through the Year 2035” (the 14th Five-Year Plan), China plans to improve the construction of transportation corridors in Xinjiang and Tibet and to improve the interconnection with neighbouring countries.⁸⁷

The AH route 9 in China is an important transportation link connecting western and eastern China. It will be one of the most important land corridors for China to develop. Basic characteristics of the AH route 9 in China are provided in Table 1 below.

Table 1. Basic characteristics of the AH route 9 in China.

Section	Indicator	Value
Jiangsu Section	Length	238 km
	Lanes	Two-way four-lane
	Connections	S72 Lianyungang-Beishugang Expressway, S73 Lianyungang-Dongshugang Expressway, G25 Chang-Shen Expressway, G15 Shen-Hai Expressway, G2 Beijing-Shanghai Expressway, S49 Xin-Yang Expressway, G2513 Huai-Xu Expressway, G3 Beijing-Taiwan Expressway
	Service Facilities	Jinpingshan Service Area, Donghai Service Area, Gangtou Service Area, Yitang Service Area, Shaolou Service Area, Bizhuang Service Area
Anhui Section	Length	52km
	Lanes	Two-way four-lane
	Connections	G3 Beijing-Taipei Expressway
	Service Facilities	Wangzhai Service Area
Henan Section	Length	611km
	Lanes	Zhengzhou to Luoyang, Zhengzhou to Lankao: Two-way Eight-lane
	Connections	S97 Ji-Qi Expressway, G35 Ji-Guang Expressway, S81 Shang-Nan Expressway, S82 Zheng-Min Expressway, S83 Lan-Nan Expressway,

⁸⁷ Source: Xinhua News Agency. 14th Five-Year Plan (2021-2025) for National Economic and Social Development and the Long-Range Objectives through the Year 2035. http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm (last accessed in March 2021).

Section	Indicator	Value
		G1511 Ri-Lan Expressway, G45 Da-Guang Expressway, S25 An-Luo Expressway, G4 Beijing-Hong Kong-Macao Expressway, G3001 Zhengzhou Ring, S49 Jiao-Tang Expressway, G55 Er-Guang Expressway, G36 Ning-Luo Expressway, G59 Hu-Bei Expressway
	Service Facilities	Henan-Anhui Service Area, Xiayi Service Area, Ningling Service Area, Civil Rights Service Area, Kaifeng Service Area, Zhongmu Service Area, Zhengzhou North Service Area, Gongyi Service Area, Luoyang Service Area, Mianchi Service Area, Mianchi Northwest Parking Area, Mianchi Southwest Parking Area, Sanmenxia Service Area, Lingbao Service Area, Henan-Shaanxi Boundary Service Area
Shaanxi Section	Length	379 km
	Lanes	Tongguan to Baoji: Two-way Eight-lane
	Connections	G6521 Yu-Lan Expressway, G65 Bao-Mao Expressway, G70 Fu-Yin Expressway, G3002 Xi'an Ring Expressway, G40 Shanghai-Shanxi Expressway, G70 Fu-Yin Expressway, G5 Jing-Kun Expressway, G85 Yin-Kun Expressway
	Service Facilities	Tongguan Parking Area, Huashan Service Area, Nansha Parking Area, Weinan West Service Area, Qujiang Service Area, Wugong Service Area, Changxing Service Area, Baoji West Service Area
	Tunnels	Wangjialiang Tunnel, Yaojiashan Tunnel, Huaishuling Tunnel, Heiling Tunnel, Luojiashan Tunnel, Huowanshan Tunnel, Hanjiashan Tunnel, Beihai Tunnel, Shimen Tunnel, Nanling Tunnel, Weijiashan Tunnel, Xiaojie Tunnel, Naxiawan Tunnel, Lao Chaiwo Tunnel, Ma Zongshan Tunnel, Weihe Tunnel
Gansu Section	Length	1691 km
	Connections	G22 Qing-Lan Expressway, G6 Beijing-Tibet Expressway (Shared)
	Service Facilities	Baihua Service Area, Ganquan Service Area, Guanzi Parking Area, Gangu Service Area, Yuanyang Service Area, Tong'anyi Service Area, Shibalipu Service Area, Jijiazui Service Area, Beilongkou Service Area, Huazang Temple Service Area, Anmen service area, Wuwei South service area, Yongchang service area, Shandan service area, Jiulongjiang service area, Jiuquan service area, Qingquan service area, Chijin parking area, Yumen service area, Bulongji parking area, Liuyuan service Area
	Tunnels	Dongkou Tunnel, North and South Cliff Tunnel, Dock Tunnel, Taohuagou Tunnel, Guanyinshan Tunnel, Tuqiao Tunnel, Taohuaping Tunnel, Maijishan Tunnel, Xiaolongshan Tunnel, Huashishan Tunnel, Qinlingguan Tunnel, Dangchuan Tunnel, Shimen Tunnel, Mumatan Tunnel, Xianrenya Tunnel, Yanziguan Tunnel, Kangjiaya Tunnel, Jintu Temple Tunnel, Jieting Hot Spring Tunnel, Ganquan Tunnel, Huaniu Tunnel, Tianshui County Tunnel, Sun Mountain Tunnel, Qinzhou Tunnel, Daxiangshan Tunnel, Gangu Tunnel, Wushan Tunnel, Guangwu Tunnel, Tujiawan Tunnel, Baihushan Tunnel, Zhaojia Lenggan Tunnel, Yanliu Tunnel, Quangou Xian Tunnel, Wushaoling Tunnel (No.1-4), Gulang Tunnel
Xinjiang Section	Length	1476 km
	Connections	G3012 Tu-He Expressway, G3014 Kui-A Expressway, G3016 Qing-Yi Expressway,
	Service Facilities	Tongli Service Area, Erbao Service Area, Yiwanquan Service Area, Chejuluquan Parking Area, Xiaocaohu Service Area, Salt Lake Service Area, Sanping Service Area, Wugongtai Service Area, Shihezi Service Area, Kuitun Service Area, Gaoquan Parking Area, Shaquanzi Parking Area, Bajiahu Service Area, Wutai Service Area, Sailimu Lake Service Area, Guozigoukou Service Area

Table 2. Basic characteristics of the AH route 9 in China.

3.1.2. Strategic Plans for Smart Highway Development

According to the 14th Five-Year Plan, China plans to speed up the construction of new infrastructure in the next five years. The digital transformation of traditional infrastructures such as transportation, energy, and municipal administration is expected to be accelerated. China will also strengthen the construction of ubiquitous perception, terminal networking, and intelligent dispatching systems. In addition to the promotion of digital industrialisation such as the 5G-based application scenarios and industrial ecology, and the pilot demonstrations in key areas such as smart transportation and smart logistics. The 14th Five-Year Plan aims to build a new picture of digital life, including the digitisation of transportation services, and new digital lifestyles with wisdom sharing, harmony, and co-governance.

On September 19, 2019, China issued the “Outline for the Construction of Nation with a Strong Transportation System”, which proposes to deeply integrate new technologies such as big data, Internet, artificial intelligence, block-chain, supercomputing, etc., in addition to the transportation industry. The Outline plans to accelerate the integration of transportation infrastructure networks, transportation service networks, energy networks, and information networks to build a ubiquitous advanced transportation information infrastructure. In addition, the Outline proposes to build a comprehensive transportation big data centre system to deepen the development of public services and e-government affairs, and to promote the application of the BeiDou satellite navigation system.

In addition, the Outline calls for accelerating the development of new business forms and models, such as improving the tourist service facilities in expressway service areas, developing the shared mobility, creating a service system based on smart mobile technology, and realizing Mobility as a Service. The development of efficient logistics and the innovated smart logistics operation models based on “Internet Plus”, the establishment of a global delivery service system, and the promotion of the upgrading of universal postal services are also mentioned in the Outline.

The Guidelines on Developing Comprehensive Transport Network unveiled by China aims at developing a modern, high-quality and comprehensive national transportation network. According to the Guidelines, by 2035, the transport network in China should be convenient, cost-effective, green, intelligent, and safe. The Guidelines also propose to promote the integrated development of the transportation infrastructure network, the transportation service network, the information network, and the energy network.⁸⁸

The Guidelines require the promotion of a smart and high-quality development of the comprehensive transportation network, such as the acceleration of the technological innovation capabilities of transportation and the promotion of digitalisation of transport infrastructure. New technologies like satellite and new-generation communication, high-resolution remote sensing satellites, artificial intelligence should be adopted. A fully covered, replaceable, and safe BeiDou high-precision service network and a high-precision transportation geographic information system platform should be built. The development of intelligent connected vehicles (e.g. smart vehicles, automated driving, and the cooperative vehicle-infrastructure systems) and the application of the Internet of Things are encouraged in the Guidelines.⁸⁹

⁸⁸ Department of Development Planning of National Development and Reform Commission. The 13th Five-Year Development Plan for Transport Standardisation. 2017. Retrieved from: https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/201707/t20170719_1196839.html (last accessed in March 2021).

⁸⁹ State Council of the People's Republic of China, Guidelines on Developing Comprehensive Transport Network, Gazette of the State Council of the People's Republic of China, 2021(08):25-37.

The Guiding Opinions of the Ministry of Transport on Promoting the Development and Application of Road Traffic Autonomous Driving Technology released by the Ministry of Transport of China emphasised enhancing the development of smart infrastructures. The Guiding Opinions call for promoting the simultaneous planning of intelligent elements such as perception networks, communication systems, and cloud-based control platforms, and building the integrated and efficient smart transportation infrastructure. It is also necessary to develop intelligent construction technologies and to encourage the integration of digital transportation facilities, roadside perception systems, in-vehicle wireless communication networks, positioning and navigation facilities, computing facilities, cloud-based traffic control platforms, etc.⁹⁰

ITS Plans for Smart Highways in Jiangsu

On November 20, 2020, the Department of Transportation of Jiangsu Province issued the Technical Guidelines for Smart Expressway Construction in Jiangsu Province (hereinafter referred to as “the Guide”). The Guide puts forward the overall ideas for the construction of smart expressway in Jiangsu.⁹¹

The Guide summarises the experience of a series of smart expressway pilot projects such as the Shanghai-Nanjing Expressway, Wufengshan Expressway, Suzhou-Taizhou Expressway, etc. It is demand-oriented and goal-oriented and follows the “systematic, practical, safe, advanced, economic, and scalable” principles. The Guide proposes the short and long-term development goals for the smart highway.⁹⁹

Soon, pilot demonstrations of smart highways in the main corridors with high traffic flow will be carried out. Furthermore, the core highway network that plays a key supportive role for the regional economic development will also be constructed. In the short term, the digitisation and intelligentisation of the entire life cycle of highway construction, management, and maintenance are expected to be finalised. In the long term, the efficient collaboration of “people, vehicles, and highways” will be realised with fully intelligent highway business management that supports automatic driving above Level 3.

The Guide also clarifies the functional, performance, and implementation requirements of the smart highway. And it also emphasises the typical applications of new-generation information technologies such as 5G, BeiDou, cloud computing, high-resolution remote sensing, and artificial intelligence in the expressways.

In addition to smart highways, Jiangsu Province is also at the forefront of the country in the construction of smart expressway service areas. According to the requirements of the “12th Five-Year Plan” of Jiangsu, it asks for the development of the service area with the characteristics of diversified facilities and business, humanised and ecological operation, professional management, etc. It also attempts to use cloud computing, big data, the Internet of Things, and other technologies in the process of construction of the service area to improve economic efficiency and service quality.⁹²

⁹⁰ Ministry of Transport. Guiding Opinions of the Ministry of Transport on Promoting the Development and Application of Road Traffic Autonomous Driving Technology.

⁹¹ The Transport Department of Jiangsu Province. Technical Guidelines for Smart Expressway Construction in Jiangsu Province. 27 November 20210. Retrieved from: https://zizhan.mot.gov.cn/VURLd865887b/OTL2026f6bb/OTLfc34c609/jiaotongxinwen/202011/t20201127_3496229.html (last accessed in March 2021).

⁹² Meng, C., Li, Z., Yang, H, Guo, Z. Construction of Smart Service Areas in Jiangsu Eastern Expressway. *China ITS Journal*. 2020(05):29-31+95.

The construction of the Jiangsu smart expressway started early, especially with lots of investment in the construction of the roadside perception facilities, such as the connected video surveillance, traffic and weather monitoring stations, weight-based toll collection stations, backbone networks, tourism websites, etc. The “96777” Customer Service Centre was also the first to be established in China.⁹³ To sum up, the construction of the Jiangsu smart expressway has been at the forefront of the country.⁹⁴

The construction of the Jiangsu smart expressway faces the following challenges. The first one is incomplete data collection since most of the data collected is at the “point” level, but not at the “line” or “surface” level. The second challenge is poor system compatibility as different manufacturers have different standards, making it difficult to be compatible. The third one is the lack of business support, many of which are only the applications of a single product, without connections between the upstream and downstream processes of business. The fourth one is that the exchange of information is difficult due to the decentralised construction architecture. The last challenge is the low service quality with a weak customer experience to travel on the smart highway.

ITS Plans for Smart Highways in Anhui

In 2018, Anhui Province invested 218 million Yuan to establish and operate the video monitoring network named the “Highway Full-process Monitoring and Management System” and the weather monitoring system named the “Highway Severe Weather Condition Monitoring and Warning System”.



Figure 3. Control room of the Highway Monitoring and Management System in Anhui.

In the video monitoring network, 1 high-altitude camera and 4 low-altitude high-definition cameras are set up every 10 kilometres, with a total of 363 newly-built high-altitude cameras and 1165 newly-built low-altitude cameras. Using high-speed private network communication technology, front-end video is transmitted to the highway monitoring centre. The data are shared with the traffic police and road administration departments.⁹⁵

The weather monitoring system is based on the existing severe weather condition monitoring facilities. With 36 newly-built automatic weather stations and 352 visibility monitoring stations, the

expressway is fully covered with an average station distance of 15 kilometres. In some key highway sections, the average distance is 3 kilometres.

As of the end of 2018, Anhui Province had built 605 Electronic Toll Collection (ETC) lanes. The coverage rate of ETC lanes at toll stations reached 100%. The total number of ETC card users exceeded 2.8 million, ranking among the top 10 in China. The ratio of non-cash payment exceeded 40%, ranking the 7th in China. The promotion and application of ETC have effectively improved the traffic efficiency of the highway network. It also improved people’s travel experience and promoted energy conservation and emission reduction.

⁹³ Yin, W. Design and Implementation of Smart Expressway. *Jiangsu Technology Information*. 2020,37(16):52-54.

⁹⁴ Jiangsu will build “Future Smart Expressway”. *China ITS Journal*. 2020(10):84-85.

⁹⁵ The Transport Department of Anhui Province. Smart Expressway for Convenient Travel. Retrieved from: http://zizhan.mot.gov.cn/st/anhui/tupianfengcai/201903/t20190319_3178054.html (last accessed in March 2021).

There are 33 toll stations with 172 manual toll lanes on the expressways of Anhui. Mobile payment is available at the ETC Customer Service Centre, supporting multiple payment methods such as WeChat, Alipay, and the UnionPay cards.

ITS Plans for Smart Highways in Henan

Henan Province issued an implementation opinion on accelerating the construction of smart highways on August 3, 2017. The opinion pointed out that the construction of the smart highway in Henan Province should achieve the goal of building a complete information infrastructure by the end of the “13th Five-Year Plan” to making it more convenient to the public. The information infrastructure includes a unified resource platform, in-depth industry applications, and rapid information services.⁹⁶

In the latest “Guiding on Construction Standards for Newly-built Expressways in Henan Province” issued in December 2020, Henan Province planned to implement the integration of the highway construction management and operational services with the new-generation information technologies such as 5G, Internet of Things, big data, BeiDou high-precision positioning, and artificial intelligence.⁹⁷

The Jixi Smart Expressway project from the Zhengzhou Xinzheng International Airport to Xihua County is one of the first pilot projects for the construction of a new generation of national traffic control networks in China. The project started at the end of December 2019 and has now been fully completed.⁹⁸

Along the Jixi Expressway, a series of AI analysis cameras, millimetre-wave radars, edge computing servers, and other new detection equipment has been deployed to sense the status of vehicles. By installing onboard intelligent terminals on the vehicles, the smart highway can provide beyond-horizon sensing capabilities and achieve lots of safety functions such as dynamic speed limit management and assisted driving to reduce the risk of high-speed driving and improve operating efficiency.

In addition, a 4.2 km-length section of the Jixi Expressway has achieved full coverage of 5G signals. New technologies such as 5G, BeiDou high-precision positioning, big data, and vehicle-road coordination are integrated to develop several technological applications with less congestion and more safety. In the future, the Jixi Expressway will become an important corridor for freight vehicles.

ITS Plans for Smart Highways in Shaanxi

The 2019 annual report of the Department of Transportation of Shaanxi Province pointed out that the construction of smart highways in Shaanxi Province should target the sharing of basic resources, the online collaboration of business management, and the data-driven support for decision-making. The key is to establish a driving path recognition system to achieve an accurate expressway billing system. Moreover, the application of cashless toll collection should be promoted.⁹⁹

⁹⁶ The Transport Department of Henan Province. Guiding Opinions on Promoting Smart Expressway Construction of the Transport Department of Henan Province.

⁹⁷ The Transport Department of Henan Province. Guiding on Construction Standards for Newly-built Expressways in Henan Province (Trial).

⁹⁸ Henan Province People’s Government. 5G Empowers Smart Expressway Construction in Henan Province. Retrieved from: <http://www.henan.gov.cn/2020/08-14/1755024.html> (last accessed in March 2021).

⁹⁹ See: 2020 Annual Report on the Work in Transport of Shaanxi Province.

The 2020 annual report of the Department of Transportation of Shaanxi Province highlighted the acceleration of smart transportation. The report pointed out that it is necessary to accelerate the development of smart transportation and to integrate new concepts in construction, maintenance, management, and other business areas.¹⁰⁰

The southern section of the Outer Ring Expressway of Xi'an is an important part of the expressway network planning in Shaanxi Province. It is constructed following the two-way six-lane high-speed standard, with a design speed of 120 km/h and a roadbed width of 34.5m. The entire section of the highway provides high-definition voice and support for VoLTE, high-speed data traffic, and other communication services. In the service areas and toll stations along the highway, a smart information network with a "5G+Wi-Fi" model will be built. It allows the highway users to enjoy free broadband services while resting in the service area, thereby improving the highway service levels and reputation. A smart high-speed operation management and service platform will be built based on the "Internet of Things + 5G + high-speed operation management + public travel information service" system structure to provide more accurate, efficient, and convenient services.¹⁰¹

The first smart toll station in Shaanxi Province, the Qinhan Toll Station of the Xi'an Xianyang International Airport Special Expressway, has been commissioned since December 2018. It has realised automatic toll collection and services through automatic payment (ETC) or self-service payment methods. This marks the official inauguration of the first "smart toll station" in Shaanxi Province.

The statistics show that, since the completion of the Qinhan toll station, the operating cost has been reduced by 28.6%, compared with the traditional toll station. The traffic efficiency has increased by 26%, and the payment transaction time has been shortened from 10 seconds to 7 seconds, which provides a more convenient and efficient travel experience. The construction of the smart toll stations is an important attempt to achieve the goal of a smart highway in Shaanxi Province.

Although a series of expressway maintenance and management information systems have been established in Shaanxi Province, they are still operating independently without an overall design. Comparing with the more developed provinces, hardware facilities are obsolete, and the upgrade of hardware is not timely. Therefore, the current level of highway maintenance management in Shaanxi Province is still low.

ITS Plans for Smart Highways in Gansu

On May 7, 2020, the work plan for smart transportation construction was issued by the Department of Transportation of Gansu Province, which proposed the development goals of the construction of intelligent transportation systems. In terms of the plan of the smart highway, the plan pointed out that, the construction of several smart highway pilot projects should be completed by 2022. By 2035, a safe, efficient, and environmentally friendly transportation system based on effective vehicle-road coordination should be built.¹⁰²

¹⁰⁰ Highway Bureau of Shaanxi Province. The Highway Bureau of Shaanxi Province Held the Symposium of Smart Expressway Construction. Retrieved from: <https://www.sxsglj.cn/content.aspx?id=222363176562> (last accessed in March 2021).

¹⁰¹ Zhao, X. "5G+Sharing" for the First Smart Expressway of Shaanxi: Exploration and Experience of ITS Solutions from China Tower of Shaanxi. 2017 National Conference on Wireless & Mobile Communication.

¹⁰² The Transport Department of Gansu Province. The Notice on the Announcement of the Working Planning of Smart Expressway in Gansu Province.

In recent years, the construction of transportation infrastructure in Gansu Province has largely developed. The level of transportation management and operation has also made considerable progress. The Smart Expressway Traffic Dispatching Centre has been established in Gansu Province, integrating road network monitoring, emergency rescue, and tunnel monitoring.

The construction of a smart expressway in Gansu uses information technologies such as GPS positioning and GIS. The meteorological service information system has been improved focusing on weather monitoring, warning, and forecasting along the highway. The real-time road condition data analysis platform based on big data and cloud computing has been built. A new live broadcast system for highway condition monitoring has been finished, realizing information via mobile APP, website, WeChat, SMS, real-time traffic information board, LED guide signs, etc.¹⁰³

On October 14, 2019, the Gansu Highway Construction Group and Airways Automobile Co., Ltd. jointly built an automated driving test demonstration area on the expressway from Liangdang to Hui County, to carry out automated driving pilot operations and vehicle-road collaborative tests. This is the first smart highway demonstration area in Gansu Province.¹⁰⁴

ITS Plans for Smart Highways in Xinjiang

At present, the construction of a smart expressway in Xinjiang is still in the preliminary development planning stage. The relevant policies are still being explored. The digitalisation and informatisation of smart highways in Xinjiang still have a long way to go.

3.1.3. Representative Smart Highway Pilot Projects

Smart highway pilot projects in S342 highway, Jiangsu

The S342 highway in Jiangsu Province is one of the trunk highways in Jiangsu. It passes through Wuxi, Changzhou, and Yixing to the west, and finally ends at the junction of Yixing and Guangde, Anhui. It is an important intercity highway in southern Jiangsu.

The S342 smart highway has implemented the latest 5G technology. At present, 60% of the demonstration highway sections have been covered by 5G signals. The highway uses cameras and radar to detect abnormal traffic conditions such as car accidents, congestion, etc. When abnormal road conditions occur, it can automatically alarm and automatically capture real-time pictures for emergency handling. In addition, 10 service scenarios such as vehicle speed guidance, vehicle confluence, pedestrian avoidance, abnormal road conditions, and road congestion can be provided through the mobile phone app. The construction of the project started in May 2018 and was completed by the end of 2020.

Autonomous truck platooning in Donghai Bridge, Shanghai

The Donghai Bridge (Figure 4) is a 32,500 metres long cross-sea bridge connecting Nanhui New Town, Shanghai, and Yangshan Town, Zhejiang Province in China. It is one of the key supporting projects of the Yangshan Port.

¹⁰³ The Transport Department of Gansu Province. Gansu Enters the Era of “Smart Expressway”. Lanzhou Morning Post. Retrieved from: <http://jtys.gansu.gov.cn/mtkjt/14180.html> (last accessed in March 2021).

¹⁰⁴ The Transport Department of Gansu Province. The Liangdang-Hui County Expressway Initiates the New “Smart Highway” Mode.



Figure 4. Donghai Bridge.

In May 2019, TuSimple completed the system development of high-speed Cooperative Adaptive Cruise Control (CACC) technology, which can achieve a stable distance of 12 meters between more than 3 trucks at a speed of 70 to 80 km/h.

As of June 2019, the construction of the test area for intelligent connected vehicles has been completed. The area includes several functional areas such as straight roads, tunnels, and rainfall simulation.

The construction of the data centre has been completed with real-time vehicle status monitoring. The preliminary planning for the V2X vehicle-road collaboration system has also been completed. At present, the automated self-driving trucks can run with other human-driven vehicles with a speed limit of 80 km/h on the Donghai Bridge.

3.1.4. Availability of Smart Infrastructure

The BeiDou Navigation Satellite System

Transportation is one of the main areas for implementing the BeiDou Navigation Satellite System. By the end of 2020, there were about 7 million business vehicles in China that have been equipped with BeiDou devices. The world's largest dynamic monitoring system for business vehicles has been built. The BeiDou system is also applied in the construction and management of railway transportation, inland waterway shipping, ocean navigation, air transportation, etc. Since the application of the BeiDou system, the number of major road transport accidents in China has reduced by nearly 50%.

Integrating the BeiDou system with the real-time kinematic positioning (RTK) technology, the precision of static positioning can reach millimetre level, and that of the dynamic positioning can reach centimetre level. The effectiveness of positioning is not affected by the weather, regardless of rain, snow, or haze. The system can also work normally in special scenes such as deserts and grasslands. In addition, the integration of the BeiDou navigation system with high-definition maps can provide intelligent driving assistance services such as reminders on sharp turns, ramps, intersections, and blind spots.

The high-precision positioning technology of BeiDou provides differential calculation and data management services based on high-definition maps. It can offer useful services such as map browsing, routing planning, data management, location information, etc. The high-precision positioning technology with high-precision positioning and lane-level route planning can provide digital maps for intelligent connected vehicles for more stable and reliable positioning services.

The 5G technology

The 5G-based intelligent transportation infrastructure includes but is not limited to the following systems:

(1) High-definition positioning platform, including a series of modules such as high-definition integrated positioning module, data calculation module, etc. to improve the positioning accuracy and reliability, which can support high-definition positioning in all transportation scenes.¹⁰⁵

(2) Ubiquitously new-generation communication infrastructure, which can leverage the advantages of 5G and high-definition positioning resources. It can promote the integration of new technologies such as 5G, artificial intelligence, cloud computing, big data, and edge computing in transportation constructions.

As of the end of September 2020, more than 690,000 5G base stations have been built and opened in China, which is more than 70% of the global total. The 5G network has covered the urban areas of Beijing, Shanghai, Guangzhou, Hangzhou, and other cities.

Autonomous driving is inseparable from vehicle communications and the CVIS. To realise the CVIS, both vehicles and infrastructures should be intellectualised. This requires the full usage of advanced technologies such as 5G, edge computing, and V2X. In addition, more sensors should be constructed on the road to perceive complex traffic conditions, so that the traffic information can be communicated in real-time.¹⁰⁶

The 5G technology is also planned to be implemented in smart highways. An integrated smart highway communication network, including the 5G network, high-definition positioning network, and CVIS communication network, is planned to be constructed to support the operation of the smart highways. The core of the integrated smart highway communication network is the CVIS communication network, integrating the four essential elements (i.e. people, vehicles, roads, and networks) in the transportation systems. With the CVIS communication network, a series of smart highway services can be implemented such as the warning of highway safety risks, the management of roadside facilities, the monitoring of bridge and tunnel slope, the intelligent service in highway service areas, the platooning of automated driving, and the test of CVIS-based automated driving.

3.1.5. Usage of Highly and Fully Autonomous Vehicles

In the 14th Five-Year Plan, China stated that a standardised policy environment should be created to regulate autonomous vehicles and intelligent logistics, and the related laws, regulations, and ethical review rules should also be improved.

In addition to the 14th Five-Year Plan, the “Outline for the Construction of Nation with a Strong Transportation System” has also suggested strengthening the study and development of intelligent connected vehicles (including intelligent vehicles, autonomous driving, and vehicle-infrastructure cooperation) to form an independent and controllable industrial chain. The outline also suggested promoting new equipment and facilities such as intelligent roads, digital pipe networks, intelligent warehousing and sorting, and the new generation of intelligent traffic management systems.

To promote the development and implementation of autonomous driving technologies, the Ministry of Transport of China issued the “Guiding Opinions of the Ministry of Transport on Promoting the Development and Application of Road Traffic Autonomous Driving Technology” on December 20, 2020.

¹⁰⁵ The Ministry of Transport of the People’s Republic of China. Guiding Opinions of the Ministry of Transport on CMCC Developing 5G Intelligent Transport Infrastructure for the Construction of Nation with a Strong Transportation System.

¹⁰⁶ CCID Group. The White Paper of Fusion Application of 5G. China Info World. 2021-02-01(008).

The guiding opinions clarified the goals for the development of autonomous driving technologies, including, by 2025, (1) positive progress shall be achieved in the research on the basic theory of autonomous driving; (2) important breakthroughs shall be made in key technologies and products such as intelligent road infrastructure and vehicle-infrastructure cooperation; (3) a series of basic and key standards for autonomous driving shall be issued; and (4) several national-level autonomous driving testbeds and pilot demonstration projects shall be established to promote the large-scale applications and industrialisation of autonomous driving technology.

The guiding opinions also offered the main tasks related to the development of autonomous driving technology. First, it is necessary to speed up the research on key technologies such as multisensory perception, vehicle to infrastructure communication, high-definition space-time services, intelligent roadside systems, cloud computing platforms, and network security. Second, theoretical studies on autonomous driving and vehicle-infrastructure cooperation should be carried out to improve the autonomous vehicle testing and evaluation methodology framework and the management system.

Presently, over 300 cities and regions are undergoing smart city planning in China. A total of 586 cities have built up intelligent centres of public security and traffic, among which 325 cities have set up intelligent dispatching platforms that are based on geographical information systems, 467 cities have implemented network control of traffic signals. There are 95,000 video monitoring nodes in China (including 25,000 highway monitoring nodes), among which there are 57,000 high-definition video monitoring nodes. Meanwhile, 280 cities feature a traffic video monitor platform.¹⁰⁷

In terms of the autonomous driving technologies for freight transport, which are important for the AH route 9, the guiding opinions also emphasised the support for the development of autonomous driving for freight transport services. The demonstration of autonomous driving for freight transport is encouraged based on the needs of freight operations under the premises of enough risk assessment and emergency response plans, to establish a safe and efficient intelligent freight transport service.

The National Strategy of China for Innovation and Development of Intelligent Vehicles provides for the following main goals:

- By 2020 - intelligent vehicles will account for 50% of new cars in China; - commercialisation of middle and high-level intelligent vehicles will have been achieved; - 90% of the expressway and big city roadways have been covered with wireless telecommunication networks for vehicles;
- By 2025 - almost 100% of new vehicles will be intelligent vehicles; - scalable high-level intelligent vehicles will be on the market; - new generation wireless telecommunications network for vehicles (5G - V2X) will meet the needs to allow for the development of intelligent vehicles;
- By 2035 - Chinese standard intelligent vehicles will earn a global reputation and China becomes a powerhouse of intelligent vehicles.

Representative Autonomous Driving Companies

In China, many companies are researching autonomous driving. The typical domestic ones are Baidu Apollo, Xpeng, NIO and Li Auto.

¹⁰⁷ UN ESCAP, Bangkok, 2017 – “Development of model Intelligent Transport Systems. Deployments for the Asian Highway network”, Paragraph 2.1.; China ITS-Country Study Report; China presentation; China Survey result. Mr. Xiaojing Wang, Director of China National ITS Centre, Chief Engineer of RION of Ministry of transport of China.

Baidu Apollo

Baidu Apollo itself cannot manufacture vehicles, however it has proposed a series of standardised interfaces for driverless systems and authorised automakers and vehicle providers to connect their systems to the Apollo open-source driverless operating platform, thereby covering a wider range of autonomous driving developers to accelerate the deployment of autonomous vehicles.



Figure 5. Baidu Apolong self-driving minibus.

In 2017, a mass production of Apollo bus with Level-4 vehicle automation began. The bus, manufactured by a consortium consisting of Baidu, Kinglong, and SB Drive, does not have a steering wheel, accelerator, or brake, and can operate at a speed of 20 to 40 km/h. It can capture and predict the movements of pedestrians and vehicles in its vicinity.

NIO and Li Auto

The automated driver-assistance system from NIO, the NIO Pilot, has two important functions, the Navigate on Pilot (NOP) and the Self-Automatic Parking Assist with Fusion (S-APA with Fusion). The NOP system integrates the navigation system with the NIO Pilot driver-assistance function, which allows the vehicle to automatically overtake, merge and cruise under certain traffic conditions according to the planned route. The S-APA with Fusion system combines the surround-view camera and the ultrasonic radar to accurately perceive the surrounding environment. For instance, the automated parking module can be activated through the NOMI system by voice, which supports the recognition of parking spaces, the recognition of multiple consecutive idle parking spaces, and the selection of parking spaces.

The Li Xiang ONE series from Li Auto also incorporated the automated driver-assistance system, relying on its Mobileye EyeQ4 visual recognition chips, intelligent front-view camera, millimetre-wave radar, 12 ultrasonic sensors, and 4 surround-view cameras.

The vehicles produced by NIO and Li Auto currently do not have the capabilities for fully autonomous driving. Their automated driver-assistance systems can be considered as Level-2 vehicle automation.

Xpeng

The Xpeng P7, with the Navigation Guided Pilot (NGP) functions, supports Level-3 vehicle automation. The NGP technology from Xpeng incorporates high-definition maps covering most highways and some urban expressways in China, collected with AutoNavi software. With the high-definition maps, the driver-assistance system from Xpeng is more suitable to the complex traffic environment in China, comparing with the autopilot technology from Tesla that entirely relies on computer visions.



Figure 6. Xpeng P7 electric car.

The NGP-based driver-assistance system has the Adaptive Cruise Control (ACC), Adaptive Turning Cruise (ATC), Lane Centring Control (LCC), and Automatic Lane Change (ALC) features, which supports the Xpeng vehicles to automatically drive from point A to point B based on the navigation route set by the user. In addition, the NGP technologies also support the Valet Parking Assist (VPA), which can learn from commonly used parking spaces and driving routes from the users to fulfil the valet parking services.

Tesla Autopilot

Tesla is one of the pioneer companies making self-driving vehicles. The Tesla Giga Shanghai is the first non-US factory, assembling Tesla Model 3 and Model Y. The Tesla Autopilot ADAS corresponds to the Level 2 vehicle automation. The system contains a set of features such as lane centring control, traffic-aware cruise control, self-parking, automatic lane changes, semi-autonomous navigation on limited-access freeways, and the ability to summon the car from a garage or parking spot.



Figure 7. Tesla Model Y autopilot car.

Since the self-driving features from Tesla Autopilot purely rely on cameras and radars, the autonomous driving performance may not be as good as Xpeng equipped with high-definition maps. However, on-road sections without high-definition maps, it is difficult to judge if the autonomous driving capacities from Xpeng would outperform Tesla.

3.1.6. Social Acceptance of HFAV

As China is the largest automobile consumer market, lots of researchers have conducted surveys and analyses on the acceptance of autonomous vehicles in China. The results show that overall, the people in China have a high degree of acceptance of autonomous vehicles. Specifically, the social acceptance of autonomous vehicles in China can be discussed from the following standpoints:

(1) The attitude towards autonomous vehicles

Many studies show that the majority of the public has a positive attitude towards autonomous vehicles. In 2018, Nordhoff surveyed 7755 interviewers in 116 countries around the world, and 81.7% of the interviewers had a positive attitude towards autonomous vehicles. According to the survey results from the Continental Group, people in China, in general, have a higher acceptance rate of autonomous vehicles than Germany and the United States. For instance, when responding to the statement that “autonomous driving is wise progress”, 53% of the respondents in Germany and 50% in the U.S. agreed. In China, 89% of the interviewees stated that they would support the technology. The deputy director of the State Information Centre of China, Xu Changming, believes that the high acceptance of autonomous vehicles in China is largely due to the rapid development of the digital economy.

The majority of Chinese unicorns are related to big data, cloud computing, and artificial intelligence, which are more highly related to autonomous driving technologies.¹⁰⁸

(2) The trust in autonomous vehicles

Studies have shown that the public is familiar with the concept of autonomous driving. They have a certain degree of understanding of the functions of autonomous vehicles. According to the “Autonomous Driving Tendency Survey for Chinese Consumer” released by JD Power in 2017, Chinese consumers have a high degree of trust in autonomous driving technology, but they also have strong concerns about the lack of laws and regulations. The study shows that 10% and 68% of Chinese consumers, respectively, said they “wilfully trust” and “may trust” fully automated driving technology. Such a high level of trust is evenly distributed among consumers of all ages. Only 4% of consumers responded that they “completely distrust” the fully autonomous driving technology.

(3) The focuses on autonomous vehicles

A study by Yang et al. in 2017 interviewed 238 people in China. The interviewees generally believed that autonomous vehicles can effectively reduce the number of traffic accidents and can respond more sensitively in special emergencies. However, they also expressed concerns about the ability of the autonomous driving system to deal with accidents, legal liability, and privacy. Among these concerns, the safety issue places the first.¹⁰⁹

(4) The willingness to pay for autonomous vehicles

In general, a great number of people in China are willing to pay extra for the new autonomous driving features. At the 7th China-South Korea Automotive Industry Development Seminar, Xu Changming, the deputy director of the State Information Centre, stated that Chinese consumers are more willing to pay for autonomous driving. In terms of costs, Chinese consumers are willing to pay \$4,600 for autonomous driving. However, the number in Germany is \$2900, and in the United States is \$3900.

Thus, autonomous vehicles could, at some point, take over most of the automotive market in China. For instance, industry respondents to a McKinsey survey indicate that passenger vehicles used for mobility services such as “Robo-taxis” will see a peak adoption rate of 62%, followed by private premium vehicles (51%) and private mass-market cars (38%). This “mobility-as-a-service” (MaaS) transformation suggests dramatic changes ahead for vehicle sales volumes, business models, and the capabilities companies will need to thrive in this new environment. In China, fully autonomous vehicles (SAE Level 4 and above) will see mass deployment in nine or ten years.¹¹⁰

3.1.7. Legal and Regulatory Framework

The legislative framework of autonomous vehicles in China has developed rapidly in recent years. The Chinese government has successively issued the “Intelligent Connected Vehicle Technology Development Roadmap of China”, the “Mid-term and Long-term Development Plan for the Automobile Industry”, and the “Guideline for Developing National Internet of Vehicles Industry Standard System (Intelligent & Connected Vehicle)”. The autonomous vehicle industry has been listed as one of the seven major industries that the Chinese government would support.

¹⁰⁸ Nordhoff S, D E Winter J C F, Kyriakidis M, et al. Acceptance of driverless vehicles: results from a large cross-national questionnaire study. *Journal of Advanced Transportation*, 2018, 2018: 5382192.

¹⁰⁹ Yang, J., Shen, M. Investigation of consumer market acceptance of automated vehicles in China. *Journal of Chang’an University (Social Science Edition)*. 2017,19(6):34-42.

¹¹⁰ Source: <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-china-will-help-fuel-the-revolution-in-autonomous-vehicles#> (last accessed in March 2021).

Nevertheless, given the current conditions in the development of transportation technologies, the legislation related to autonomous driving in China is very cautious, mainly involving the open road test of autonomous vehicles. In addition, the current level of laws and regulations is relatively low. Only some regulatory documents and national standards have been initiated as the policy guidelines.

For example, in December 2017, the Beijing Municipal Commission of Transportation issued the “Guiding Opinions on Promoting the Autonomous Vehicle Road Testing of Beijing” and the “Rules for the Management of Autonomous Vehicle Road Testing of Beijing”. These documents stipulated the implementation conditions, vehicle requirements, and driving requirements of the autonomous vehicle road test. In April 2018, the Ministry of Industry and Information Technology, the Ministry of Public Security, and the Ministry of Transport jointly issued the “National Administrative Rules of Road Testing of Self-Driving Vehicles”, which stipulates the requirements for test subjects, test vehicles, license applications, and traffic regulations. In addition, other cities including Shanghai, Tianjin, Chongqing, and Shenzhen also have successively issued the local management regulations for the autonomous vehicle road test. Although the above-mentioned rules and regulations are different in some details, they generally pay attention to the responsibilities involved in the road test of autonomous vehicles like the application process of road test and accident handling.

At present, the laws and regulations related to autonomous vehicles have not been systematically established yet. However, they have already greatly contributed to the development of the autonomous vehicle industry. According to the “Strategies for the Innovative Development of Intelligent Vehicles” jointly released by the National Development and Reform Commission and 11 other ministries in 2020, the domestic laws and regulations will be gradually introduced closer to 2025. It is expected that by 2025, autonomous driving-related technologies, industries, infrastructure, regulations and standards, product supervision, and network security systems will be further regulated.¹¹¹

Compared with the development of autonomous driving technologies, the legislative progress in China is slightly lagging. Current regulations that have been issued are mainly the autonomous vehicle road test specifications and industry standards with low levels of regulations. There is still no substantial progress in the revision of the existing road traffic safety laws for autonomous vehicles which is suggested to be considered from the following aspects:

(1) The clarification of the legal concept of autonomous vehicles

The accurate definition of the legal concept of autonomous vehicles is an important prerequisite for the establishment of the legal system. The clarification of the difference between autonomous vehicles and traditional man-driven vehicles and the clarification of the legal scope of “autonomous vehicles” is of great significance to the formulation of relevant laws and regulations.

(2) The revision of current laws and regulations

It is necessary to support the road tests for autonomous vehicles. In addition, the road sections and environments for the road tests and the responsibilities of the autonomous vehicle manufacturers should be clarified. The autonomous vehicles provided for road testing must be checked for compliance with laws and regulations. The licenses can only be issued after the review has been completed and the vehicles must be operated along the routes designated by the public security departments.

¹¹¹ Wang, L., Wang, J. Research on Management and Legislative Protection of Autonomous Vehicles in China: Perspective of Roadway Traffic Safety Management. *Journal of Beijing Police College*. 2021(01):8-12.

(3) The regulation of liability determination

The laws and regulations should require that all autonomous vehicles must be equipped with vehicle data recorders (i.e. “black boxes”) to record the details of different stages to determine the responsibility for possible traffic accidents. If it is found that the accident was caused by automatic driving (or a system failure), the automakers should bear the associated responsibility. In addition, the differences between non-commercial autonomous vehicles and commercial autonomous vehicles should also be defined in the legislation.

(4) Preliminary legislation in the demonstration areas

A series of intelligent connected vehicle demonstration areas have been built in Shanghai, Chongqing, Suzhou, and Beijing to perform road tests of the autonomous vehicles. A variety of driving environments can be simulated in these demonstration areas, such as highways, urban roads, and suburban roads. The operating conditions of autonomous vehicles in the demonstration areas can be studied to support the formulation of relevant laws and regulations.

3.2. Kazakhstan

3.2.1. Technical and Operational Condition of the AH route 9

The Kazakhstan section of the AH route 9 runs from Khorgos at the eastern border with China to the cross-border point of Jaysan at the western border with the Russian Federation. The route crosses the territories of five oblasts (provinces): Aktyubinsk (591 km), Kyzylorda (810 km), Turkestan (294 km), Zhambyl (427 km), and Almaty (460 km), and bypasses the cities of Almaty and Shymkent.

In December 2017, the authorities of Kazakhstan announced the completion of the construction of their section of the AH route 9 from the Chinese border along the existing A-2 highway to the city of Shymkent and then along the M-32 and A-24 highways to connect with the Russian R-239 highway. Implementation of this massive road project took more than eight years with 2,452 km of roads reconstructed, 1,391 km upgraded to technical category I, and 1,061 km upgraded to category II¹¹². Under the guarantees of the government of Kazakhstan, the project involved over \$5 billion allocated by IBRD, ADB, IDB, EBRD and JICA.

The civil works under the project were mainly completed between 2009 and 2017 and presently are under the defect liability period. However, there are a few segments still not open to traffic due to works in progress, namely the construction of the 840 m tunnel and adjacent 39 km road section in Turkestan oblast as well as the upgrade of the Otar – Uzynagash section in Almaty oblast, both financed by IBRD.¹¹³

At policy level the implementation of the Western Europe – Western China Road Project was encompassed by the first five-year National Infrastructure Development Plan “Nurly Zhol” for 2015-2019¹¹⁴ which was prolonged in 2019 till 2025.¹¹⁵

The project has provided for widescale rehabilitation and upgrade over the whole length of the corridor which significantly improved the technical and operational condition of the road, optimised time in travel, reduced road user costs and enabled the deployment of tolling system on Almaty-Khorgos section with a view to extend it over the whole corridor by 2025. Particularly, over 1,500 km of the road has been upgraded to IA / IB technical categories (dual carriageway with 2 lanes in each direction) corresponding to “Highway” design standard.

At present the Government is considering 2 new projects within the AH route 9 to construct bypass roads for Shymkent (48 km) and Turkestan (30 km) with possible IBRD financing which will help to reduce time in travel for transit road traffic, minimise congestions, mitigate environmental impact and improve road safety situation in the cities of Shymkent and Turkestan. The total cost of the projects is estimated at 68 bn KZT (\$160 m) with planned implementation in 2021-2022.

An overview of key technical and operational parameters of each subsection is presented below.

¹¹² Source: ST RK 2025-2017. Public Motor Roads. Technical Classification. Retrieved from https://online.zakon.kz/Document/?doc_id=37965558 (last accessed in February 2021).

¹¹³ Source: South-West Roads: Western Europe-Western China International Transit Corridor (CAREC 1B & 6B) (P099270). The World Bank: Implementation Status & Results Report (2020). Retrieved from <http://documents.worldbank.org/curated/en/843771595278294346/Disclosable-Version-of-the-ISR-SOUTH-WEST-ROADS-WESTERN-EUROPE-WESTERN-CHINA-INTERNATIONAL-TRANSIT-CORRIDOR-CAREC-1B-6B-P099270-Sequence-No-24> (last accessed in February 2021).

¹¹⁴ See <https://adilet.zan.kz/rus/docs/P1800000470> (last accessed in February 2021).

¹¹⁵ See <https://adilet.zan.kz/rus/docs/P1900001055> (last accessed in February 2021).

Section 1: Jaysan – Aktobe

This 99-km section represents the west-most segment of the AH route 9 connecting Jaysan, a village at Kazakh-Russian border point (Figure 8), with the city of Aktobe (414k population), an administrative centre of Aktyubinsk oblast.



Figure 8. A queue at Jaysan border control point.¹¹⁶

This section runs over relatively flat terrain with one lane for traffic in each direction. It was upgraded with EBRD financing in 2013. It has asphalt concrete pavement reportedly in fair condition along the entire length, with 1 major intersection and 14 bridges of 856 linear meters length. The width of shoulders is 1 to 2 meters on each side. There are seven filling stations located along this road. Average annual daily traffic is rather moderate comprising around 9,000 of cars, 100 trucks and 25 trailers. Seven major traffic accidents were reported in 2019 including three fatal accidents.

Throughput capacity of Jaysan border control point is about 1,500 vehicles per day (up to 3,000 in summertime) with 4 lanes for traffic in each direction and 6 passport control points for drivers and passengers. Incidentally, this creates long queues at border controls with wait time up to several hours. It is therefore strongly advisable for the relevant authorities to upgrade the border controls and enhance their capacity in line with the growing volumes of cross-border traffic.

Section 2: Aktobe – Kyzylorda Oblast border

This section consists of 262 km of single lane and 215 km of dual lane asphalt concrete carriageway rehabilitated in 2005 and 2011 with the Government's financing. Presently it is reported to be in fair technical condition. The 262 km segment is in worse condition with plans to upgrade it under the National Infrastructure Development Plan to 2025 with the estimated project cost of 192 bn KZT (\$455 m). The road has 4 major intersections, 21 bridges (1,136 m length), 4 rest areas and 15 refuelling points. Adjusted AADT is 9,850 car units/day that corresponds to 70% of the designed capacity.

26 traffic accident and 6 fatalities were registered in 2019. After the upgrade of the II technical category segment into the I technical category this section will become a toll road whereas the existing I category segment may already become toll road before the end of 2021.

¹¹⁶ Source of image: https://express-k.kz/news/ekspertiza/chto_proiskhodit_na_pogranichnom_punkte_zhaysan_-131773

Section 3: Kyzylorda oblast border – Kyzylorda city

This 566-km long single lane road section was upgraded to II technical category in 2010-2015 with IBRD financing and rehabilitated in 2018-2019. The type of pavement is asphalt concrete, reportedly all in good technical condition, with soft shoulders on each side. There are 7 major intersections along the road. Within the borders of Kyzylorda oblast (which includes Section 4) there are 65 bridges of 3,909 m length. There are 32 rest areas and 11 refuelling points along this section. In 2019 the road authorities recorded 21 traffic accidents with 13 fatalities.

The adjusted AADT in this section is 25,140 car units/day which represents 180% of its designed capacity. Consequently, congestions may occur in peak season, as well as premature pavement deterioration from excessive traffic loads. It is advisable to consider this section for an upgrade to 2 lanes in each direction among the priority infrastructure projects of the Government.

Section 4: Kyzylorda city – Turkestan oblast border

This category I road section (2 lanes for traffic in each direction, >2 m shoulders on each side) of 246 km length was upgraded during 2010-2015 with IBRD financing and rehabilitated in 2018-2019. The width of asphalt concrete dual carriageway is over 14 meters (including >1 m median), being reportedly in good technical condition all over.

This section has 6 major intersections with secondary roads, 14 rest areas and 5 refuelling points. The adjusted AADT is 40,620 car units/day which is 145% of designed capacity which may limit substantially the speed of traffic and result in rapid deterioration of pavement. 20 road accidents (4 fatal) were recorded by road authorities in 2019.

Section 5: Turkestan oblast border – Shymkent

This category I road of 200 km length entirely runs over flat terrain. It has asphalt concrete (56 km) and cement concrete (144 km) pavements upgraded in 2011-2013 with EBRD and ADB financing, reported to be in good technical condition. It has dual carriage way (2 lanes in each direction) with >1 m median and hard shoulders >2 m all over. There are 40 bridges (2,106 m length), 5 rest areas and 21 refuelling points along the road. As many as 27 road accidents (15 fatal) were reported in 2019. Adjusted AADT is 26,191 cars/day approaching the designed capacity level (94%). According to MIID this section will become a toll road before the end of 2021.

Section 6: Shymkent – Taraz (excluding bypasses)

This category I road (2 lanes in each direction) connects one of three biggest cities, Shymkent (1.1 m habitants), with the administrative centre of Zhambyl oblast, the city of Taraz (360 k habitants). The section was partially upgraded to the first technical category in 2014-2015 with EBRD and ADB financing and reported good technical condition as of 2020. A 14 km part of the section passes through hilly terrain which had necessitated the construction of 840-m long tunnel in Turkestan oblast (works ongoing with IBRD financing since 2014, bypass roads used by traffic, expected commissioning – end of 2021).¹¹⁷

¹¹⁷ This mountainous tunnel is the first and the only project of a kind in the country – due to complexity of design and civil works the initial project completion has been extended by about 5 years, partially due to collapse of the tunnel in 2019.

About half of this section has cement concrete pavement designed for higher axle loads and traffic volumes. There are 13 bridges (443 m long), 3 rest areas and 7 refuelling points available along this section. In 2019 ten accidents were reported (2 fatal).

The adjusted AADT is 12,190 cars/day which represents only 44% of the designed throughput capacity. MIID is planning to deploy a tolling system along this section in 2021 once the tunnel is commissioned.



Figure 9. Construction of road tunnel in Turkestan oblast.¹¹⁸

Section 7: Taraz – Almaty

Following the upgrade of this 450-km long road to category I, a new direct link was created between Taraz, the administrative centre of Zhambyl oblast, and Almaty, the biggest city and former capital of the country (2m+ habitants), bypassing the territory of neighbouring Kyrgyzstan and reducing the distance between the two settlements by about 50 km by building a new a 24-km mountain pass. The road has asphalt concrete (82 km) and cement concrete (368 km) types of dual carriageway (2 lanes in each direction) with a median, all reported to be in good technical condition. There are 23 bridges (1,380 m) and 14 refuelling points (no rest areas were yet available). The project was financed by IDB and ADB and was implemented between 2011 and 2015. Adjusted AADT is 11,854 car units/day corresponding to 42% of designed capacity. Due to complex road profile along with severe weather conditions of the mountainous pass this section ranks 1st in the AH route 9 by the number of road accidents (65) and fatalities (30).

In order to improve the traffic safety situation, it is highly recommendable for the road authorities to consider the deployment of surface condition monitoring and weather information systems for road users on this section as a priority, possibly under the MIID ITS deployment plan to 2025.

Section 8: Almaty – Khorgos

This 295 km¹¹⁹ length road was upgraded to technical category I with cement concrete dual carriage way in 2015-2018 under IBRD project that also financed the deployment of tolling system in 2019. Presently this road is the only toll road with the AH route 9. As it provides a cross-border link with China, it is being used intensely by heavy freight traffic nearly 24/7 (up to 400 trucks per hour were reported by the road authorities in 2020). The technical condition of the road is good. It has 12 major

¹¹⁸ Source of image (November 2020): <https://otyrrar.kz/2020/11/edinstvennyj-v-kazahstane-tonnel-nakonets-to-dostroyat/> (last accessed on 22 February 2021).

¹¹⁹ There is an alternative route Almaty-Khorgos of 306 km length which is not considered under the Study.

intersections, 55 bridges (800 m length) including a new bridge across Ili river built in 2018, 1 rest area and 3 refuelling points which is by far not enough to meet the demand generated by about 15,000 trucks and trailers traversing this section daily.

The capacity of the toll gates (Figure 10) is believed to be sufficient to cope with the flow of cross-border traffic, however according to media reports it may take a truck driver from several days to months to pass the border control point (designed capacity 5,000 vehicles per day) due to physical and bureaucratic constraints.¹²⁰



Figure 10. Toll gates at Nur Joly entry point at Kazakhstan-Chinese border.

AADT is 32,129 car units per day that corresponds to 115% of the designed capacity. The 2019 records show 28 traffic accidents (5 fatal). Due to high altitude above sea level the road is often closed in the wintertime because of low visibility and glazing. Frequent traffic congestions are reported in the vicinity of the Almaty bypass road. These factors may impact the operation of HFAV and need a thorough trip planning, special equipment and vehicle winterisation.

Based on the analysis of available technical condition data of the road, as well as associated infrastructure and roadside facilities, there may be concluded that the current state of physical infrastructure of the AH route 9 within Kazakhstan may only allow operation of HFAV with low levels of automation and under the supervision of an onboard operator.

Roadside Facilities

In compliance with the National Standard of Kazakhstan¹²¹, depending on available infrastructure and services the roadside facilities are classified into four categories from A to D, where “A” corresponds to the highest standard of service and “D” corresponds to the lowest standard. The availability of roadside facilities along the AH route 9 and their respective categories are show in Table 3 below:

¹²⁰ Source: <https://eurasianet.org/kazakhstan-it-system-at-china-border-increases-corruption-and-lines> (last accessed in February 2021).

¹²¹ National Standard of Kazakhstan. ST RK 2476-2014. Public Motor Roads. Requirements for Roadside Facilities and Their Services. https://online.zakon.kz/Document/?doc_id=37782982 (last accessed in February 2021).

Table 3. Availability of Roadside Facilities Along the AH route 9.

Category	Available Services and Infrastructure	Recommended Spacing, km	Recommended Placement and Area	No. of Facilities on the AH route 9	
				Compliant	Non-compliant
A	Refuelling, motel, indoor WC, bathroom, retail, canteen, car maintenance, car washing, guarded parking, cash dispenser, POS terminal, picnic area, medical aid, warming room, tourist office, playground, baby care room, laundry wash, trade and entertainment.	150 - 240	Interleaved, > 7 ha	6	1
B	Same as A, except ATM machine, POS terminal, tourist office, trade and entertainment.	80 - 120	Interleaved, 5 to 7 ha	18	3
C	Indoor WC, retail, canteen, picnic area, warming room	20 - 60	Interleaved, up to 3 ha	62	32
D	Refuelling, indoor WC, retail, warming room	40 - 50	Both sides, up to 2 ha	65	41
Total number of roadside facilities along the AH route 9			228	151	77

Table 1. Roadside facilities along the AH route 9 and their classification per the National Standard.

Category A represents multipurpose roadside facilities (see Figure 11, for example) capable to provide the road users with diverse and high-standard services. Category B facilities offer limited services still adequate for a comfortable rest at stops throughout the journey, whereas C and D are rather “just-enough” for the basic needs of travellers such as warming in wintertime, indoor WC, refuelling and snacks.



Figure 11. Sample design of “A” category road facility.¹²²

As of January 2021, out of 228 road facilities along the AH route 9, 151 were found to be compliant with the National Standard by KazAvtoJol JSC.

The latter has reported that the remaining facilities would be brought in compliance with the Standard by the end of 2025. In order to facilitate the development of road facilities an agreement has been made between the national operator KazAvtoJol JSC and Baiterek Holding which provides for grace loan financing through five commercial banks of Kazakhstan with main conditions being: (i) one

¹²² Source of image: <https://www.zakon.kz/4982174-v-zko-razvivayut-kachestvennyy.html>

billion KZT max project cost (\$2.4 million); (ii) max credit term of 10 years; and (iii) annual interest rate of 8%. This measure may help to boost the development of the roadside facilities in the country and make the quality of service suitable for international carriers.

Road maintenance

The Aktobe-Almaty segment of the AH route 9 is maintained by Kazakhautodor whereas the maintenance of the Almaty-Khorgos toll road is performed by the Directorate of Toll Roads under KazAvtoJol JSC.

In 2020 the budget allocation for the maintenance of the AH route 9 totalled around 6.2 bn KZT (\$15 m), where about 500 m KZT (\$1.2 m) was the financing of Almaty-Khorgos section. Notably, the volume of financing for maintenance works on toll roads in the country is determined solely based on the amounts of charges collected. MIID believes that the deployment of tolling system over all international highways (11,000 km by 2024) will allow to maintain them through performance-based contracts to be introduced in lieu of the existing price-per-quantity model.

Due to harsh climatic conditions prevailing in the territory of Kazakhstan, winter maintenance is considered one of most critical activities to keep the roads open to traffic all year round. Severe winters with heavy snowstorms and temperatures ranging from -50°C to +50°C often create problems for freight long-haul vehicles in central and north-west parts of the country. Due to extreme weather conditions the roads are often closed during the wintertime at instant notices that makes it difficult to plan trips so that to avoid blockages which may last from several hours to several days.¹²³ During such emergency stops an unmanned vehicle may be exposed to an increased risk of theft or vandalism. From HFAV operation standpoint such environmental conditions may become a serious limiting factor requiring a thorough trip planning, special safety and security equipment and vehicle winterisation.

3.2.2. National and Regional Policy Initiatives

The Study has revealed several policy initiatives undertaken by Kazakhstan to support the future development of HFAV-related technologies at country level. Also, the country is an active member of several policy initiatives in the field of HFAV at regional level under the aegis of CIS, the Eurasian Economic Union (EAEU) and its relevant bodies.

(1) The 2020 – 2025 National Infrastructure Development Programme “Nurly Zhol”

The National Infrastructure Development Programme of Kazakhstan to 2025¹²⁴ provides for execution of “studies and research on institutional and technological framework for the development and introduction of driverless technologies for road transport, railways and sea transport”. It also provides for “adaptation of the transport infrastructure to the operation of unmanned vehicles including the development and application of geoinformation and navigation systems and technologies”.

¹²³ According to Kazakhautodor, during the winter period of 2020-2021 over 500 vehicles were rescued from weather-related blockage on republican roads and over 1,500 people were placed at 132 warning points located throughout the country. There were 881 registered cases of partial or complete road closures due to snowstorms (658), glazing (78), mist (35) and snow avalanches.

¹²⁴ Approved by the Governmental Decree #1055 of 31 December 2019, <http://adilet.zan.kz/rus/docs/P1900001055> (last accessed in February 2021).

The action plan of the Programme however does not include any specific actions (nor the relevant budgetary allocation) in this regard other than an action for the Ministry of Industry and Infrastructure Development of Kazakhstan “to submit proposals to the Government of Kazakhstan for the development of legislative and regulatory framework for the operation of unmanned aircraft systems”. The other modes of transport have not been covered by the action plan of the Programme.

(2) ICT Priority Activities Roadmap

Action #12 of the ICT Priority Activities Road Map¹²⁵ provides for “design, development, introduction, support, modification and implementation of unmanned vehicle driving systems as well as systems and devices for satellite navigation, mobile communication and emergency transport service calls”. No information was found however about the current status of implementation of this action being under personal responsibility of the vice minister in charge.

(3) The 2013 – 2022 Development Strategy of National Highway Operator KazAvtoJol JSC

In outlining various aspects of regulatory framework, pricing and energy efficiency of road transport, the 2013-2022 Development Strategy of KazAvtoJol JSC¹²⁶ admits that the introduction of autonomous vehicles, along with the improvement of energy efficiency of the road transport, can create a positive effect for this sector.

At the same time, in discussing further the relevance of such global trends in the development of freight and passenger transport for Kazakhstan to year 2025, the document concludes that the introduction of driverless cars and autonomous trucks has yet insignificant relevance.

(4) The 2018 – 2020 EAEU Harmonised Transport Policy Implementation Roadmap

In 2017 the Eurasian Intergovernmental Council approved an action plan (road map) for 2018-2020¹²⁷ that provides for coordinated transport policy among the EAEU member countries. The document aims to reveal and remove the barriers for the international road transportation, improve the quality of transport services, strengthen transport links between Europe and Asia, develop innovations and promote digital transformation of the industry including the introduction of green technologies and unmanned vehicles.

Paragraph 20 of the Roadmap envisages “creating conditions for planning and conducting joint scientific research in order to develop and implement advanced transport technologies, intelligent transport systems, energy-saving and green technologies, including technologies that expand the use of alternative fuels and reduce the greenhouse gas emissions, high-speed transport systems, GPS / GLONASS satellite navigation systems, ICT for transport applications, unmanned vehicles and creating unmanned vehicle traffic zones.”

(5) The 2019 – 2024 Navigation Development Roadmap of CIS Countries

On 25 October 2019 the governments of CIS countries enacted the 2019 – 2024 Navigation Development Roadmap that has determined the minimum requirements for the availability (continuity) and precision of navigation data for the needs of road vehicles, including HFVAV.

¹²⁵ See “List of priority activities in the field of information and communication technologies” approved by the order of the Minister of Digital Development, Defense and Aerospace Industry of Kazakhstan #31/NK of 11 April 2019, in force until 1 January 2029, https://online.zakon.kz/Document/?doc_id=35280216#pos=5;-106&sel_link=1006883851_2 (last accessed in February 2021).

¹²⁶ Source: <http://adilet.zan.kz/rus/docs/P1300001409> (last accessed on 19 February 2021)

¹²⁷ Approved by the Decision of the Eurasian Intergovernmental Council # 3 of 25/10/2017. Link to official publication: <http://adilet.zan.kz/rus/docs/H17M0000003> (last accessed in February 2021).

The Roadmap recognises that highly and fully AVs may soon become operated broadly which will impose new qualitative requirements to associated navigation services. Such vehicles are believed to require an intense interaction with the road infrastructure, ITS and with each other, hence the system will need to ensure the usability of navigation data by the automated driving systems (ADS).

The document recommends the concerned ministries and bodies of CIS countries to exploit the Roadmap as a guidance in developing and modernizing their navigation systems in the medium term. Being the CIS member country, Kazakhstan has adopted the Roadmap for implementation.

(6) The 2018 – 2020 Action Plan of the Memorandum between the Eurasian Economic Committee and the International Congress of Industrialists and Entrepreneurs

The Action Plan was signed by the parties on 29 March 2016 and subsequently approved by the Order of the Eurasian Economic Commission No. 100 on 29 May 2018. It is notable that item 9 of the document has envisaged “formulation of propositions for the member countries to manufacture, in their respective territories, innovative vehicles, including electrically-driven and driverless vehicles”. With regards to Kazakhstan this initiative is partially covered by the ICT Priority Activities Roadmap referred to in the *National Policies and Programs* subsection above however no progress updates have been found during the Study.

As the above initiatives are rather fragmented, to become a full-fledged party in the emerging transition towards the use of autonomous vehicles, Kazakhstan has to boost and streamline its efforts by adopting the national roadmap and launching the development of the most essential regulatory documents to enable testing and subsequent commercial operation of HFAV, as well as the country’s integration into the future digital initiatives aiming to facilitate smart and green transportations between along the Europe – China road corridor.

3.2.3. Research and Development Initiatives

The Study has revealed only one project related to HFAV in Kazakhstan which was implemented by Nazarbayev University (NU) in the city of Nur-Sultan during 2018-2020.

The initiative was a joint research project of NU and VIST Group (the Russian Federation) in collaboration with KAMAZ automotive factory launched with the purpose to install ADS onboard a standard KAMAZ-5490 Neo truck and run field tests of the modernised vehicle in Kazakhstan.



Figure 12. Driverless truck built on the basis of KAMAZ-5490 Neo.

According to NU, the truck was equipped with lidars, radars and positioning systems manufactured by Continental, Quanergy and Trimble. System integration, programming and tuning have been performed by the programmers of VIST Group who also conducted dynamic tests of the truck at the Skolkovo testbed in the Russian Federation. This was the first phase of the project following which the truck was delivered to Kazakhstan and handed over to the NU research group who has equipped the vehicle with a computer vision system, enabling recognition of the road signs/markings and oncoming objects, and providing for automated routing and adaptive route alteration.

The study was rather a research / educational experiment since the vehicle was provided for 1 year only and was subsequently returned to the owner. The truck has not been tested on public roads and was not intended for commercial operation in Kazakhstan.

3.2.4. Usage of Highly and Fully Autonomous Vehicles

The Study has revealed that neither fully, nor highly automated vehicles have been designed, developed, tested, validated, or put in commercial operation in the country to date.

Realising that the adaptation of national infrastructure and technology, as well as creation of enabling regulatory environments for HFAV will soon become key factors to contribute to future competitiveness of transportation system as a whole, a risk exists that not considering this subject among the priorities of the national digital agenda may plunge the country into a technology gap of several decades, undermining its chances for success in the global competition for new markets. Therefore, creating enabling and encouraging environment by the government is essential to provide stakeholders with adequate incentive and momentum to succeed in this challenging journey to the future.

Along with adequate measures of state support, the growing turnover of international road freight may give new opportunities to road operators that could help them to develop their capacity for investing into robotic trucks. This, plus the induced demand for associated delivery services might generate significant additional traffic along the Kazakhstan segment of the AH route 9, thus substantiating and “capitalising” the future switch to driverless trucks. Engaging a “technology-oriented” mindset however is a first prerequisite to start the revolutionary jump into the future, where domestic carriers will become the main driving force for the introduction of driverless culture.

3.2.5. Current Status and Development Plans for Smart Infrastructure

Intelligent Transport Systems

Presently the scope of ITS elements available along the AH route 9 is limited to tolling system deployed on the Almaty-Khorgos section (295 km).

As part of the digitalisation of transport and logistics in Kazakhstan, a comprehensive ITS is being created by the Ministry of Industry and Infrastructural Development (MIID) that consists of eight subsystems divided into republican and regional levels. At the republican level, the ITS comprises four subsystems, as follows:

- An integrated subsystem covering road user charges collection on toll roads, traffic information and driver warning subsystems, which have already been deployed by KazAvtoJol on Nur-Sultan–Temirtau, Almaty–Kapchagay and Almaty–Khorgos (part of the AH route 9) highways length of 469 km.¹²⁸ Works are in progress to deploy toll collection facilities on 13 more sections (5,500km) of the republican highways with the introduction of 16 toll roads in total by 2023;
- The special automated measurement tool (SAMT) for weighing of vehicles in motion, monitoring of traffic intensity and electronic registration of travel permits. Twelve SAMT points were commissioned in 2018 with the planned increase to 46 points by 2021;
- The road assets management system that aims to optimise road expenses based on actual road condition data. Established in 2019, the National Centre for the Quality of Road Assets is the

¹²⁸ To operate the ITS, the national road operator, KazAvtoJol, deployed its own FOC routes along a major part of these three highways.

operator of this system. The economic effect of improved roadworks planning is estimated at \$290 million by 2025;

- The route adherence monitoring and dispatching subsystem that aims to improve road safety for both freight and passenger traffic. This subsystem is a private financial initiative.

At the regional level (which includes cities), the ITS will include four subsystems: photo and video recording, passenger transportation monitoring and e-ticketing subsystem, traffic management system, and parking management system.

the AH route 9 is considered one of priority roads for the deployment of the ITS elements, which will encompass the following areas: (i) introduction of tolling system on Almaty-Shymkent and Shymkent-Kyzylorda sections in 2021 and Aktobe-Jaysan section by 2025; (ii) installation of SAMT equipment along the whole corridor; (iii) launch of road user information services; and (iv) deployment of speed monitoring and traffic rules enforcement facilities.

In 2020 toll collection systems were additionally deployed on 5,800 km of roads (to be commissioned in 2021) with the establishment of 16 customer service centres and 2 data processing centres. By the end of 2024 it is planned to introduce tolling on 5,200 km of roads, thus by 2025 the total length of toll roads in the country will reach 11,000 km. The value of road user charges on toll section of the AH route 9 for trucks ranges from \$1.19 for light trucks (<2.5 t) to \$5.97 for heavy trucks (15-25 t) per 100 km of mileage.

Under the existing contract with a private investment company for the widescale deployment of tolling systems in the country, 63 new SAMT stations will be installed by the end of 2023, including 9 stations to be installed along the AH route 9. This will enable a smoother passage of trucks via the transport control and weighting points, minimise the impact of human factor, reduce the loss of time for weighting, enhance the transparency of axle load control and related legal enforcement. Overall, according to MIID, about 25 bn tenge (\$60 million) of private funds will be invested in the development of tolling systems and ITS in the country by 2025. Respective contract with the private investor was signed in 2020 covering 11 years concession period, whereupon the ownership of the system will be transferred to KazAvtoJol JSC.

It is expected that the implementation of the project will create 500 new jobs, enhance the competence of domestic companies in the field of ITS, ensure the adequate collection of funds for maintenance and preservation of roads as well as reduce the number of road accidents through the deployment of traffic speed control systems along the national road network.

The value of road user charges collectable on I category roads will be equivalent to those already introduced on other toll roads whereas no charges will apply to II and III category roads. It is planned that the tolling system will be based on wireless / gateless technologies with the integration of respective software into the existing tolling system of KazAvtoJol, already deployed along 682 km of roads in the country.

The creation of national ITS is among the 12 priority projects of the “Digital Kazakhstan” programme which sees the main task of the digitalisation of transport and logistics in increasing the volume of freight traffic through the country. It is expected that the reduction in transit time will significantly increase the volume of cargo in all directions from China through Kazakhstan to Europe, Turkey, and Iran. The main results will be obtained both through the transition to electronic document management and through the introduction of ITS, which will allow the increase of volume of cargo transport by providing high-quality and safe road infrastructure between the regions of Kazakhstan and international traffic. The intelligent system will combine the functions of video surveillance,

traffic management, driver notification of weather conditions, and electronic payment for transport services.

Developing advanced transport infrastructure based on ITS will also be a part of the implementation of the Smart City concept in Kazakhstan.¹²⁹ Smart City is an initiative to improve the efficiency of urban resources and services management and improve infrastructure through the introduction of innovative solutions to create a comfortable environment for citizens.¹³⁰ The “smartest” cities of Kazakhstan include Nur-Sultan in the first place, Almaty in second, and Uralsk in third, as reported by Tengrinews.kz regarding the press service of the Ministry of digital development, innovation, and the aerospace industry where the employees of the Ministry evaluated the work on digitalisation carried out by the regions. The study involved 14 regional centres and three cities of national significance. The assessment was based on the smart cities reference standard, which consists of 11 different areas and 80 indicators considering digital initiatives such as transport, telecommunication, and others.¹³¹

LTE, 3G and GSM coverage

The availability of high-speed wireless data transmission infrastructure along the AH route 9 is very limited:

- 5G coverage only exists in 1-2 pilot projects in the biggest cities;
- 4G coverage is only available within cities;
- 3G coverage is only available within urban areas and their close surroundings;
- GSM (2G) coverage is available on about 80% of the AH route 9;
- About 40% of Aktobe-Kyzylorda section does not have even GSM coverage.

As seen from the above, the present status of the coverage is not adequate to enable hi-speed connectivity required for the operation of HFAV and advanced ITS along the AH route 9.

To improve situation, the “Digital Silk Way” pillar of the above-mentioned Digital Kazakhstan Programme envisions the development of new generation mobile data infrastructure such as 4G (by 2023) and 5G (long-term plans) networks in each rayon centre¹³² of the country however this initiative by itself only will not be sufficient to address the coverage gaps to the HFAV operability standard.

Bringing the level of the communication infrastructure to the state enabling a fully functional high-speed data exchange will require significant investment and time. A dedicated feasibility study is recommended to assess the respective parameters.

As for 5G, at country level, Kazakhstan has become the first country in Central Asia to launch pilot 5G service in October 2019 as it rolled out the latest wireless technology in Shymkent, the third most populous city. 5G can offer 20 times faster data speeds than 4G long-term evolution (LTE)

¹²⁹ Analytical report of the Eurasian Economic Commission, "On the existing in the member States of the Eurasian Economic Union intelligent transport systems used in the field of road transport and road economy", Moscow, 2019, available at: <http://www.eurasiancommission.org> (last accessed in February 2021).

¹³⁰ Available at <https://egov.kz/cms/ru/smart-cities> (last accessed in February 2021).

¹³¹ Available at https://tengrinews.kz/kazakhstan_news/nazvanyi-samyie-umnyie-goroda-kazahstana-389334/ (last accessed in February 2021).

¹³² Rayon is an individual territorial unit within oblasts; rayon centres are settlements where rayon government's office is located (currently with population ranging from 7 to 200 thousand people).

networks and better support for artificial intelligence and virtual reality with low latency, giving impetus to the Kazakh government's plans.

The Government has further announced plans to launch the deployment of 5G network in all settlements populated above 50k, however at the initial stage of the project it will not be accessible by individual subscribers but designed for government and private institutions.¹³³

According to some experts¹³⁴, one of key obstacles for 5G deployment is the intense usage of dedicated frequency bands (3.4 – 3.8 GHz) by satellite communication facilities of military organisations. The bands of 4.8 – 4.99 GHz and 27.1 – 27.5 GHz, as proposed by the Government to the market, cannot be used due to unavailability of suitable commercial equipment (lower band) and very limited coverage (upper band).

While the overall positive momentum in the deployment of 5G is obviously present, there should be noted that neither the Government, nor the telecom operators have yet disclosed any plans to expand the 5G coverage along the public roads. It is therefore unlikely that within a mid-term 5G mobile services will be available for road users and autonomous vehicles outside, or too far away from the biggest and most populous cities of the country.

Fibre-optical cable lines

Since independence, over 12,500 km of fibre-optical cable (FOC) lines have been laid in Kazakhstan, mostly along existing roads and railways. This includes the construction of the National Information Superhighway by the semi state-owned telecom operator, Kazakhtelecom JSC. A few “digital bridges” were also put in place to connect Kazakhstan's FOC network with the ICT infrastructure of Kyrgyzstan, the Russian Federation, Uzbekistan and China. As a result of these efforts, the country's telecommunications network was fully digitised by the end of 2015.

Publicly open FOC maps¹³⁵ show that several telecom operators have their lines in parallel to the major part of the AH route 9 within Kazakhstan. There is a 400-km gap, however, between Aralsk and Karabutak where FOC infrastructure does not exist. In the absence of high-speed wireless data transmission, the deployment of FOC lines along the AH route 9 might be a very attractive solution requiring by far less investment and time to provide the users and the vehicles with stable broadband connectivity so essential, if not vital, for the operation of autonomous and connected vehicles in the future. To facilitate this process even further, it is strongly advisable for road authorities and telecom operators to consider co-deployment of the missing parts of FOC lines jointly during the execution of design and rehabilitation works on the concerned road sections.

Geolocation coverage (satellite and land-based)

The operation of HFAV requires a high-definition satellite-based positioning system, which should comprise mobile radio communication channel, reference base station network, network control centre, and a fibre-optic communication line. Ideally, the high-precision positioning system must enable collection, storage and processing of data retrieved from both satellite and ground-based

¹³³ Source: Caspian News, <https://caspiannews.com/news-detail/5g-network-goes-live-in-kazakhstan-2019-10-23-49/> (last accessed in February 2021).

¹³⁴ Yevstigneyev, I.A. (2019). Road Infrastructure and Highly Automated Vehicles. SAPR and GIS for Motor Roads. 2 (13), p. 44-50. DOI 10.17273/CADGIS.2019.2.7

¹³⁵ For example, see the ITU Interactive Terrestrial Transmission/ESCAP Asia-Pacific Information Superhighway Maps, available at <http://www.itu.int/itu-d/tnd-map-public/> (last accessed in February 2021).

stations to generate and transmit adjustment data to the users. The frequency and accuracy of real-time positioning should be designed to ensure an adequate operation and functionality of ADS.

The operability of cell towers and satellite communication channels for public and private users in the country is maintained by KazSat system which comprises two telecom satellites (KazSat-2 and KazSat-3). As the lifetime of KasSat-2 will expire in 2023, KasSat-2R satellite system will have been launched by that time.

Apart from the national satellite telecom infrastructure, the GPS-based geolocation systems are in active use in the country in such areas as geodesy and cartography, land surveys and setting out for civil works, as well as land, air and marine navigation. Normally, the precision and coverage of GPS are adequate for HFAV operation, however, to enable precise positioning the onboard equipment of the vehicles should ensure reliable and continuous reception of the data while moving at any speed within the permitted band. As for ground-based reference stations, no information was found during the Study about their availability along the AH route 9.

Digital road models

The purpose of digital road models is to provide HFAV with full situational awareness of the operating environment to ensure that ADS can deal with various road situations, manage and resolve potential traffic conflicts with other vehicles. The digital road model should normally include the following:

- large-scale maps of roads, road marking, lane centre lines, road signs and traffic lights;
- road polygon;
- dynamic traffic conditions data (obstructions, accidents, bad weather conditions, poor road surface etc.);
- roadside infrastructure and services;
- HFAV control commands layer;
- ITS interfacing subsystem.

Presently digital road models are not spread in Kazakhstan due to very limited fields of their application. The National Infrastructure Development Plan to 2025 envisions that digital terrain models will be put in place for use by the road construction machinery, however no progress has been reported so far towards the achievement of this objective.

Digital models for the AH route 9 do not exist and will have to be developed to enable the operation of HFAV in the future. While developing and introducing the digital dynamic maps, international telecommunication standards in the field of ITS should be considered as well as other relevant regulations at local and international levels.

3.2.6. Social Acceptance of HFAV

The Study has not revealed any dedicated surveys or researches to quantify the extent of potential user acceptance of the autonomous vehicles in the country. According to several stakeholders interviewed during the study, the use of HFAV in the country by commercial carriers is not presently seen as a realistic opportunity, at least for coming 7-10 years period. The idea by itself was perceived rather conservatively.

Several road transport experts and operators interviewed during the Study have been quite sceptic about potential interest of the industry in the introduction of driverless vehicles. The topic has definitely not been considered as “development priority” by road operators as well, who believe they must rather fight for markets with their current, man-driven trucks in the environment of “aggressive international competition”. This is understandable, given that in 2019 over 60% of international deliveries from/to Kazakhstan by road were performed by foreign carriers. As a contrary to domestic operators, an opinion was expressed by the head of innovation policy department of UNECE in 2018 that the capital of Kazakhstan might be one of the best places for testing the driverless vehicles.

3.2.7. Data Security and Privacy Concerns

In the Global Cybersecurity Index (GCI) of 2018, Kazakhstan ranked second among CIS countries with a good score in the legal pillar after having unified the requirements in the field of information and communication technologies and information security.¹³⁶ Globally, the country ranked 40 out of 175 countries in 2018 having improved by 42 positions compared to 2017.

The digitalisation initiative puts an increasing emphasis on an effective cybersecurity strategy: over the past three years Kazakhstan has conceptualised the development of cybersecurity through the adoption of the “Cyber Shield of Kazakhstan” concept that encompasses 336 critical objects for cybersecurity, as well as several legislative acts and a large number of ministerial orders. In addition, testing laboratories have been created for the study of malicious code and the international coordination centre for information security has been established. The number of scholarships has been increased to promote relevant education programmes among the students.¹³⁷

Protection of personal data in the country is regulated by “Personal Data and Data Protection Law” dated 21 May 2013¹³⁸ which provides for cornerstone definitions and sets forth the key principles for collection, processing and protection of personal data, including: (i) observance of constitutional human and civil rights and freedoms; (ii) legality; (iii) confidentiality of personal data of limited access; (iv) equality of rights of subjects, owners and operators; and (v) ensuring the security of an individual, society and the state. Being rather focused on national security issues, the law does not include any specific provisions regulating the use of automated or connected vehicles.

The EAEU technical regulations require mandatory certification of software and telecommunication equipment. Annually, the government actualises the register of national standards in the fields of data security, data protection and IT security that presently include 68 national and harmonised technical standards. As a conclusion, over the past few years Kazakhstan has created a strong legislative framework for ensuring data security and personal data protection, which may serve as a solid foundation for the development of more specific legislation, data infrastructure standards and user services related to the operation of HFAV in the country.

For safe and secure operation, HFAV in their turn must be reliably protected from electronic jamming, interception of control and leakage of transmitted information, including personal data of users. The design of highly automated vehicles should consider the minimisation of risks from information security threats and software vulnerabilities. Information security solutions should be integrated into the control system of HFAV during its design and development stages.

¹³⁶ Global Cybersecurity Index (v3), 2018. Retrieved from <https://www.itu.int/en/ITU-D/Cybersecurity/Pages/global-cybersecurity-index.aspx> (last accessed in February 2021).

¹³⁷ Source: <https://strategy2050.kz/ru/news/kak-razvivaetsya-kiberbezopasnost-kazakhstana/> (last accessed in February 2021).

¹³⁸ Available in Russian language at <https://adilet.zan.kz/rus/docs/Z1300000094> (last accessed in February 2021).

3.2.8. Legal and Regulatory Framework

Kazakhstan is in the early stages of setting up the legislative environment enabling the operation of HFAV. However, the legislative gaps preventing an immediate introduction of autonomous vehicles are not only relevant to the national legislation, but also exist at the level of intergovernmental treaties participated by Kazakhstan.

A key area for improvement at global level are the restrictions imposed by the Vienna Convention on Road Traffic (1968)¹³⁹: one of the fundamental principles of the Convention has been the concept that a driver is always fully in control and responsible for the behaviour of a vehicle in traffic. In the present times, this fifty-year-old principle prevents the use of ADS in fact, requiring that each vehicle must have a driver.

At national level, the operation of HFAV on public roads is completely blocked by the absence of any regulatory framework in this area. The national traffic rules do not contain any definitions related to autonomous vehicles; such aspects as insurance and liability for traffic accidents involving automated vehicles are totally uncovered.

Since 2014 the Criminal Code of Kazakhstan has a dedicated clause dealing with the crimes in the field of informatisation and communications, which defines 38 corpus delicti for crimes against electronic information resources and systems or telecommunication networks. The Code of Administrative Offences of Kazakhstan also describes several misdeeds entailing administrative responsibility including sanctions against white-collars who failed to care about information security, including improper action in personal data protection.

Quite a few transport and legal experts in the country have a common understanding of the need for creating a fully-fledged regulatory framework for the operation and development of HFAVs. In an article reviewing the legal aspects of transport sector development in the country¹⁴⁰, expert calls upon the adoption of a “Driverless vehicle production, operation and legal status law”. He believes that such law will facilitate the implementation of the Digital Kazakhstan Programme which aims to digitalise operation of all modes of transport and the transport infrastructure.

Under the initiative to strengthen the digitalisation legal framework, in 2020 the Ministry of Digital Development, Innovation and Aerospace Industry¹⁴¹ initiated a draft law on innovation, science and technology development aiming to amend 30 legislative acts presently in force, including the Land Code, the Budgetary Code, the Entrepreneurship Code, Informatisation Law and others, in order to foster the innovations, science and technology development of the country.

As of January 2021, the draft law had a few amendments on various aspects of digitalisation, information management and cybersecurity, research and development, spatial data management, support of domestic IT developers etc. with the purpose to (1) precise and actualise the existing legislation in the field of innovation and scientific and technology development; (2) provide additional / enhanced incentives to the innovation activities; and (3) improve coordination of state innovation policy and introduction of recognised international principles and approaches.

¹³⁹ Available at <https://unece.org/DAM/trans/conventn/crt1968e.pdf> (last accessed in February 2021).

¹⁴⁰ Marat Sarsembayev: Improvement of Kazakhstan legislation to address transport sector problems. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan, UDC 347.7, State Classifier of Scientific and Technical Information 10.23.51

¹⁴¹ Formerly known as the Ministry of Digital Development, Defence and Aerospace Industry. Reorganised by the Decree of the President of Kazakhstan on 17 June 2019.

The law further proposes to setup regulatory framework for driverless vehicles that is believed to support the development of innovations in the country and stimulate the international investors to consider Kazakhstan as a country suitable for the introduction for innovative technologies in the context of declaring 2021 as a Year of Digitalisation for Kazakhstan by the President Tokayev. The dossier of the draft law concludes that proposed AI and driverless transport initiatives represent a great step into the digital future.

In March 2020 the Eurasian Economic Commission initiated an amendment package to the existing technical standards and regulations (TSR) of EAEU¹⁴² which should come into force in December 2021 to cover, inter alia, the following:

- Expand the definitions of TSR with new terms and categories;
- Actualise forms and schemes for compliance assessment;
- Endue the electronic documents with legal force equal to hard copies;
- Precise certification procedures for automatic driving vehicles;
- Introduce requirements for safety declaration (certification) of automatic driving vehicles;
- Introduce sustainability and safe disposal requirements;
- Introduce Environmental Class 5 requirements for petrol heavy-duty engines;
- Expand the list of vehicles that must carry onboard a satellite navigation system.

The implementation of the above changes will help to address the key gaps in the existing standards and regulations of EAEU to facilitate the importation, certification and registration of the autonomous vehicles in EAEU including Kazakhstan. Assessing the adequacy of the new legislation needs a deeper analysis which is not covered by the Study.

Meanwhile the process of admitting an automated vehicle to operation is determined in accordance with technical regulations TR CU 018/2011. Until the general requirements for HFAV will have come into force, such vehicles are considered “innovative” and should be certified as defined by paragraph 16 of the regulations, that is, by the decision of the authorised technical regulation body of EAEU member state where the conformity assessment is carried out.

With the implementation of ongoing legislative initiatives Kazakhstan will become a few steps closer to the creation of enabling legal environment for HFAV operation in the country. Considering that this process will require a huge interdepartmental effort at all levels of the government, as well as specialised competencies of the stakeholders, it is highly advisable to use relevant international experience as much as possible. A dedicated sectoral study with the support of international experts might facilitate the efforts of the government to implement the necessary changes and reforms in a most effective and expeditious way.

¹⁴² I.e. Technical Regulations of the Customs Union “On Safety of Wheeled Vehicles” No. TR CU 018/2011 and several international, regional and national standards that determine methods and rules of testing, inspections and measurements to ensure compliance with TR CU 018/2011.

3.3. The Russian Federation

3.3.1. Technical and Operational Condition of the AH route 9

In the Russian Federation, the construction of road infrastructure for the development of the AH route 9 is included in the Governmental “Comprehensive plan for the modernisation and expansion of the main transport infrastructure to 2024”.¹⁴³ Thus, the entire Russian section of the AH route 9 from St. Petersburg to the Kazakhstan border should be ready by 2024, while some of its sections have been commissioned since 2018. Noteworthy, almost a third of the population of the Russian Federation lives within the capture zone of the corridor and more than 40% of the GDP of the Russian Federation is produced.

Presently the automobile route from Kazakh border (Sagarchin border checkpoint) to the city of St. Petersburg across the territory of Russian Federation encompasses 6 segments of federal highways: P-239 “Orenburg Highway”, M-7 “Volga”, M-5 “Ural”, A-113 “Central Ring Road” (CRR), M-10 “Russia”, and M-11 “Neva”.

P-239 “Orenburg Highway”

This 824-km section links Sagarchin border checkpoint located at Russian-Kazakh state border with the M-7 “Volga” road passing via Akbulak, Sol-Iletsk, Orenburg, Bavly, Bugulma, Almetyevsk, Chistopol, and Shali.



Figure 13. A typical view of P-239 road “Orenburg Highway” in Orenburg oblast.

The road has asphalt pavement throughout and mostly one lane for traffic in each direction. Oncoming traffic flows, except for several sections, are not separated by a median lane or fencing. The road marking is absent on many sections. There are numerous level crossings of the road with other roads and pedestrian crossings. The lighting is only available within a few areas. The intensity of traffic is generally low.

In the Chistopol and Novosheshimsky districts the road crosses hilly terrain with a spiral section, long descents and ascents, where the road mostly has 3 lanes, 2 of which are used by ascending traffic.

The road passes through several settlements with the speed limits set at 40 to 60 km/h. In the Almetyevsky district, the road crosses a regulated railway crossing. The roadside infrastructure of the P-239 road is poorly developed. Most of hotels, cafes and bus/truck stations are located within cities and settlements.

M-5 “Ural” Orenburg-Moscow Road

From the city of Orenburg, the AH route 9 follows the federal highway M-5 “Ural” passing through the cities of Samara, Tolyatti, Syzran, Kuznetsk, Penza, Ryazan, and Kolomna then adjoining the A-

¹⁴³ Source: <https://tass.ru/ekonomika/9678785> (last accessed in August 2021)

113 “Central Ring Road” (CRR) in the vicinity of Moscow. The M-5 “Ural” road is part of the international route E30 that also connects the Asian and the European parts of the Russian Federation. The distance from Orenburg to the A-113 “CRR” highway is about 1,400 km. The road has asphalt pavement with road marking throughout and passes through numerous settlements where the speed of traffic is limited to 40-60 km/h whereas the traffic load is quite high. The major part of the road has two lanes for traffic in each direction separated by median lane or fencing. Road lighting is available on several sections of the road as well as within all settlements. The road has numerous level crossings with other road and pedestrian crossings.



Figure 14. The M-5 “Ural” Orenburg-Moscow road bypassing a settlement.

The roadside infrastructure of the M-5 “Ural” road is well developed and is being upgraded continuously.

M-7 Kazan – Moscow “Volga” Road

From the city of Kazan, the AH route 9 follows the federal highway M-7 “Volga” bypassing the cities of Nizhny Novgorod and Vladimir towards the A-113 “Central Ring Road”, bypassing the Moscow agglomeration. The M-7 road is part of the international route E22 and the main route that connects the European part of the Russian Federation with Siberia.

The distance from Kazan to the A-113 road’s connection point is about 800 km. The road has asphalt pavement throughout and passes through many settlements that have a speed limit of 40-60 km/h. The M-7 road has a high traffic load. The road is mostly marked, providing two lanes for traffic in each direction separated by median or fencing.

From Cheboksary to Nizhny Novgorod, the road has three lanes for traffic, with the middle lane used only for overtaking. This segment of the road crosses many hills and has numerous sharp turns. There are numerous level crossings with other roads and pedestrian crossings. Road lighting is only available at several sections and within settlements.



Figure 15. Filling Station at the M-7 Kazan- Moscow “Volga” road.

A 409-km section of the M-7 “Volga” from Nizhny Novgorod to Moscow is the most traffic-intense segment of the road. The roadside infrastructure of this road is well developed and is being upgraded continuously.

A-113 “Central Ring Road” (CRR)

This 336-km road surrounds the city of Moscow providing a bypass link to divert transit traffic from yet overloaded transport network of the Moscow agglomeration. A 110 km segment of CRR represents a part of the AH route 9 (highlighted in red on Figure 16).

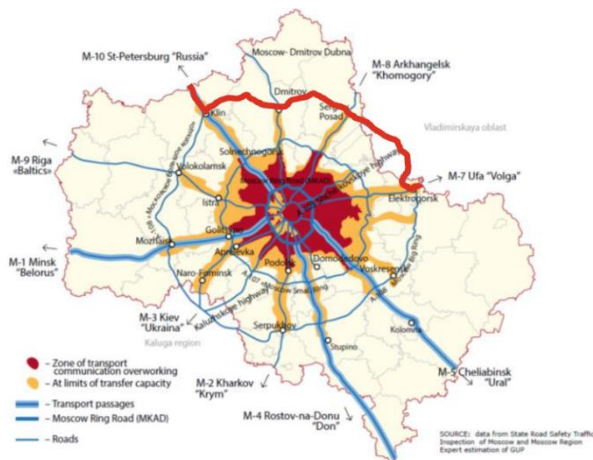


Figure 16. Scheme of CRR segment of the AH route 9 around Moscow agglomeration.

CRR is a newly built four-lane road with the perspective of widening up to 6-8 lanes and estimated speed of traffic of 110-140 km/h. The road became a toll road in January 2021 with the value of charge for trucks varying from 7.2 to 15.7 roubles (\$0.01 – \$0.22) per km.

This road has asphalt concrete pavement, lighting, road marking and median / fencing to separate the traffic flows. In compliance with “highway” category requirements the road does not have any level crossings with other roads or pedestrian crossings, providing for traffic interchanges at connections. The roadside facilities along this road are under development.

A-113 is the largest infrastructure project in the Moscow region of the Russian Federation to date¹⁴⁴. With the introduction of innovative traffic monitoring and management system, as well as free-flow tolling system, CRR can be considered a “smart road”.

¹⁴⁴ Source: <https://avtodor-tr.ru/ru/CRR/> (last accessed in August 2021)

M-10 “Russia” Moscow – St. Petersburg Road

The federal highway M-10 “Russia” is a part of international route E105 that connects Moscow with St. Petersburg with the total length of about 600 km. The road has asphalt pavement with two lanes for traffic in each direction separated by median / fencing.



Figure 17. Traffic congestion on the M-10 “Russia” road.

The road passes across complex landscapes, which largely determined the parameters of the carriageway with varying number of lanes.

At some sections the width of the carriageway is limited to one lane for traffic in each direction which causes congestions pertaining to bad weather conditions and accidents that often involve trucks. The Tver – Novgorod section of M-10 road has three lanes for traffic, with the middle lane used for overtaking. The road crosses numerous settlements where the speed of traffic may be limited to 40-60 km/h. Road lighting is available on several segments and within settlements. The traffic load all along M-10 is high.

Presently the reported daily traffic of M-10 road is 130,000 – 170,000 vehicles that exceeds the designed capacity of 40,000 vehicles several times. This results in diminishing the average speed at approaches to Moscow to 10 km/h and 5 km/h in peak hours. The number of accidents along M-10 three times exceeds the country’s average values. The level of air pollution is 3 to 5 times the value allowed by Russian sanitary norms.

M-11 “Neva” Moscow – St. Petersburg Road

This highway represents an alternative link between Moscow and St. Petersburg proving a high-speed land connection for the users who prefer to pay tolls for congested M-10 toll-free road. The construction of this highway was launched in 2010 and should have been completed by 2018. During 2014 – 2019 several sections were opened to traffic with a 59-km section (northern bypass of Tver) not built out of the total length of 669 km. M-11 is one of the first major toll roads in the Russian Federation.



Figure 18. Toll gates at the M-11 "Neva" road.

The road has IA technical category asphalt carriageway with the number of lanes for traffic varying from 2 to 5 in each direction and designed traffic speed up to 150 km/h. As required by the IA category standard, the road does not have any level crossings with other roads or pedestrian crossings all along.

Due to the missing 59-km long Tver bypass the transit traffic is presently forced to use the alternative link of M-10 "Russia" road around Tver. The roadside facilities along M-11 road are under development.

3.3.2. Strategic Plans for the AH route 9 Development

The Transport Strategy of the Russian Federation to 2030 approved by governmental order No. 1734-r¹⁴⁵ of November 22, 2008, provides for the Russian Federation's "integration into the world transport system and the realisation of the country's transit potential". The implementation of this goal will require to develop globally competitive transport corridors with integrated transport and logistics infrastructure, as well as to introduce ITS-based workflow management systems for delivery.

In 2015, Russian President Vladimir Putin and Chinese President Xi Jinping approved a cooperation agreement within the framework of the "One Belt, One Road" project, and China created the "Silk Road Development Fund", investments in which are estimated at close to \$40 billion. In autumn of the same year, the Russian state Corporation Avtodor, managing the country's toll roads, signed a Memorandum on financing the ITC project with the Development Bank of China. In October 2018, the Russian Government published "A comprehensive plan for the modernization and expansion of the country's main infrastructure until 2024", which includes tasks for the construction of Russian sections of the Europe-Western China ITC: the Moscow-Nizhny Novgorod-Kazan Expressway, the Tolyatti bypass with a bridge over the Volga, and the Russian section of the Meridian Highway.

In July 2017 the Government of the Russian Federation adopted "Digital Economy of the Russian Federation" programme¹⁴⁶ to 2024, which envisages "to ensure coverage of all federal highways with communication networks capable of wireless data transmission necessary for the development of advanced intelligent logistics and transport technologies."

The programme includes other similar measures aiming to providing the transport infrastructure (including federal highways and railways) with the capacity for wireless data transmission.

Under the framework of the Treaty on the Eurasian Economic Union of May 29, 2014, the following joint actions are envisaged for the member states:

- coordinated development of transport corridors between European and Asian countries;
- coordinated development of transport infrastructure and unification of technical regulations and parameters of transport corridors;
- coordinated policy of attracting foreign investment for the development of transport corridors;
- promoting joint ventures for international passenger and cargo transportation and freight forwarding;
- development of international logistics centres.

¹⁴⁵ Source: <https://www.garant.ru/products/ipo/prime/doc/94460/> (last accessed in August 2021)

¹⁴⁶ Source: <http://government.ru/docs/28653/> (last accessed in August 2021)

The “List of Transport Routes of the Eurasian Economic Union” was approved by the decision of the EAEU Interstate Council No. 605 of September 28, 2012.

In addition, the following EAEU documents have been adopted to foster the development of transport infrastructure at regional level:

- Strategy for the development of international logistics centres of EAEU for 2009 – 2020; and
- Comprehensive plan for the development of the infrastructure of roads and railways covered by the EAEU List of Transport Routes.

The Plan, among other things, provides for the upgrade of existing infrastructure international transport corridors to ensure their compliance with the requirements of the European Agreement on International Motorways of 1975 (AGR), the European Agreement on International Main Railway Lines of 1985 (AGC), the European Agreement on International Combined Transport Lines of 1991 (AGTC), the Intergovernmental Agreement on Asian Highways of 2004 and the Intergovernmental Agreement on Trans-Asian Railways of 2006, and The Convention on Road Traffic and on Road Signs and Signals of 1968.

Pursuant to the international agreements, the Russian Federation executes reconstruction and modernisation of existing roads and infrastructure, including those constituting the AH9 route. Along with the reconstruction of M-5 “Ural” and M-7 “Volga” roads being parts of AH9 route, corresponding to category 1 and category 2 roads, the country builds new “highway” class roads. One of most recent examples are the completion and commissioning the segments of Central Ring Road A-113 and the ongoing construction of the last section of M-11 “Neva” highway, both being parts of the AH route 9.

Among strategic plans of the Ministry of Roads is the construction of the Moscow – Nizhny Novgorod – Kazan highway with a length of 729 km to be launched in 2021, with the expected commissioning in 2024.

In 2019 a group of Russian businessmen proposed to build an alternative route to enable movement of road trains, including driverless vehicles, from China to Europe across the Russian Federation called “Meridian”. The initiative was supported by the Government of the Russian Federation and the project design is presently ongoing, with over 80% of privately-owned lands reportedly acquired to enable the construction of this 2,000 km new toll road.¹⁴⁷ The investment needs of the project were estimated at RUB 600 billion (\$8.3 billion), with the expected completion in 2024.

3.3.3. Current Status and Plans for ITS Deployment

Central Ring Road

As part of ITS deployment initiative, the 3rd section of the Central Ring Road, being a segment of the AH route 9, has been equipped with 72 video cameras, 76 traffic sensors, 47 dynamic information boards and signs, 7 weather stations, 6 free-flow toll gates, and 67 “vehicle to infrastructure” interfaces.

¹⁴⁷ Source: <https://www.kommersant.ru/doc/4640505> (last accessed in August 2021)

According to the official information of the developer of the ITS system at the Central Ring Road, the system can interact with autonomous vehicles. As for manned vehicles, ITS can provide their drivers with information and alerts about a dangerous approach and obstacles in the carriageway as well as direction change and stop warning.

Built-in AI algorithms allow the system not only to accurately recognise license plates, but also detect the models of vehicles. In the event of any deviation (i.e. accident, congestion, appearance of a foreign object, pedestrian or animal on the highway), the system immediately notifies all road users. The warnings about potential hazard appear on information boards installed along CRR and can also be transmitted to on-board computers of vehicles. In the future, the drivers will be able to receive warnings on their smartphones through mobile application.

Smart road infrastructure can also interact with self-driving vehicles by constantly monitoring the road situation, collecting data from connected infrastructure, and exchanging signals with the autonomous vehicles. Autonomous vehicles can receive alerts from ITS about emergency situations, obstacles, pedestrians crossing the road where such crossing is prohibited etc.

CRR ITS is controlled centrally from a dedicated control room situated by the road with a view to use this centre for coordination of all toll roads along the North-South corridor. This will include integrating the ITS of the M-12 “Moscow - Nizhny Novgorod – Kazan” highway in the future, being part of AH9 and the West – East transport corridor.



Figure 19. Interior view of the Central Ring Road's ITS control room.

The deployed CRR ITS has been fully adapted to operate in the climatic conditions of the country.

For the first time in the Russian Federation, a barrier-free toll collection system “Free Flow” is being introduced at CRR comprising 12 “Free Flow” gates.

State company “Avtodor”, responsible for the development of main roads, intends to replicate the experience of ITS implementation in M-11 Moscow – St. Petersburg and CRR projects in terms of ITS functionality, software, and hardware specifications.

According to Avtodor¹⁴⁸, the Central Control Room of CRR in the Moscow Region can be used as a basis for a unified ITS and consolidated management system for connected vehicles operating within the Russian Federation. Avtodor believes that consolidating the data within a single node could be a much cheaper solution vs. the deployment of separate control rooms along federal highways, thus significantly reducing the cost ITS implementation in the country.

“Safe Road” Programme

Under the national project “Safe and High-Quality Roads”¹⁴⁹, envisaged for 2019-2024, it is planned to deploy ITS along the highways of federal and regional significance, focusing on the automation of traffic management. The project scope provides for ITS deployment along 120 sections of federal highways and 60 sections of regional roads by 2025.

In addition, by 2025 the project aims to introduce ITS in 64 urban agglomerations with population exceeding 300k habitants. The total amount of funding for these initiatives is estimated at 42 billion roubles (\$580 million) to year 2025.

In 2020, the Federal Road Agency invited applications from the regions for the allocation of funds for the implementation of ITS. 56 applications were received from 50 regions and 22 regional projects were selected. Arkhangelsk, Belgorod, Volgograd, Vologda, Ivanovo, Kemerovo, Kursk, Oryol, Rostov, Ryazan, Samara, Saratov, Sverdlovsk and Tula Regions, the Republic of Tatarstan, Buryatia, Dagestan, and Sakha (Yakutia) will receive funding under the project for the deployment of intelligent transport systems in their respective areas.

As part of the ITS deployment in urban agglomerations, the Federal Road Agency has been studying the possibility of creating an integrated management system for the regional ITSs that aims to include (i) an integrated system of information and analytical services; (ii) Integrated monitoring centre for regional ITSs; and (iii) a central repository of master data.

The scope of the ITS for urban agglomerations is expected to include the following functions and modules:

- multifunctional workplace for departments and authorities;
- traffic management module;
- user information service;
- maintenance of roads and engineering structures;
- control of violations (traffic rules, parking, weight and size restrictions, transportation of dangerous goods etc.);
- monitoring and coordination of public passenger transport;
- parking management;
- transport security;
- toll roads; and
- services for connected and highly automated vehicles (V2X).

The system is being designed to integrate three administrative levels: federal, regional and municipal.

¹⁴⁸ Source: https://dorinfo.ru/star_detail.php?ELEMENT_ID=88648 (last accessed in August 2021)

¹⁴⁹ Source: <https://bkdrf.ru/> (last accessed in September 2021)

CARAVAN/CAVLANE Project

CARAVAN is another innovative project of the Russian Federal Road Agency which is aimed to create digital infrastructure on federal roads for common, connected, and self-driving vehicles, using technologies of C-ITS, V2V, V2I, and V2X. The vision of the project is to create international Smart transport corridors with service continuity across borders.

CAVLANE – the Connected Automated Vehicle Lane Consortia was initiated by the Finnish Ministry of transport together with a few private companies from Finland and the Russian Federation. The objective of CAVLANE is to create new services, products, and standards for crossing borders. New intelligent services increase road safety, improve mobility and logistics, boost businesses, and create markets for innovations.

The CAVLANE/CARAVAN smart route, which originates in Finland’s largest cities and runs via Helsinki through the border with the Russian Federation to Saint Petersburg, Moscow, and Kazan to the border with Kazakhstan and China.

The project tests cross-border interoperability of different relevant international standards and directives for communication, C-ITS, automatic driving, platoon driving, use of fibre-optic cables for cross-border and custom procedures, information of travellers, and road users about traffic and weather conditions, traffic jams, and queues at the cross-border points, road-side services, road works and accidents, navigation and selecting detour routes, etc.

In May 2018, the first demo test of autonomous trucks and self-driving vehicles within the CARAVAN/CAVLANE project was demonstrated.

The road infrastructure was equipped with all necessary means to enable operation of autonomous trucks and cars, including a real-time high-definition vehicle positioning system, incident detection, and recording system, measurement of traffic flows parameters, and a back-up positioning system.

The digital model of the road was created together with other additional digital services such as protection of information flows of CAN bus and registration of unauthorised impacts on control elements of autonomous vehicles and trucks, as well as identification of the impact of the imposition of false GPS coordinates. The testing site deployed cellular system of LTE standard, engineering communications, including fibre-optic cables. Two KAMAZ trucks, one shuttle bus, and two cars were tested.

The ultimate goal of the CARAVAN/CAVLANE consortium is to create a full-fledged service environment for connected and autonomous vehicles along the international transport corridor from Europe to China.

3.3.4. Adequacy of the AH route 9 Infrastructure for Autonomous Vehicles

An assessment of the “level of technology maturity” (LTM) of HFAV-related technologies has been conducted in line with the national standard of the Russian Federation GOST R 58048-2017 “Technology transfer.

Technology maturity assessment methodology guide”¹⁵⁰ which has the following grading system:

¹⁵⁰ Source: <https://docs.cntd.ru/document/1200158331> (last accessed in August 2021).

Grade	Level of Technology Maturity
LTM1	Key technology principles have been studied and published
LTM2	Concept of technology and/or its application has been formulated
LTM3	Critical functions and/or characteristics have been confirmed analytically and empirically
LTM4	Component and/or model has been tested in laboratory environment
LTM5	Component and/or model has been tested in an environment close to reality
LTM6	Model of system/subsystem or prototype has been demonstrated in an environment close to reality
LTM7	Prototype of system has been demonstrated in operating conditions
LTM8	Real system has been finalised and qualified during tests and demonstrations
LTM9	Real system has been validated through successful operation (goal achieved)

The assessment showed a fairly high level of technology maturity of the individual components:

Components (domestically available technologies)	LTM Grade
Technologies for intelligent driving	LTM5
Technologies for communication, vehicle telematics, navigation systems and equipment	LTM8
Technologies for traffic flow management at transport and logistics hubs	LTM6
Technologies for the introduction of “one stop” principle at border crossing points	LTM6
Technologies for the implementation of the “green channel” principle for foreign trade operators	LTM6

Several roads have recently been commissioned under various ongoing road construction and rehabilitation projects, such as the M-11 Neva road (Moscow – Saint Petersburg) and the A-113 Central Ring Road around Moscow, which have been equipped with modern ITS systems that potentially allow the operation of highly automated and fully autonomous vehicles. However, the implementation of ITS systems along the entire the AH route 9 within the Russian Federation is fragmented assuming that HFAV can only be operated with variable restrictions.

Summarising the above, an overall level of technology and infrastructure as an integrated system for potential operation of HFAV along the AH route 9 is estimated as rather low, with LTM grade 3, which means it is not fully adequate for the usage of automated vehicles in international transportations across the Russian Federation.

3.3.5. Social Acceptance of Highly and Fully Autonomous Vehicles

As reported by Arthur D. Little company at the Urban Mobility Forum in December 2020, interviewing over 23,000 people from 13 countries has shown that the level of confidence in autonomous car technology has dropped from 64% in 2015 to 53% in 2020. The results for the Russian Federation showed that only 36% of people interviewed would be ready to use autonomous transport at present time. Among “top fears” highlighted by 61% of Russians was the risk of autopilot failure. Personal data security risk was mentioned by 30% of people surveyed.

Despite this, in August 2020, Autonet scientific institute presented the results of its own survey, according to which at least 77% of Russians are currently ready to use self-driving taxis, and this figure has increased significantly since 2019.

A comparison of the data from several independent surveys showed that Russians are waiting for the appearance of driverless vehicles more than, for example, US citizens. Three-quarters of the surveyed members of “Partners for Automated Vehicle Education” organisation have expressed concerns with current immaturity of driverless technologies.

3.3.6. Legal and Regulatory Framework

In the Russian Federation, as in the other countries introducing autonomous vehicles, there are many aspects related to their operation that do not yet have an adequate legal coverage. The existing legal system needs to be adjusted in line with the new “unmanned” realities and this is not a matter of one law, but rather a systemic goal encompassing all key areas of civil relations.

Presently, lack of regulatory framework represents one of most serious obstacles for the development of unmanned transport in the country. To surmount this, within the framework of the order of the President of the Russian Federation, a set of measures is being developed to enable testing and phased introduction of HFAV on public roads by 2024.

Based on an overview of current legal situation in the Russian Federation, a “first-need” package of regulatory documents should include: (i) general requirements for automated driving systems; (ii) general requirements for the organisation of carriage with HFAVs, including international trips; (iii) operational tolerances and validation methods for HFAV parameters; (iv) general requirements to human-machine interface; and (v) coverage of data protection and cybersecurity of HFAVs.

Typical legal challenges to address also include liability for traffic accidents involving such vehicle and conflicting requirements for data depersonalisation whereas a huge amount of data is collected by HFAV and transmitted to operators during a trip.

Currently the elaboration and adoption of related laws and regulations is not progressing fast partially pending the test data of the ongoing pilot runs of HFAVs in the country which are yet to be collected and analysed.

3.3.7. Representative Research and Development Projects

Key areas of developments in the field of highly automated and fully autonomous vehicles in the Russian Federation currently include the following:

- development of prototypes of highly automated and fully autonomous vehicles and studying possibilities of their application for long- and short distance transportation of goods and passengers, as well as for the transportation of goods and passengers in restricted areas and industrial sites;
- development and introduction of smart road infrastructure; and
- development and introduction of telematics and information management systems in the field of transport, logistics and coordination of transport operators.

These activities involve a significant number of development teams and are implemented in many ways including several government-driven projects and technology initiatives. The following groups of developers can be distinguished for their significant contributions to the development and application of HFAVs in the Russian Federation:

- “Traditional” players of automotive industry – KAMAZ, GAZ Group, Solers;
- Government agencies and companies (FSUE “NAMI”, FSUE “Zaschitainfotrans”, “Avtodor”);
- IT giants entering the market of driverless transportation technologies (Yandex, Sberbank);
- IT companies that have traditionally been engaged in transport telematics and automation of certain types of fleet (rolling stock, telematics and navigation, quarry equipment), that have stepped into the market of driverless transport (RT-Invest Transport Systems and subsidiaries, Transsistemotekhnika, Zyfra Group);

- Associations and non-profit partnerships in the field of navigation and telematics (GLONASS);
- Research and educational institutions (MADI, KFU).

Pilot routes for HFAV testing

Pursuant to the Decree of the Government of the Russian Federation of November 26, 2018 No. 1415¹⁵¹ a pilot operation of highly automated vehicles on public roads will be implemented in Moscow and in Tatarstan from December 1, 2018 to March 1, 2022.

Further to the Decree of the Government of the Russian Federation No. 200¹⁵² of February 22, 2020 the number of regions where testing of self-driving cars is allowed has been expanded with Vladimir, Samara, Nizhny Novgorod, Novgorod and Leningrad Regions, Khanty-Mansi and Yamalo-Nenets Autonomous Districts, Krasnodar Territory, Chuvashia and St. Petersburg. The testing of autonomous vehicles within these territories has been permitted for two years starting March 1, 2020.

During 2019-2020 the Ministry of Transport of the Russian Federation was studying the ways of practical application of highly automated and fully autonomous vehicles as part of a research project called “Scientific, technical and regulatory support for the development and creation of digital infrastructure for information, telecommunications and navigation support for transit cargo transportation along the Primorye-2 international transport corridor using highly automated and connected vehicles” (see Figure 20. Section of “Primorye-2” international corridor provided for HFAV testing.). The executor of the research was the Federal State Unitary Enterprise “Zashchitainfotrans” subordinate to the Ministry of Transport of the Russian Federation.

The report prepared within the framework of this research proposes to create a Pilot Zone (testing area) within “Primorye – 2” international transport corridor that connects the Russian port of Zarubino with the Chinese city of Hunchun. This testing area should be in force during 2021-2025.

The Pilot Zone encompasses three elements of transport infrastructure being (i) Zarubino Port, (ii) a 71-km road connecting Zarubino Port with border checkpoint at Russian – Chinese border and (iii) the international checkpoint “Kraskino”.

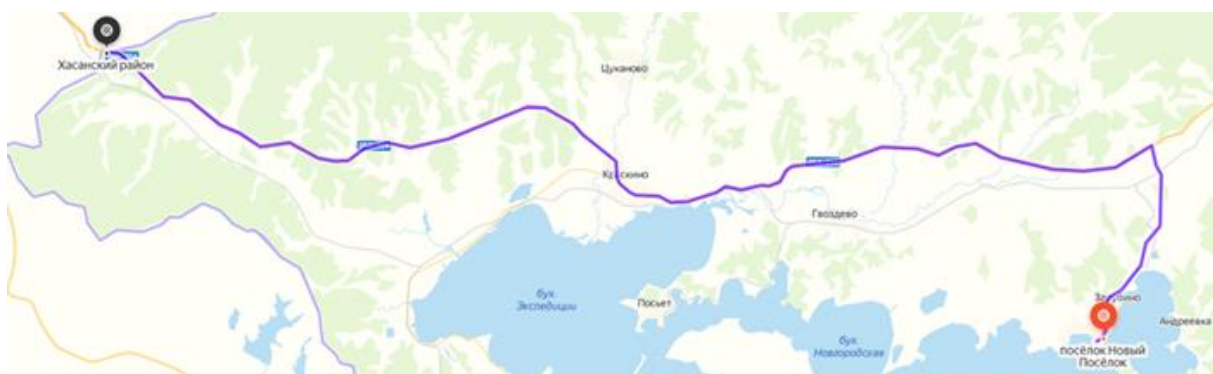


Figure 20. Section of “Primorye-2” international corridor provided for HFAV testing.

¹⁵¹Source: <http://static.government.ru/media/files/OBo8MsELPAARJr3XiqI0mW8IxLea7Lh.pdf> (last accesses in September 2021)

¹⁵² <http://publication.pravo.gov.ru/Document/View/0001202002260025> (last accesses in September 2021)

The testing of HFAs within the pilot zone aims at achieving the following goals:

- Determine ways of practical application of HFAs developed by Russian entities in road freight transportation along the international corridors;
- Elaborate key algorithms of interactions between operators, transport infrastructure / facilities and vehicles under real operating conditions;
- Elaborate ways of interaction with foreign partners (China) within the framework of the pilot project;
- Develop institutional and legal framework for the operation of HFAs in road traffic along the international transport corridor) including coordination between state regulatory authorities e.g. customs authorities and transport control authorities;
- Elaborate the mechanism for crossing international checkpoints by autonomous vehicles without the risk of violating the law, including the algorithms of customs checks and other relevant operations without, or with minimised, attendance of officials from state regulatory bodies;
- Determine the ways for further development of relevant technologies and organisational principles for the use of HFAs in regular operations along the international transport corridor.

Notably, the pilot project does not currently pursue any commercial objectives and was not intended to anticipate any return of investments allocated for its implementation.

Automotive industry players

KAMAZ Public Joint-Stock Company

As one of the biggest Russian automotive designers and manufacturers, KAMAZ was actively involved in the development of highly automated and driverless vehicles. Since 2018, the company has launched the production of 8 new models of road vehicles, including electric trucks, buses and trolleybuses equipped with autonomous driving systems. Presently, KAMAZ is developing and testing HFAs for several applications, including a driverless version of KAMAZ-43083 truck suitable both for road and workshop operations. This project, “Odyssey”¹⁵³, aims to deploy pilot routes for workshop operations of the autonomous trucks. Another model, a driverless all-wheel drive truck KAMAZ-5350, can be operated under the conditions of cross-country terrain is presented on Figure 21 below.

¹⁵³ Source: <https://vestikamaza.ru/posts/odyssey-vse-o-bespiilotnom-proekte-kamaza-foto/> (last accessed in August 2021)



Figure 21. Driverless truck KAMAZ-5350.

KAMAZ is developing a special programme for the platooning of autonomous trucks within the Russian Federation and along international transport corridors in cooperation with the Federal Road Agency (Rosavtodor) and the State company Avtodor (the federal operator of toll roads in the Russian Federation).

For road haulage KAMAZ is developing a fully autonomous vehicle that does not have a driver's cab and can move in both directions (Figure 22).



Figure 22. Cabinless unmanned vehicle by KAMAZ.

In April 2020, KAMAZ presented “Avatar”, a driverless vehicle concept where the autonomous driving module can be installed on the cab’s roof of any truck equipped with a robotic gearbox, electronic accelerator pedal, electronic brake system, electric power steering and CAN bus. With the availability of these components, the “Avatar” can convert any truck into a driverless vehicle. A KAMAZ-43118 flatbed truck was used as a test unit for the first installation of “Avatar” (see Figure 23). All systems responsible for automated driving are redundant.

In case of a massive failure affecting both ADS and vehicle communication channel the vehicle will be safely stopped.

Reported accuracy of ADS-controlled trajectory of the vehicle in motion is 0.2 m. The vehicle can be operated in “manual”, “autonomous” or “remote control” mode. The remote control over the vehicle is executed through an industrial Wi-Fi or LTE network, with a VHF unit being also available. In the unmanned mode the truck is able to move at a speed of up to 60 km/h.



Figure 23. KAMAZ-43118 flatback truck equipped with “Avatar” kit.



Figure 24. Driverless shuttle by KAMAZ.

Another representative AV project is the development of an unmanned minibus “SHUTTLE” (Figure 24). The project was first presented at the Moscow International Motor Show (MIMS) in 2016.

NAMI

Since 2012, a leading Russian state research institute in the field of automotive theory and technology, NAMI, has been developing various elements for autonomous driving that included traffic management systems, computer vision systems, navigation and control drives.

In 2014 – 2015, NAMI automatized KAMAZ-65206 truck by developing steering, acceleration and deceleration control systems, as well as implementing ADAS functions (LDW, RSR, FCW, SLA). Since 2016, NAMI has launched R&D works upon an autonomous 12-seat bus for servicing dedicated routes, as well as, jointly with KAMAZ, an unmanned road train. The NAMI’s R&D products were also used for the development of the cabinless electrical freight vehicle based on KAMAZ model with the 4th level of automation, controlled by a remote operator.

The scope of NAMI’s R&D works on domestic ADAS components include architecture, algorithms, electronics, software, and installation. NAMI experts helped to develop 11 national standards for ADAS.

NAMI has conceptualised the deployment of platooning for intercity freight transportations across public roads using virtually coupled road trains consisting of cabinless freight vehicles.



Figure 25. Prototype of cabinless freight vehicle by NAMI on a test run.

Under cooperation with the Ministry of Education and Science of the Russian Federation, in 2017 – 2020 NAMI designed and built a prototype of the cabinless freight electric vehicle on the basis of KAMAZ chassis¹⁵⁴ (Figure 25).

Another notable project implemented by NAMI in cooperation with the Ministry of Education and Science in 2017-2020 was R&D works to design ITS for platooned passenger vehicles for operation in the northern areas of the Russian Federation, the Arctic and Antarctic¹⁵⁵.

Software developers and hardware manufacturers

Yandex

¹⁵⁴ Source: <http://nami.ru/projects/cargo-drones> (last accessed in August 2021)

¹⁵⁵ Source: <http://nami.ru/projects/intelligent-transport-system> (last accessed in August 2021)

Yandex is one of the most active developers of self-driving cars in the Russian Federation. Having launched the testing of unmanned vehicles since 2017, their current fleet consists of about 200 vehicles run in the Russian Federation, the United States and Israel.

In March 2019, Yandex and Hyundai Mobis signed an agreement of intent to create a platform for self-driving cars. The first prototype of the unmanned Hyundai Sonata was created in 2019 in collaboration with the engineers of Mobis. Presently the fourth generation of Yandex self-driving cars based on Hyundai Sonata has been on trial (Figure 26).



Figure 26. Self-driving Yandex car based on Hyundai Sonata model.

There are plans to extract unmanned vehicles into a separate business line under Yandex Self-Driving Group (Yandex SDG) to be followed by taking over Uber's share in Yandex SDG, a \$100 million investment injection and issuance of a \$50 million convertible loan. Notably, to date Yandex already invested \$150 million into the development of unmanned cars¹⁵⁶ whereas no R&D activities were implemented in regards of the autonomous trucks.

Sberbank

In 2019 Sberbank incorporated SberDigitalAuto aiming to develop infrastructure and technologies for the promotion of automotive services within the “Sberbank ecosystem”. There are plans to transfer SberDigitalAuto under Sber Automotive Technologies, whose scope includes creating a platform for autonomous vehicles and automotive operating systems (OS)¹⁵⁷.

Sberbank reports¹⁵⁸, the first self-driving cars of Sber Automotive Technologies reached out to the streets of Moscow in December 2020 for testing in the environment of a winter metropolis under the conditions of high humidity, negative temperatures, poor visibility, and heavy traffic.

MADI (Moscow Highway Institute)

MADI is testing their first fully self-driving car on the streets of Moscow. The vehicle is equipped with special sensors allowing to monitor the obedience of the parking rules by other road users.

¹⁵⁶ Source:

<https://yandex.ru/search/?lr=213&text=%D1%8F%D0%BD%D0%B4%D0%B5%D0%BA%D1%81%20%D0%B1%D0%B> (last accessed in August 2021)

¹⁵⁷ Source: https://www.sberbank.ru/ru/press_center/all/article?newsID=329c8c95-163b-4087-9aab-fcbe19cf71d8&blockID=1303®ionID=77&lang=ru&type=NEWS&fbclid=IwAR1iIgrHm4MqxLBPZeFoiI5MNdNpJz4XyXw8ayDcbBo8IUUVaAaBzL3D9uQs (last accessed in August 2021)

¹⁵⁸ Source: <https://press.sber.ru/publications/pervaia-seriia-bespiilotnikov-sber-vyekhala-na-ulitsy-moskvy-dlia-ispytaniia> (last accessed in August 2021)



Figure 27. MADI self-driving test vehicle.

In 2016-2018 MADI participated actively in CARAVAN project implemented by the Federal Road Agency. Within the framework of CARAVAN, Traffic Management and Safety Department of MADI presented an unmanned vehicle based on Ford Focus II. Under this project MADI had to deal with three major tasks: (i) development of unmanned vehicle of 3/4 levels of automation based on a serially produced vehicle; (ii) creation of a digital road model; and (iii) determining the ways to reveal any illegal interference with unmanned vehicle during operation and bringing it to a forced stop in case of a cyberattack.

Electric Transport Technologies

Electric Transport Technologies¹⁵⁹ is implementing the following projects in the field of HFAV:

- (1) “Matreshka” – a driverless 8-seat minibus;
- (2) “Electric Bus” – a 98-seat urban electric bus developed for a Russian bus manufacturer;
- (3) “Electric Car” – an electric vehicle based on VAZ 1817 model with electric drive and electrochemical generator using hydrogen fuel cells;
- (4) NIT2 – a small-scale production of various autonomous commercial vehicles.



Figure 28. Driverless taxi MATRESHKA created by Electric Transport Technologies.

Zyfra Group

Zyfra Group¹⁶⁰ is a Russian developer of highly automated and connected transport systems used for isolated production sites including mining industry. Zyfra Group develops and implements solutions using industrial AI and IoT as well as robotic industrial transport.

Under their R&D programme Zyfra Group has automatized several types of quarry equipment such as a mining dump truck BELAZ 7513R whose functionality includes autonomous movement along the cargo transportation route, scanning the environment, unmanned loading and unloading. The vehicle can be operated both remotely and by a driver.

GLONASS Research Institute

In 2019 GLONASS Research Institute organised a contest rally “Winter City” between several developers of autonomous cars at NAMI testbed with the support of RVC, ASI and the Skolkovo Foundation. Participated by 13 teams, the contest aimed to assess the ability of unmanned vehicles to run reliably under winter conditions.

¹⁵⁹ Source: <http://ev-tech.me/ru/> (last accessed in August 2021)

¹⁶⁰ Source: <https://www.zyfra.com/ru/> (last accessed in August 2021)

To qualify successfully, the cars had to demonstrate the ability to bypass obstacles, move in traffic, cross controlled and uncontrolled crossings, make left turns and proceed for parking. Apart of the autonomous cars, a few man-driven vehicles, pedestrians and road workers were simulating real traffic conditions.

A winning contestant's vehicle was to run a 50 km distance across icy testbed within less than 3 hours while observing traffic rules.

Five teams were qualified to partake the final stage of the contest held in December 2019 near Moscow: MADI (Moscow), BaseTracK (Moscow), StarLine (Saint Petersburg), Nizhniy Novgorod state technical University and Auto-RTC (Taganrog). Official publications on this event are available on the NTI website¹⁶¹.

GAZ Group

Presently GAZ Group is testing a fourth-generation unmanned vehicle which was built on the basis of Gazelle Next platform. For that, testbed was built to simulate real urban environment that includes road signing, crossings, turns, parking, circular traffic, and traffic lights.

In September 2020, for the first time in the country, a commercial freight trip of automated vehicle Gazelle Next (see Figure 29) was performed carrying vegetables from Vladimir to Moscow.



Figure 29. Automated vehicle Gazelle Next.

The car drove in autonomous mode for about 240 km in the traffic flowing along the M-7 Volga highway where it has at least two lanes for traffic in each direction, road marking and level intersections with other roads and pedestrian crossings. The trip took place in the night to minimise exposure to traffic congestions and was accompanied by a trained onboard engineer to oversee the performance of ADS. Once during the trip, the person had to rapidly take over the control of the vehicle but in general the delivery was completed without any incidents.

GLONASS

GLONASS is a non-commercial partnership and a federal network operator mandated to facilitate the development and application of navigation technologies. The entity includes Yandex, MTS, Megaphone, VimpelCom, and Rostelecom. In December 2020 GLONASS tested an ADS in traffic near Moscow where the functionality of V2X equipment¹⁶² was particularly on trial by lead hardware and software companies represented by Fort Telecom, MVS Group, Kaspersky Lab, Sreda Solutions, Keysight and NAMI. Test results were used to support the development of universal technical standard for data transmission and exchange which does not presently exist in the country.

¹⁶¹ Source: https://ntinews.ru/in_progress/gonka-tehnologiy/vse-taki-oni-edut-kak-bespilotniki-pokoryali-russkuyu-zimu.html (last accessed in August 2021)

¹⁶² V2X communication technology is based on the 802.11n radio standard in the 5.9 GHz band providing short-range communication that allows vehicles to exchange data with roadside equipment and other vehicles.

3.3.8. Usage of Autonomous Vehicles

In 2018 autonomous vehicles appeared on Russian public roads for the first time. Presently there are nearly 200 automated vehicles in the country being tested in 13 regions. To minimise the exposure of autonomous vehicles to traffic accidents such testing is normally run on designated bus lanes alongside the public transport. The relevant amendments to the Traffic Rules have been prepared and submitted for approval and effectuation in the near future.

In 2021 the Ministry of Transport, the Ministry of Industry and Trade, the Ministry of Internal Affairs and the Ministry of Economic Development finalised a roadmap for the introduction of self-driving cars on public roads in the Russian Federation. Once the roadmap is approved, in addition to regulatory and R&D initiatives on autonomous vehicles, it will also set specific target dates for the creation of 5G coverage zones to support V2X communications. Following the last stage of the process, which involves the approval of the Technical Regulations of the Customs Union providing for the requirements to self-driving cars, such systems will be potentially ready for commercial operation.

In turn, the Russian transport companies are quite interested in developing highly automated and fully autonomous vehicles. In particular, since the end of 2020 one of the largest Russian road carriers of combined cargo – PEK – has been studying the use of unmanned vehicles for interregional transportation of goods, inter-warehouse cargo transportation and robotic intra-warehouse transportation.¹⁶³ PEK also plans to use HFAV for freight transportation over a section of the AH route 9. PEK stated their willingness to cooperate with the full range of solution providers, including truck manufacturers, start-ups, venture funds, universities and research centres, as well as suppliers of HFAV components for the implementation of these plans.

Yandex is working on a special programme for the autonomous Yandex-Taxi in Moscow, Kazan, and other cities in the Russian Federation, Kazakhstan, Uzbekistan, Kyrgyzstan, and other countries of EAC.¹⁶⁴ A few special programmes for autonomous vehicles have been set in the Russian Federation on the Federal level: AutoNet, AutoData, Digital trucks, and Digital truckers, led by National Technology Initiative.¹⁶⁵

A large-scale experiment on the use of self-driving heavy-duty vehicles is ongoing in the far North where the entire trip of automated vehicles through the tundra, winter roads and oilfield territories is controlled remotely by a control centre operator. The outcomes of these experiments are believed to determine a right moment in time where the full-fledged usage of unmanned vehicles on public roads can be allowed.

However, according to individual developers of automated driving systems, the key problem remains the lack of dialogue in the industry: the development companies have not yet provided the results of their tests with statistics on the types of road accidents and other drawbacks that are crucial for the development of regulatory framework and determination of their implementation timeframe. If current situation sustains, the entry of self-driving vehicles into commercial operation in the country may be postponed beyond 2024.

¹⁶³ Source: <https://pecom.ru/bespilot/> (last accessed in August 2021).

¹⁶⁴ Source: <https://www.tadviser.ru/index.php/> (last accessed in August 2021).

¹⁶⁵ Source: <https://www.tadviser.ru/index.php/> (last accessed in August 2021).

4. Conclusions and Policy Recommendations

4.1. Lessons Learnt from Technological Status and Regulatory Investigations

The Study has revealed that the level of technology development and adequacy of the physical and smart infrastructure for the operation of HFAVs varies between the target countries, although there are commonalities in the development trends and efforts at respective national levels.

In China, the progress in the development of the AH route 9 varies significantly along with the catchment provinces and regions. In Jiangsu Province, the government paid great attention to the deployment of smart infrastructure and technologies and the pace of implementation is high. Comprehensive and systematic planning for smart highways has been put in place and major achievements have been demonstrated. In the provinces of Anhui, Henan, and Gansu, the local governments have also adopted their development plans and demonstrated a few achievements within recent years. Shaanxi Province has initiated several ITS projects along with the development of existing highways. However, Xinjiang is still at the initial stage of smart highway development and planning. The government has not yet issued systematic development guidance for smart highways.

In Kazakhstan, the implementation of the “Western China – Western Europe International Road Corridor Project” in 2009 – 2018 has significantly improved operational performance of the AH route 9 for road users resulting in the increase of speed limits from 90 to 110 km/h and times increased throughput capacity of bottlenecked sections. However, with the growth of traffic over the past years several sections have become exposed to excessive loads versus their design parameters that may impede a smooth flow of freight traffic along the corridor in the near future.

Whereas China and Kazakhstan have decided to upgrade their existing roads, the Russian Federation chose to build a completely new corridor comprising six major segments: The Western Speed Diameter in St. Petersburg, the M-11 highway from St. Petersburg to Moscow, the Central Ring Road around Moscow, the Moscow – Kazan Expressway, and the Meridian, a full-fledged highway to the border of Belarus. All these projects are at different stages of completion varying from the start of design and survey work to fully commissioned highways, with the ultimate target completion by 2024.¹⁶⁶

Among the findings from the review of status on HFAVs in the target countries, technical components required for the operation of HFAVs to draw policy recommendations include, but not limited to, the following:

- Road environment to accommodate HFAVs on the road traffic with other types of vehicles (e.g., signalised and unsignalized intersections and traffic signage);
- Wireless networks to utilize communication technologies for HFAVs and control centres (e.g., DSRC and 4G/5G);
- Communication technologies to exchange necessary information and data among vehicles, infrastructure, and other facilities and objects (e.g., V2I, V2V and V2X);
- Automated controls in vehicles to operate HFAVs with limited human interventions on the roads (e.g., digital maps and sensors);
- Monitoring and control centres to provide necessary actions and strategies for HFAV controls and operations by real-time monitoring.

¹⁶⁶ Source: https://dorinfo.ru/99_detail.php?ELEMENT_ID=73640 (last accessed in August 2021)

In terms of current activities, significant presence of domestic manufacturers of HFAsV ready for commercial operation was noted in China along with broadly available and fast-evolving smart technologies and infrastructure that already enable their usage on roads. At the biggest automotive market in the world, China has strong prerequisites to pioneer an intense commercial usage of HFAsVs for both domestic and international transportations. The experience of China well deserves further research and dissemination among the countries of the region as an example of coherent and purposive action.

In the Russian Federation intense R&D activities have been notices in the field of smart systems for HFAsVs, including the manufacture of several models of automated cars and trucks currently being at various stages of trial runs on dedicated test areas including public roads and a segment of the AH route 9. The country has adopted the national plan envisaging a set of concrete measures to boost R&D activities, put in place the regulatory framework and enable the launch of commercial operation of HFAsVs by 2024.

Several initiatives regarding the development and usage of smart systems have also been revealed in Kazakhstan, which is apparently entering the first stage of a progressive motion towards the introduction of HFAsVs. The country has put in place the national plan for the development of smart transport systems along the AH route 9 and initiated a package of amendments to existing laws and regulations to create a favourable environment for the future development and introduction of digital technologies used for HFAsVs.

Generally, the common focusing areas of current activities guiding for the use of HFAsVs in the target countries can be summarised as follows:

- Industry-academia-government collaboration for the increased efficiency and effectiveness of HFAsV development and operation;
- Part of national smart transport-related plans to align with HFAsV development direction under the overarching national plans;
- National level pilot studies/experimental tests led by the public sector to provide overall guidance of HFAsV development and operation;
- Collaborative work between countries to harmonize the technical requirements and understand each country's relevant plans and strategies;
- Enactment of relevant legislations to support HFAsV operation and development with concrete legal status;
- Relevant frameworks and standards development to provide comprehensive technical, political, and operational direction of HFAsVs.

Considering the initial stage of technological developments, most activities are related to strengthening the foundation for the introduction of HFAsVs, which encompass multiple sectors.

4.2. Lessons Learnt from Feasibility Studies

The Study has provided for feasibility studies of HFAsV operability in China, Kazakhstan, and the Russian Federation. They allowed to determine several factors of consideration for the development of policy recommendations categorised in six groups including “political”, “technological”, “legal”, “economic”, “social” and “environmental” factors. Table 4 presents major factors and their details.

Table 4. Summary of major factors determined by feasibility studies for the development of policy recommendations.

Factors	Details
Political	<ol style="list-style-type: none"> 1. Clear and inclusive national guidance to support the introduction of HFAVs. 2. Explicit government policies or programmes for the development of HFAVs. 3. International cooperation to support the operation of HFAVs.
Technological	<ol style="list-style-type: none"> 4. Adequacy of roadside facilities for HFAVs. 5. Different technical requirements and procedures in place for border control points. 6. Coverage and speed of wireless networks. 7. Precision issues of satellite-based positioning system. 8. Technical capacity of operators for HFAVs. 9. Concerns on potential cybersecurity from HFAVs. 10. Technical barrier between different modes of transport for multi-modal transport.
Legal	<ol style="list-style-type: none"> 11. Transport and traffic rules for the operation of HFAVs. 12. Legal fundamentals for the insurance of liability for HFAVs. 13. Data protection laws for the use of HFAVs. 14. Specified customs regulations for HFAVs. 15. Regulatory/legal frameworks for HFAVs. 16. Formalised process of the service and maintenance of HFAVs. 17. Customs rules and procedures for HFAVs in international transport.
Economic	<ol style="list-style-type: none"> 18. Affordability to purchase HFAVs due to higher capital costs. 19. Increased cost of infrastructure to support HFAVs.
Social	<ol style="list-style-type: none"> 20. Social hesitance to accept HFAVs. 21. Concerns on unemployment due to replacement of human drivers with HFAVs. 22. Increased safety and mobility by technological advancement from HFAVs.
Environmental	<ol style="list-style-type: none"> 23. Difficult climatic conditions that may hinder the operation of HFAVs.

4.3. Policy Recommendations

It was noticed that the development of HFAVs is gaining attraction among countries along the AH route 9. This dramatic change in technological paradigm for the transport sector might bring about positive results in the achievement of sustainable transport. However, due to complexities by its nature, diverse impacts are expected which need prompt attention by policymakers to keep momentum for facilitating HFAVs along the AH route 9. In this sense, the following policy recommendations could be considered at the national and route-specific levels.

4.3.1. Proactive Policy Support at the National Level

Countries along the AH route 9 may already be aware of the advantages of HFAVs to some degree. As found from feasibility studies, relevant initial plans and strategies for this new technology have developed in some countries but with a limited scope. Considering different levels of development, national governments are encouraged to be prepared for the upcoming operations of HFAVs with proactive policy support. Examples of possible action items that might be considered by governments are as follows:

- Investigating the technological development status of smart transport systems including HFAsVs;
- Reviewing policy, regulatory and legal status, level of technical and institutional capacity, and budgetary situation for HFAsVs;
- Prioritizing local needs when adopting HFAsVs;
- Determining the direction of national policy from various aspects – political, technological, legal, economic, social, and environmental;
- Strengthening the collaboration among stakeholders (industry, academia, and government), and neighbouring countries.

4.3.2. Enhancement of Cooperation and Collaboration Among Neighbouring Countries

Movement of people and goods with HFAsVs among countries along the AH route 9 will be forthcoming. If there are significant gaps in terms of technological developments between adjacent countries, this would be problematic for the efficient movement of people and goods with HFAsVs along the AH route 9. Given that this new technology is expected to bring unprecedented benefits to the transport sector at the transnational level, cooperation and collaboration among neighbouring countries along the AH route 9 is encouraged to achieve mutual advantages. Following items are some examples that governments might consider:

- Sharing agendas, goals, plans and lessons learnt among neighbouring countries;
- Formulating customs rules, technical requirements and procedures for HFAsVs in international transport;
- Encouraging international logistics projects and programme aimed at the development of interregional logistics activities;
- Encouraging multilateral dialogues among neighbouring countries.

With enhanced cooperation and collaboration among neighbouring countries along the AH route 9, the technological development gap can be narrowed which will strengthen the streamlined movement of people and goods with HFAsVs along the AH route 9.

4.3.3. Guidelines on Establishing Overarching Strategies Along AH Routes

As acknowledged, technologies for HFAsVs have not entirely materialised yet. Only some countries along the AH route 9 have initiated relevant plans and strategies at a fundamental level. Different levels of technological developments are of an issue in addition to large discrepancies of understanding, knowledge, and capacity of policymakers among countries along AH routes. To supplement these issues, overarching strategies and detailed action plans need to be developed for greater guidance about HFAsVs. This top-down approach can supplement the gaps found within countries and among countries, which include technological, financial, political, institutional and legal barriers, through the same direction among countries along AH routes. Moreover, considering the initial stage of technological development for HFAsVs, the overarching strategies along AH routes will prevent any compatibility and interoperability issues between existing and future systems in transport. Possible action items are listed below that can be considered by countries as examples:

- Examining status of development levels of smart transport systems in target countries, and their needs and priorities;
- Encouraging the dialogue among stakeholders including industries, governments, authorities, associations, academia, insurance companies and institutions;
- Facilitating discussions for the standardisation of relevant technologies for HFAsVs;
- Setting up the region-wide direction (including frameworks, plans or guidelines) to support the development of HFAsVs;

- Sharing issues on social and environmental aspects related to the adoption of HFAVs;
- Implementing capacity building programmes for the greater understanding and knowledge of necessary requirements for HFAVs;
- Encouraging collaborative research, and developing institutional mechanisms for enhancing cooperative works related to HFAVs;
- Increasing the preparedness for emerging technologies (e.g., smart mobility) which can be used with HFAVs.

It is expected that countries along AH routes will eventually head for the same direction through overarching strategies which could maximise the advantages of HFAVs for the achievement of sustainable transport.

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