Intelligent Transportation Systems for Sustainable Development in Asia and the Pacific

Working Paper by the Information and Communications Technology and Disaster Risk Reduction Division

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The shaded areas of the map indicate ESCAP members and associate members.

The cover: The cover image depicts the Incheon Grand Bridge and the Incheon International Airport Highway, Republic of Korea. The illuminated highway path recalls lit fibre optic cables.

Image source: UNESCAP

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Contents

Text Boxes and Figures

List of acronyms

AIM	Advanced Incident Management
API	Application Programming Interface
APTS	Advanced Public Transportation System
ATC	Advanced Traffic Control
ATIS	Advanced Traveller Information System
ATMS	Advanced Transportation Management System
AVI	Automatic Vehicle Identification
BIS	Bus Information System
BRT	Bus Rapid Transit
BTO	Build–Transfer–Operate
CALM	Communication Air-Interface, Long and Medium range
CBTS	Cashless Bus Ticketing System
C-ITS	Cooperative Intelligent Transport System(s)
CVO	Commercial Vehicle Operation System
DSRC	Dedicated Short-Range Communication
ETCS	Electronic Toll Collection Services
GIS	Geographical Information Systems
GPS	Global Positioning System
IoT	Internet of Things
IPTV	Internet Protocol Television
ISO	International Organization for Standardization
ITS	Intelligent Transport System(s)
OBE	On-Board Equipment
RSE	Roadside Equipment
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VDS	Vehicle Detection Systems
VII	Vehicle Infrastructure Integration
VMS	Variable Message Sign
Wibro	Wireless Broadband Internet

Preface

Asia-Pacific is becoming increasingly urban; a trend reflected in much of the developing world. The share of urban population is expected to grow from its current level in Asia of 48 per cent to 64 per cent by 2050. Long-term economic prospects show that prosperity among urbanites will also grow, and therefore the demand for public and individual transport will increase. Consequently, car ownership is likely to continue its rapid rise. China alone gained an additional 17 million new cars in 2014, taking ownership to a record 154 million. As an obvious consequence, road traffic congestion can be expected to become more intricate, further exacerbating already high negative environmental, social and economic impacts.

Information and communications technology can mitigate these impacts. Applications of information and communications technology in the transport sector, have led to the development of so-called "intelligent transport systems" (ITS). ITS improve traffic efficiency and safety, with positive outcomes for sustainable development. Though driven initially mostly by the more advanced countries (United States, Japan, and some European countries), ITS are increasingly being used by developing countries, which are confronted with urgent needs to improve traffic in rapidly growing cities. ITS are also becoming increasingly tailored to the specific needs of developing countries, and recent evolutions in information and communications technology such as the analytical power offered by open and big data further raise the prospects for ITS to be designed within developing countries in response to their specific needs.

The present paper reviews how intelligent transport system (ITS) applications relate to the facilitation of transport from a sustainable development perspective. First, by looking at a large number of effective practices, it shows how ITS can be elaborated to improve transport users' experience and sustainable development outcomes. Second, it analyses some of the policy areas where governmental intervention is necessary. In this regard, it shows how establishing a national strategy is essential for facilitating replicability and expansion of projects and for exploiting the huge potential of open and big data for improved traffic management. Furthermore, policies that ground ITS on existing international standards, will avoid uncoordinated and duplicative approaches. Similarly, the intervention of information and communications technology (ICT) regulators is needed for the allocation of radio frequencies for ITS. Third, the paper identifies financing of ITS as a key challenge and the paper examines various financing and governance models for ITS in Asia and the Pacific. Finally the paper considers some of the issues for which a regional response is necessary, and highlights the need for technology-neutral regional coordination. This working paper does not attempt to provide an exhaustive coverage of ITS and their policy implications, but rather to contribute to raise the profile of ITS as potential tool for sustainable development in the ESCAP context.

ESCAP provides a long established policy dialogue platform that provides opportunities for discussing issues cutting across several policy sectors such as transport and information and communications technology. ESCAP has prepared this working paper as part of its cross-sectoral collaboration in the implementation of paperless trade and transport facilitation systems, with the support of the United Nations Development Account. In October 2014, ESCAP held a joint session of both its ICT and Transport Committees, this allowed policy specialists from both the information and communications technology and the transport sectors to meet and discuss areas of common interest. A first version of this paper was presented at this joint session, and the policymakers of both sectors recognized the role of ITS in achieving sustainable development goals and furthering regional cooperation and connectivity.

Background

This working paper explores the potential brought about by information and communications technology (ICT) in improving the sustainability of road transport through the implementation of Intelligent Transport Systems (ITS). The paper has been prepared by the ICT and Development Section of ESCAP, and is addressed to ICT policymakers of developing countries in Asia and the Pacific. Its objective is to draw the attention of ICT policymakers to the new potentials of ICT in improving sustainable road transport in the region, highlighting specific ICT policy measures for which interventions will be necessary. The paper starts by looking at some of the transport related challenges in rapidly urbanising Asia-Pacific and defining Intelligent Transport Systems (Section 1). Section II explores some of the major applications and ICT innovations that have enabled the emergence of new forms of Intelligent Transport Systems. The paper then turns to policy and regulatory frameworks that need to be put in place for the successful implementation of ITS. The paper concludes with a number of policy recommendations to ICT policymakers, examining the potential contribution that regional organisations such as ESCAP could provide.

I. "Intelligent Transport Systems" in Context

A. The Urban Setting and its Development Challenges

The world is industrializing and urbanizing on a global scale that follows consistent patterns. Some 54 per cent of the world's population live in urban areas, creating many challenges related to urban living[1]. The United Nations has projected that two thirds of the world's population will be urban by 2050 – or an increase of 2.5 billion to current urban communities[2]. One in eight people currently lives in one of the 28 so-called mega-cities that hold over 10 million inhabitants[3].

Many high-growth urban areas can be found in the developing countries of Asia and the Pacific, with the region itself accounting for more than 53 per cent of the world population. According to UN Habitat (2014), in the Asia-Pacific region, India and China alone are projected to add 404 and 292 million urban dwellers respectively to the world's urban population. Most Asian countries are confronted with complex issues in planning to meet a range of challenges in providing adequate infrastructure for water supply, sanitation, energy, transportation, as well as public services for their emerging mega-cities.

These future mega-cities will be confronted with a host of challenges linked to housing, safety, employment, and the delivery of public services including urban mobility. Urban mobility is expected to worsen during the 21st century in developing countries with increased car ownership, and also due to the projected rapid expansion of urban perimeters in under-planned agglomerations. This will cause additional traffic congestion which can be expected to result in

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[1] *World Urbanization Prospects*, UN-Habitat, 2014.
[2] Ibid.
[3] ETSI homepage, <http://www.etsi.org/technologies-clusters/technologies/intelligent-transport>

additional costs to motorists, as well as increased air and noise pollution, stress and losses to traffic accidents. Moreover, insufficient mobility between places of residence and of economic activity could further penalise and marginalise the poorer segment of population, limiting their development prospect[4]. Inadequate public transport systems compound the problem of urban sprawl and traffic congestion by further encouraging private vehicle ownership and usage.

In this context, ICT can play a key role in improving the delivery and efficiency of infrastructure for sustainable development in urban areas. ICT can support the implementation of smart power grids, better water management, effective early warning systems in case of natural disasters and better transport infrastructure, also called intelligent transport systems. This is owed to important innovations and their commercialisation in a number of areas including sensing, detection and transmission equipment, innovations in data storage and processing that allow the rapid and continuous exploitation of "big data"" in urban contexts, improvements and declining costs in geo-positioning systems and of course the advent of mobile telephony (including mobile broadband). These new technologies and their applications to infrastructure can greatly enhance the efficiency and sustainability of infrastructure services, not least in the field of transport. However, reaping the sustainable development benefits from these technologies require new holistic approaches that may involve government agencies working in very different areas. In the case of intelligent transport systems, transport and ICT authorities will need to enhance their cooperation. This paper analyses some of the main challenges from an ICT-policy making perspective.

B. Defining "Intelligent Transport Systems"

Information and communication technologies have recently been applied in programmes to support sustainable urban development. In particular, initiatives in the transportation sector aim at improving the safety, efficiency and sustainability of large cities. Intelligent transportation systems (ITS) are among the first applications in this sector. ITS are, generally speaking, combinations of technologies for increasing efficiency in vehicular traffic. Mainly focused on road transport, ITS also have applications in rail, water and air transport and include navigational devices. The scope of this paper however is mostly limited to urban road transport.

Globally, ITS development has been driven largely by Government policy in the United States, while the technology has evolved generally under the leadership of private developers in Western Europe. The rationale for governmental leadership in formulating ITS policies is to avoid duplication in structural investments and to enable systematic management of ITS services to evolve.

ITS and related information technology solutions for transport infrastructures are becoming a key means of boosting urban mobility. While ITS are often promoted, no unified definition of ITS prevails. Client agencies or countries in much of the world are apt to adopt definitions that accord with their specific purposes or objectives. ITS in different cities have been implemented according to the physical infrastructure and the policy environment in each place, including their

[4] UN-Habitat online <http://unhabitat.org/urban-themes/mobility/>

state of urban development and their level of readiness to accept and use ITS services. While similar problems prevail in each place, they have been dealt with in different ways.

Table 1 shows how different ITS representative organizations and countries have adopted various ITS definitions. Leading ITS countries such as the United States, Japan and some in Europe primarily focus on vehicle-oriented safety and efficiency, while later ITS adopters (among them, China and Indonesia) have tended to develop ITS to mitigate traffic congestion.

Table 1 Definitions of ITS by different institutions or countries[5]

Organization	**Definition**
European Union	Applications of information and communication technology to transport
European Road Transport Telematics Implementation Coordination Organization	A system that integrates information and communication technology with transport infrastructure, vehicles and the user
ITS United Kingdom	A combination of information and telecommunications technology that enables provision of online information in all areas of public and private administration
European Telecommunications Standards Institute	Telematics and all types of communications in vehicles, between vehicles, and between vehicles and fixed locations; not restricted to road transport
ITS Japan	A system that capitalizes on leading-edge information technology to support the comfortable and efficient transportation of people and goods, anticipating a “quantum leap” in safety, efficiency and comfort
ITS Canada	Applications of advanced and emerging technologies (computers, sensors, controls, communications and electronic devices) in transportation systems to save lives, time, money, energy and the environment
Republic of Korea[6]	A transportation system that (a) improves efficiency and safety through automated systems management; (b) provides transportation data through services that integrate such state-of-the-art technologies as electric control and communication with vehicles and other transport facilities
Malaysia[7]	Applications of advanced and emerging technologies (computers, sensors, controls, communications and electronic devices) in

[5] Intelligent Transport System for sustainable mobility, UNECE.
[6] Intelligent Transport Society of Korea, <http://www.itskorea.kr>
[7] ITS Malaysia, <http://www.itsmalaysia.com.my/content.php>

	transportation systems to save lives, time, money, energy and the environment; and the integration of information and communication technology with transportation infrastructure, vehicles and users
Philippines[8]	Applications of computing, electronics, information technology and communications to solve problems in all transport sectors
China[9]	A new generation of transportation systems for improving safety, efficiency, accessibility and sustainability in transportation through application of advanced information technology

Source: Intelligent Transport System for sustainable mobility, UNECE, unless otherwise specified.

C. ITS and Sustainable Development

ITS deployment serves the public interest with significant impacts in improving traffic efficiency, as described in the following paragraphs.

Traffic Management

From a holistic viewpoint, ITS deployment is key to maximizing efficiency in traffic management. Among the greatest impacts of ITS services are the lightening of congestion and consequent shortening of travel durations. For example, in the Republic of Korea, ITS services have helped increase the average speed of traffic by 15 to 20 per cent[10].

Presenting real-time traffic information to drivers on the road is another way ITS can improve traffic outcome. Drivers, in general, intuitively avoid traffic jams and manage their speed rationally. With reduced congestion and improved traffic efficiency, public transportation (via rail, bus and taxi) becomes ever more punctual and reliable, inducing rising public trust in, and use of, those services.

Improved traffic efficiency also enables transportation managers to respond promptly to traffic incidents. Emergencies can be avoided by alerting drivers to potential hazards, which in turn further reduces congestion and pre-empts accidents.

[8] GHD, <http://www.ghd.com/global/services/intelligent-transport-systems/>
[9] The 8th China Annual Conference and International Exhibition on Intelligent Transport Systems, Sep. 26-28, 2013, available at <http://www.itschina.org/huikan/en/02/index.html>, accessed February 2015.
[10] The Department of Transport of Korea, “ITS Development Strategy”, 2012.

Carbon Emission

Environmentally speaking, ITS deployment induces traffic efficiency and fluidity to grow, and encourages the use of public transport, resulting in reductions in CO_2 emission and other air-borne pollutants such as small particles. Demand for emission reductions will spur the development of public or collective ITS services.

Transportation generates a large share of the environmental burden of CO_2 emissions (especially when counting the extraction of fossil fuels as a polluter in this sector). Data from 2012 from the International Energy Agency (IEA)[11] suggests that transportation accounts for 22 per cent of energy consumption related to CO_2 emission, with 74 per cent of total CO_2 emissions in the sector coming from road traffic. Exhaust emissions thus are a major source of pollution, and the level of particulate emissions in motor vehicle exhaust has a significant impact. Hence, exhaust emissions are a key target in attempts to reduce pollution, as the level of particulate emissions from motor vehicle exhausts are such a significant factor in air pollution[12].

According to the ITS development strategy of the Department of Transport in the Republic of Korea, ITS contribute to decreasing fuel consumption and greenhouse gas emissions through reducing traffic congestion and preventing motor vehicles from idling. Carbon emissions from transport are expected to decline by 12 per cent by 2020. Furthermore, an annual CO_2 reduction of 19,000 tonnes[13] is anticipated when ITS are implemented for 1,000 km of the national highway network. “High Pass”, the electronic toll collection service on major roads, is also expected to achieve an annual reduction of 23,000 tonnes.

Integrated ITS services that support individual vehicles can yield an estimated 15 per cent reduction in carbon emissions[14]. ITS services and technologies, including the Advanced Public Transportation System (APTS) in public transportation, enhance public transport punctuality and usability—a premise confirmed by the ITS development plan of the Republic of Korea. People's use of public transportation will likely increase relative to that of personally owned vehicles[15].

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[11] The International Energy Agency, IEA statistics 2012, “CO2 emissions from fuel combustion – highlights”, available at http://www.iea.org/publications/freepublications/publication/CO2emissionfromfuelcombustionHIGHLIGHTS.pdf, accessed February 2015.

[12] Clean Air Initiative for Asian Cities Center Inc. "ACCESSING: Air Pollution and Greenhouse Gas Emissions Indicators for Road Transport and Electricity", 2012: http://cleanairinitiative.org/portal/node/11573, accessed February 2015.

[13] Korea Road and Transportation Association, available at http://www.krta.co.kr/04_data/data07.htm?Item=board5&mode=view&s_key=2020&x=0&y=0&s_t=1&No=299, accessed February 2015.

[14] RITA, Benefits Database Overview, <http://www.itsbenefits.its.dot.gov/>

[15] The Ministry of Land, Infrastructure and Transport of Korea, “Vehicle Road Transportation ITS Plan 2020”, 2012.06, available at http://www.krta.co.kr/04_data/data07.htm?Item=board5&mode=view&s_key=2020&x=0&y=0&s_t=1&No=299, February 2015.

Economic Value

ITS deployment improves the efficiency in the use of transport infrastructure, which yield economic dividends. Through delivering current accurate real-time information, ITS can help optimize the use of existing infrastructure and transportation systems.

Another dividend from ITS implementation comes from improving efficiency in moving both people and freight, which tends to benefit overall economic activity and productivity. Standardized, integrated forms of co-operation between logistics and road traffic management can enhance the productivity of logistics and transport businesses. ITS technologies using freight tracking systems in coordination with the global positioning system or on-board monitoring help eliminate unnecessary mileage. Such improvements have again yielded a reduction of 15 per cent in freight movement in Scandinavia[16].

ITS solutions not only create economic value within the transport sector, but also lead to the development of a range of front-to-back (or integrated) industries in such sectors as automobiles, electrical equipment, communication networks, software and engineering. ITS services and infrastructure are inconceivable without the coordination of elements from all those sources. In enhancing a national or a city transport network, ITS accelerates the growth of many related industries in a variety of ways. The jobs created tend to be of a skilled and high-quality calibre. In the United States, the Department of Transportation has forecast that 60,000 jobs will be created relating to ITS over the next 20 years[17].

ITS can also contribute to poverty reduction by improving the travel time and travel costs for poorer city dwellers, providing them with new economic opportunities in distant areas of their cities. This is an essential development contribution in large cities in developing countries where large sections of the populations are likely to live in peripheral slums that are remote from economic opportunities, typically situated in urban centres. By reducing the time, the costs and the stress associated with travel time, ITS are likely to contribute to poverty alleviation by – among others- facilitating transit through public transport. Buses are often the mode of choice for urban transport by the poorest in the developing countries[18]

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[16] RITA, op. cit.

[17] Scott Belcher (President of the Intelligent Transportation Society of America), "Congress: Invest in Intelligent Transportation Systems to create jobs", available at: http://thehill.com/blogs/congress-blog/technology/70623-congress-invest-in-intelligent-transportation-systems-to-create-jobs, accessed February 2015.

[18] UN-Habitat 2014. *Poverty and sustainable transport: How transport affects poor people with policy implications for poverty reduction - A literature review*.

II. Overview of ITS Applications and Products

A large range of information and communication applications in the transport sector have been developed in recent years, creating many opportunities to improve the sustainability of transport systems, especially in urban areas. Electronic sensors, geo-positioning navigation systems, video surveillance devices, vehicle probes and wireless communications enable data to be accumulated, analysed and communicated in real time, or near real time, in ways that can greatly improve traffic efficiency and safety. According to recent research, the global market for ITS was valued at USD 14.59 billion in 2012, and is expected to reach USD 38.68 billion by 2020, which represents an annual growth of 13.0 per cent from 2014 to 2020[19].

A. Supporting Infrastructure and Technology

In recent years, ITS-based navigation and monitoring systems have improved with the development and fitting of Dedicated Short Range Communication (DSRC), the Global Positioning System (GPS) and Communication Air-Interface, and Long and Medium Range (CALM) technologies[20]. Of these, DSRC is a short-to-medium-range wireless communication protocol and standard that is widely implemented around the globe as the communication module for Electronic Toll Collection Services[21] (ETCS), operating across a wide frequency bandwidth range. Examples of DSRC usage for electronic toll collection services (ETCS) in developing countries include the “FASTag” system implemented in India and discussed in Box 1. DSRC is a technology for various kinds of transport services using the 10MHz to 75MHz frequency bandwidth in a frequency range of 5.9GHz within an allocated national band. It has a communication range of 300 metres (1,000 feet). In the Republic of Korea, DSRC has been implemented widely in the Daejeon region and successfully used in a traffic information service – a global first[22]. While Japan and Western European nations have mounted similar efforts, they have shown greater interest in harnessing the wireless standard to a range of ITS service developments, including traffic data collection and the Bus Information Service (BIS). These emerging technologies will be compatible and inter-operable with most current ITS technologies.

[19] Available on: <http://www.grandviewresearch.com/industry-analysis/intelligent-transportation-systems-industry>

[20] *Global Intelligent Transportation Systems Market Report 2013, Trends, Adoption Worldwide Forecasts to 2017*.

[21] The Ministry of Land, Infrastructure, Transport and Tourism of Japan estimates that toll-gate congestion represented approximately 30% of all expressway congestions in Japan while ETC users now account for 86.2% of all vehicles on expressways in Japan. Available on: http://www.mlit.go.jp/kokusai/itf/kokusai_itf_000006.html, http://www.mlit.go.jp/road/ITS/pdf/CO2reductionbyITS.pdf, accessed February 2015.

[22] See http://www.tta.or.kr/data/reportDown.jsp?news_num=978, accessed February 2015.

Box 1: Electronic Toll Collection Systems in India

Electronic Toll Collection (ETC) enables clear identification of vehicles registered in a toll payment programme, directly debits accounts of registered users, and provides alerts to law enforcers regarding violations in toll payment regulations.[23] This technology can significantly cut the traffic congestion at toll stations by greatly accelerating the payment process. ETC is becoming an increasingly popular method of toll collection across the world; with technologies such as Automatic Vehicle Identification (AVI), Video Enforcement Systems (VES), Automatic Vehicle Classification (AVC), and Vehicle Positioning Systems (VPS) being employed in a number of countries. ETC is increasingly being applied in several Indian cities for addressing inefficiencies resulting from delays at toll stations.

A joint study[24] conducted by the Indian Institute of Management (IIM) Calcutta and the Transport Corporation of India (TCI) showed that operational inefficiencies encountered by freight transportation vehicles at toll stations in India amounted to a total cost of nearly USD 5.4 billion; with USD 600 million for time wasted in waiting at toll stations across the country, and USD 4.8 billion for extra fuel costs incurred by the slowing down and stoppage of vehicles at toll stations. The findings of this IIM-TIC study were based upon operational efficiency surveys covering 10 major transportation routes of India.

In September 2014, the Indian Government launched the first-ever national ETC programme under the name "FASTag". The FASTag system utilizes RFID devices that are affixed to the windshield of vehicles to be read by the devices installed in dedicated FASTag lanes at toll stations. The appropriate amount of toll tax, determined by the class of the vehicle, is then automatically deducted from the registered user's account.

Under the FASTag programme, ETC systems are operational at an estimated 473 toll stations across India. The first ETC system was opened on the Delhi-Mumbai highway in October last year. After the full deployment of ETC systems nationally, it is anticipated that the estimated stoppage delay at toll stations, ranging between 5% to 25% of the total journey time, will be significantly reduced.

DSRC, being a short-range communication protocol, offers a reliable and competitive technology for vehicle to vehicle (V2V) as well as vehicle to infrastructure (V2I) communications, including for example for the detailed measurement and analysis of the gaps between and speeds of vehicles. One major advantage of DSRC technology in ITS is its extremely low latency in communications[25]. The minimum requirements for DSRC technology to work are a vehicle with a DSRC device, a form of On-Board Equipment (OBE) and a road with Road-Side

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[23] As defined in Indian Institute of Technology Madras. (2010). *Intelligent transportation systems: Synthesis Report on ITS Including Issues and Challenges in India,* available at: https://coeut.iitm.ac.in/ITS_synthesis.pdf, accessed July 2015.

[24] Indian Institute of Management Calcutta and Transport Corporation of India. (2010). *Operational Efficiency of National highways for Freight Transportation in India*. http://www.tcil.com/tcil/pdf/TCI%20&%20IIM%20Study%20Report.pdf, accessed July 2015.

[25] "An Overview of the DSRC/WAVE Technology", Yunxin (Jeff) Li, available at: http://www.nicta.com.au/pub?doc=4390

Equipment (RSE). If the vehicle with OBE travels on a road with RSE, the two devices will communicate with each other through DSRC, sending information that the RSE will typically subsequently relay to a remote processing centre via wireless or fibre-optic links. The information the RSE receives from the OBE can be shared with other RSE and used in analysing traffic flow and congestion. DSRC offers a suite of ITS services including ETCS, the collection and provision of traffic information, and information directed from the roadside to vehicles, such as traffic signalling[26]. The tool can reduce time spent in traffic jams and can play a role in incident management[27]. In the United States, a Vehicle Infrastructure Integration (VII) project was conducted with DSRC technology on main highways across the country, aiming at improving safety and easing traffic congestion. The Smart Way project in Japan further utilizes DSRC technology to provide a vehicle safety and real-time navigation service in order to guide a driver to the most time-saving and safe route, which in turn has an environmental impact in reducing carbon emission[28].

It will be necessary to harmonize frequency usage for ITS to be compatible across borders, allowing drivers to benefit from data transmission as they drive abroad. Efforts to set aside and develop a single frequency might, arguably, be hampered by differences in ITS frequency range among countries—which would necessarily inhibit the development of regionally compatible ITS. In any case, inter-operability among different transportation facilities must be improved if countries want to be able to set up a hyper-connected society based on an ITS installation. A good example of cross-border ITS is provided by the so-called Cooperative ITS (C-ITS; see the explanation in the section below) Corridor Joint deployment project between Austria, Germany and the Netherlands. This project aims at creating a Rotterdam–Frankfurt–Vienna axis as early as 2015. These arrangements comprises a Road Works Warning (RWW) module, which passes along information about any planned road works to drivers, and a Probe Vehicle Data (PVD) module that relays current traffic information through Integrated Traffic Control Centres. Both C-ITS services use as their primary technology such short-range communication protocols as Wi-Fi and DSRC, which operate at 5.9GHz, or cellular networks (3G, 4G). Both applications are expected to enhance road safety and provide the basis for improved traffic flow[29].

Finally, with the increasing data intensity of ITS, the availability of fibre-optic communication along the roads can also be expected to become an important facilitating factor of ITS deployment, as ever larger quantities of data will have to be exchanged, ranging from toll-booth

[26] Study on the future DSRC service and standardization of frequency, Korean Communications Agency, 2002.02, available at http://www.kca.kr/open_content/report.do?act=down&fileno=1&r_no=260, accessed February 2015.

[27] Research on development of performance evaluation of DSRC traffic information system, 2012, available at: http://www.ex.co.kr/cmm/fms/FileDown.do?atchFileId=FILE_000000000004725&fileSn=0, accessed February 2015.

[28] Final report on development of performance evaluation of DSRC traffic information system, Korea Expressway Corporation, 2012.01, available at: http://www.ex.co.kr/cmm/fms/FileDown.do?atchFileId=FILE_000000000004725&fileSn=1, accessed February 2015.

[29] BMVI, Cooperative ITS Corridor Joint deployment, 2013, available at: http://www.bmvi.de/SharedDocs/EN/Anlagen/VerkehrUndMobilitaet/Strasse/cooperative-its-corridor.pdf?__blob=publicationFile

information to updates on real-time traffic conditions from closed-circuit television (CCTV) cameras. ITS networking thus requires a growing capacity for data processing to deal with real-time communication between a wide variety of remote field devices and traffic control centres[30]. Fibre-optic links will therefore play an essential part of ITS infrastructure. Fibre-based ITS infrastructure is displacing twisted-pair copper and coaxial cable for both data and video transmission in urban and rural areas around the world[31]. CCTV video transmission, incident detection, and replacement of traffic-signal loop sensors all contribute to this growth. For transmitting data from roadside ITS infrastructure to a data processing centre, fibre-optic links provide for greater bandwidth, transmission distances and signal immunity[32].

Box 2: The Asia-Pacific information superhighway initiative

The Asia Pacific information superhighway is an initiative supported by ESCAP to close the digital divides by boosting the availability, reliability, resilience and affordability of broadband services across the region. Among other objectives, the initiative aims at filling missing links in cross-country fibre optic cable networks by encouraging the use of rights of ways of other infrastructures to deploy fibre optic cables. This entails encouraging the deployment of fibre along railways, electric transmission lines, pipelines, as well as roads and highways, thereby allowing for important savings, as much of the cost associated with fibre deployment is in fact owed to civil engineering work such as trenching[33].

The fibre that is thus deployed can be leased or sold to telecommunication data carriers, inducing additional revenues for the utility that is hosting the fibre, while providing avenues for expanded broadband networks and services. Typically, railways, high-voltage power transmission lines, and pipelines are by default equipped with fibre optic for supervisory control and data acquisition (SCADA) purposes.

Adding fibre optic cables to roads will therefore not only facilitate the implementation of future data-intensive Intelligent Transport Systems, but also open new opportunities for additional revenues for road operators and expanded broadband networks and services in the region.

B. "Vehicle-to-Everything", an Emerging Core Technology

The term Vehicle-to-Everything (V2X) refers to vehicles sharing useful traffic information with one another with regard to their own movement, using GPS, DSRC and Internet of Things (IoT) technology, among others. Such information can include notification of traffic that lies ahead and warnings of possible collision, information that is shared with other vehicles and road infrastructure while the vehicle is on the road. V2X is a pathway along which most of the leading

[30] FIBER-OPTICS.INFO, Fiber Optic Intelligent Traffic Systems, available at: http://www.fiber-optics.info/articles/fiber_optic_intelligent_traffic_systems, accessed February 2015.
[31] FIBER-OPTICS.INFO, op. cit.
[32] Ibid.
[33] UNESCAP, 2014, *Working paper on Harnessing Cross-sectoral Infrastructure Synergies*, available at: http://www.unescap.org/resources/working-paper-harnessing-cross-sectoral-infrastructure-synergies.

ITS countries in Europe, Japan and the United States are directing their research and business development.

Despite continuous efforts to improve transport systems, challenges related to traffic and road safety remain prevalent. V2X technology may therefore be part of the solution by providing ITS services such as cooperative warnings of collisions, traffic jams and hazardous locations, mainly related to safety. Leading ITS countries are actively promoting the research and development in V2X technology, anticipating the time when vehicles will be able to recognize traffic situations on the road and take action in advance.

A recent survey comparing countries in terms of the number of original technologies and patents in next-generation ITS placed Japan, the United States and Germany as the top three players, followed by France, the United Kingdom and Sweden. The Republic of Korea and Singapore tied as the leading ITS nations in Asia apart from Japan[34]. The survey also estimated the dedicated research funding raised by countries for ITS. The United States has put $77 million into multimodal research, with an additional $14 million into technology transfer and evaluation. Of those funds, research on a connected vehicle related to V2X technologies comprises some $49 million of the multimodal research fund[35].

The Japanese ITS-Spot data system constitutes an interesting illustration of the application of V2X technology. ITS-Spot is a vehicle-infrastructure cooperative system promoted by the Japanese Ministry of Land Infrastructure, Transport and Tourism[36]. ITS-Spot features a network of 1,600 DSRC probe devices communicating with cars and a central system where data are integrated and fed into predictive traffic models in real time[37]. Data collected includes travel data such as time, location and speed, behavioural data including time, yaw and acceleration. ITS-Spot uses interactive communication between vehicles and road infrastructure to provide dynamic route guidance, safe driving support and ETCS. Dynamic route guidance provides optimal route options to a destination by analysing the real-time traffic situation. ITS-Spot can further collect information on emerging or existing accident “black spots” and call drivers’ attention to them, offering an alternative route. Services also include reports of weather conditions at the destination and real-time video of traffic conditions in tunnels, among others. The data collected by ITS-Spot are used in transport surveying and planning (for example continuous travel speed surveys), designing congestion countermeasures, identifying accident-prone areas, surveying conditions concerning the passage of special-purpose vehicles or vehicles transporting hazardous materials, and surveying the usability of roads during heavy snowfall or during natural disasters. The project has resulted in reduced travel time on major axes, identifying hazardous locations on roads, such as points where “sudden braking” occurs frequently, and take remedying actions such as painting warning signs on the road surface or

[34] ITS development strategy to foster a new growth power and realize smart green transportation”, Committee of strengthening national competitiveness, 2012.01, available at: http://www.smarthighway.or.kr/smart_pro/nboard/download.php?mode=mdown&no=901, accessed February 2015.

[35] RITA, ITS Strategic Research Plan 2010-2014, <http://www.its.dot.gov/strategic_plan2010_2014/2010_factsheet.htm>

[36] http://www.mlit.go.jp/kokusai/itf/kokusai_itf_000006.html, accessed February 2015.

[37] http://www.mlit.go.jp/road/ITS/pdf/CooperativeSystemandProbeData.pdf

improving visibility by trimming roadside vegetation. The Ministry of Land, Infrastructure, Transport and Tourism is planning to install 1,500 more ITS-Spot stations with an investment of about $93 million[38].

C. The Co-operative ITS Paradigm

Computing advances have enabled a form of "ubiquitous" communication technology to enhance connectivity among information systems and roads, vehicles and drivers through so-called C-ITS. The International Organisation for Standardization (ISO) defines C-ITS as "[forming] a subset of ... overall ITS that communicates and shares information between ITS stations to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone systems".

These next-generation systems use wireless communication to enable constant communications between vehicles and between vehicles and roadside infrastructure[39]. C-ITS can, for example, inform a driver of potential hazards like roadwork or icy surfaces ahead through messages sent either by vehicles (such as incoming vehicles at an intersection) or through the infrastructure. Ultimately, wireless communication technologies are to be installed in vehicles for a networking system designed to maximize efficiency, safety and comfort for passengers. Austrroads estimates that, with a 100 per cent C-ITS market uptake, serious casualty crashes could be reduced by more than one quarter, perhaps up to 35 per cent[40].

In effect, C-ITS represent an extension of conventional ITS and achieves a greater level of comfort and safety for vehicle users through the provision of real-time information. For example, major vehicle manufacturers including BMW, Chrysler, Fiat, and Volkswagen have organized an industrial association, the Car-to-Car Communication Consortium (C2C-CC), devoted to improving transport safety and efficiency through the application of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) modalities. The consortium aims to establish industrial standards for intervehicular communication in Europe from 2015 onwards, with specific technologies covered under this designation after a verification process. Technologies on the agenda for this vehicle-centred ITS include a warning system for forward collision to protect passengers, route guidance for avoiding congestion and reducing fuel consumption, and intervehicular communication links[41].

D. Advanced Transportation Management Systems

Advanced Transportation Management Systems (ATMS) operate with infrastructure fitted with vehicle detection systems, automatic vehicle identification and CCTV to allow for real-time traffic

[38] Kyung Dong Ryu, "Japanese government, prevention of traffic accidents in advance", <http://www.etnews.com/20140711000180>, accessed February 2015.
[39] AARB Group, presentation on Cooperative Intelligent Transport Systems (C-ITS), available at: http://www.arrb.com.au/admin/file/content2/c7/C-ITS%20webinar%20presentation-final.pdf, accessed February 2015.
[40] Ibid.
[41] V2X communication, rise as a core technology of ITS, Korea Communications Agency, 2014, available at: http://kcaresearch.kr/bbs/bbs_view.asp?pItem=&pType=&idx=170, accessed February 2015.

data to be both sent and delivered through various service devices or facilities including Variable Message Sign (VMS), the World Wide Web or mobile devices. The data are transformed into various ITS services including Real-time Traffic Information, BIS and ETCS. The diffusion of such information helps alleviate a range of environmental and congestion problems. In the case of South East Asia, most mega-cities have installed such ATMS technologies as traffic signals, CCTV and VMS in order to optimize their current transportation infrastructures. An interesting illustration is system recently tested in Bangkok (Thailand), which combines sensors fitted on the highways with probabilistic modelling to evaluate the impact of small changes in traffic patterns, and take remedial actions. (see box below).They have also installed APTS technologies to improve public transportation.

Box 3: Real-time traffic information and traffic condition prediction in Bangkok, Thailand

The Stochastic Cell Transmission Model (SCTM), developed by the Hong Kong Polytechnic University and King Mongkut's Institute of Technology Ladkrabang Thailand, uses predictive mathematical modelling to provide real-time road traffic information for intelligent traffic management systems.[42] This research was awarded the Asia-Pacific Economic Cooperation (APEC) ASPIRE Science Award in 2014.[43]

The traffic prediction system, based on SCTM, uses a probabilistic modelling technique to combine traffic-flow algorithms with highway sensors for creating a real-time information system. This system predicts traffic conditions and anticipates probable deviations in normal traffic, once a minor change in traffic patterns is detected that can have major consequences. The predictions enable the relevant authorities to undertake appropriate traffic-control measures, such as switching lane directions, in order to reduce highway congestion.

When the system was tested on a 17-mile stretch of the Bangkok expressway[44], it resulted in a net economic benefit of USD 1 million over a one-year period, and also successfully streamlined the daily commute in an area serving over 14 million people according to an independent estimate.[45] This system is also being integrated with a mobile application that alerts vehicle drivers of upcoming route congestion and suggests alternatives.

In 2013, ATMS applications accounted for the largest segment of the global ITS market in technology and services at 39.9 per cent, while advanced transportation pricing systems took 26.9 per cent, the Advanced Traveller Information System (ATIS) took 13.2 per cent, the APTS took 12 per cent, and the rest, co-operative systems, took 8 per cent. Between 2014 and 2020,

[42] R.X. Zhong, A. Sumalee, T.L. Pan and W.H.K. Lam. *Optimal and robust strategies for freeway traffic management under demand and supply uncertainties: An overview and general theory.* Source: http://www.researchgate.net/publication/227427054_Stochastic_cell_transmission_model_%28SCTM%29_A_stochastic_dynamic_traffic_model_for_traffic_state_surveillance_and_assignment

[43] APEC. (2014). *Scientist's Traffic Prediction System Cuts Congestion in Bangkok*. Source: http://www.apec.org/Press/Features/2014/0923_ASPIRE.aspx

[44] A. Sumalee. *Deployment of Stochastic State Estimation System and Intelligent Transportation Platform on Southern Ring Road Expressway Corridor in Bangkok*.

[45] As quoted in Wiley. (2014). *Traffic-busting professor wins 2014 Aspire Prize*. Source: http://www.wiley.com/WileyCDA/PressRelease/pressReleaseId-112325.html

APTS is expected to be the fastest-growing market segment, at an estimated compound annual growth rate of 13.7 per cent.

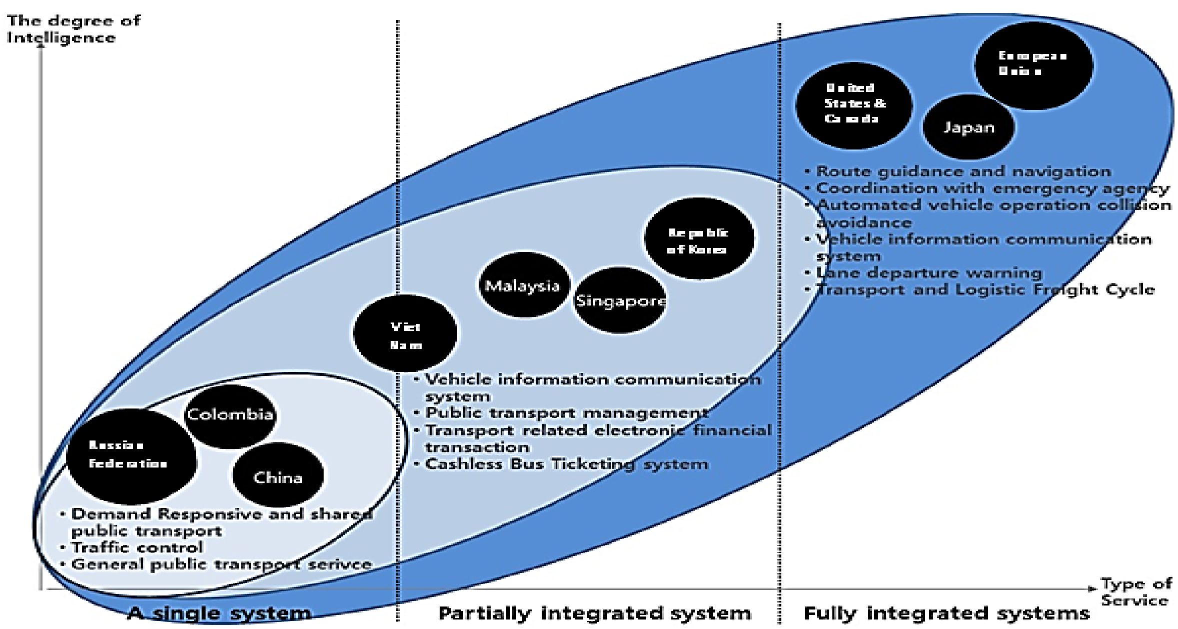
III. Policy and Regulatory Requirements for ITS Services

ITS technology implementation at the national level crucially depends on human resources availability, and the level of political support for the improvement of transport systems. Early in the 1980s, leading ITS countries (a few European countries, the United States and Japan) adopted ITS systems for vehicles, including ETCS and Advanced Vehicle Systems (AVS), while ITS real-time traffic information services with integrated ETCS were mainly developed in the decade after 2000. In the near future, advanced services based on Advanced Traffic Control (ATC) and Advanced Incident Management (AIM), currently under testing, should be commercialized.

Historically, ITS applications have evolved differently in Asia. Developing countries in South East and North East Asia (and in South America) developed ITS services through Bus Rapid Transit (BRT) systems, drawing on national public funds. Those countries sought to address problems of pollution, traffic congestion and runaway urbanization through ITS service-oriented means of electronic payment or traffic management. Such services tended to be based on BIS, Bus Management System (BMS), CCTV and the use of Integrated Traffic Information Centres.

The figure shows various ITS services that operate in different countries, according to the degree of intelligence [Y-axis], corresponding with their status as single systems, partially integrated systems, or fully optimized and integrated systems [X-axis].

Figure 1 ITS service development stages, by country



Source: ISi Lab, Graduate School of Information, Yonsei University, Republic of Korea

A. “Big Data” and Privacy Issues

Despite the advances in security that V2X systems provide, bottlenecks in terms of further reduction in accidents seem to be related to drivers’ physical limitations, such as disabilities, and cognitive limitations – for instance, slow reflexes. Consequently, the trend in ITS services is for such entities as vehicles, pedestrians and traffic infrastructure to become ever more interconnected, with the express aim of preventing traffic accidents[46]. As each entity engages in information-sharing, the connectivity of devices also raises privacy issues, since services could possibly invade users’ privacy at various stages of data collection, storage and analysis.

Some leading ITS countries have invested in next-generation ITS service development. The Connected Vehicle Research project, which is supported by the United States Department of Transport, ITS Japan, and COOPERS in Europe, can be considered a successful research-and-development initiative. Safety Pilot, another ITS service under development whose purpose is to adopt a C-ITS-based passive driving system, is currently at testing and validation stage prior to commercialization[47]. Three regions in Viet Nam (Hanoi, Da Nang and Ho Chi Minh) plan to develop Integrated Traffic Control Centres by 2015. The centres will help collect information about traffic flow, road accidents and closed routes from real-time traffic information that will eventually lead to the easing of traffic congestion.

Applications of big data analysis are used in analysing traffic movements and improving speed and accuracy in the provision of real-time ITS services. The availability of massive amounts of data collected from many different forms of traffic infrastructure (such as V2I and V2V data, congestion and usage data, and payment data from toll roads and public transport), typically leads to the design and implementation of new ITS services.

One form of big data on vehicle users that can potentially be available for collection and analysis is of patterns of personal movement and transport habits. Again, the possibility of invasion of privacy arises. Nevertheless, because the use of personal data can be instrumental in improving safety features of ITS services, the 2013 ITS Congress noted that the key emerging technologies will be associated with big data applications[48]. Bringing together mobile devices and big data analytics, ITS service providers will be able to improve the type and quality of information for users as well as help create services and business models that support the delivery of personalized information to commuters and other infrastructure users. In the ITS-Spot example from Japan described above, the data are collected centrally and analysed to enable improvements in road management and product development, among other research[49].

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[46] Kyung Pyo Kang, “How to innovate safety of C-ITS based transportation”, The Korea Transport Institute Vol. 192 2014.02

[47] V2X communication, op. cit., available at: http://kcaresearch.kr/bbs/bbs_view.asp?pItem=&pType=&idx=170, accessed February 2015.

[48] Evolution and potential of ITS in Japan, Global Trend Briefing, KISTI MIRIAN, available at: http://mirian.kisti.re.kr/futuremonitor/view.jsp?record_no=243526&service_code=04, accessed February 2015.

[49] Vehicle-Infrastructure Cooperative Infrastructure Cooperative System and Probe Data in Japan System and Probe Data in Japan, Ministry of Land, Infrastructure, Transport and Tourism, available at: http://www.mlit.go.jp/road/ITS/pdf/CooperativeSystemandProbeData.pdf .

Big data can also be used in improving public transport, as exemplified by the experience of Seoul Metropolitan City in using big data to design new night-bus routes (see lead 1 below).

Box 4: Creating new bus routes in Seoul with "big data"

Should a 24-hour bus route through the city be established in Seoul? The debate began in the City Hall in 2012 using the Social Networking Service (SNS). To respond to public demand, Seoul Metropolitan City combined public data from transit cards about start-destination points with public transport data from taxicabs and all forms of public transport. Collection of data in this second parameter required the logging of five million discrete events of people travelling between midnight and 5 am. This big dataset was further combined with 30 million bits of data drawn from individual "smartphones". Using geographical information system (GIS) resources, the route designers visualized on a map of how people take public transport at night. Their analysis enabled them to propose ideal bus routes, interval times and bus stop locations, leading to the launch of a big data-based ITS service in September 2013. Within three months, average daily night-bus users reached 6,079, with 138 people per bus. The results suggest that the usage of night-time bus routes is 25 per cent heavier than that of buses operating during the day[50].

B. Using Open Data in Building ITS

In many ITS leading nations, ITS developments have proceeded with the open data movement. "Smart city" development and open government, as well as the open data movement strive to make data accessible to commercial developers whenever possible, and have resulted in an open innovation platform on which new ITS services can be developed, implemented and commercialized[51]. Public agencies collect traffic data from various infrastructural sources such as GPS and telematics; selling, leasing or releasing them freely into the public domain in order for private developers to create ITS-related service applications. Two significant benefits accrue by using open data: first, ITS services can be exploited using Open Application Programming Interfaces (Open API) so that ITS services in various areas can be activated; and second, open data standardization, as implemented when data is collected and passed on, can improve the level of interconnectivity of different ITS services[52].

The open data movement is a significant global engine of growth for ITS services. Government departments should make individual decisions on how much data they want to share openly with the public. Many transportation authorities are providing new or improved services by utilizing open data-based ITS. The need exists, however, not just to offer one-way services to drivers, but to offer services over an open platform that facilitate the release of big data and its analysis and storage by users and third parties. User innovation can help create a range of new

[50] VENTURE SQUARE, http://www.venturesquare.net/529875, accessed February 2015.

[51] Ministry of Land, ITS National Traffic Information Center, Traffic Information OPEN API, http://openapi.its.go.kr/api/openApi, accessed February 2015.

[52] POSSE (Promoting Open Specifications and Standards in Europe), Open ITS Initiatives, http://www.posse-openits.eu/en/Open-ITS-Initiatives/Overview/, accessed February 2015.

ITS services, stimulating further rounds of open collaboration through attracting the participation of global and local entrepreneurs. Open participation to service developments will also build up ITS capacity and grow the capacity to analyse patterns of customer actions using big data.

Leading ITS designers in Europe, the United States and Japan have broadly agreed that the open data movement can act as a business platform for triggering new ITS service developments. Some Asian countries too, have deliberately released data in the transportation field, with India[53] and Singapore[54] setting up open data portals and launching service development to create a genuine ITS service ecosystem. The open data trend should affect other advanced Asian countries and is likely to spread across the region. Examples of setting parameters for use can be found in the Midata programme of the United Kingdom or in Smart Public and Vendor Relationship Management[55] in the United States.

To prevent the abuse of ITS services, secure authentication and authorization procedures are needed. The broadcast of outgoing transmissions, for instance, that reveal user location, may require a more advanced privacy policy and robust security than currently exist. One case where data privacy is built into the system is the Japanese ITS-Spot, in which (a) drivers and vehicles cannot be identified, (b) "probe" data near the point where the engine stops is not transmitted, and (c) the driver can also choose not to transmit probe data. Policy recommendations related to the use of open data in ITS are further detailed in Section IV-F.

Box 5: "Open data" application in Seoul

A highly successful application of open data in the Republic of Korea is "Seoul Bus", which has already been downloaded 10 million times. A university student developed it with Open API that had been released by the Ministry of Land. Users access APTS information to find departure or arrival times of any form of public transportation[56]. The application provides users with precise bus schedules updated in real time. "Seoul Bus" is one of the most popular applications developed under the patronage of Seoul's Public Application Management System, which monitors the quality and the number of people using a number of applications developed for the Seoul Metropolitan Government.

C. Improving the Transport of Goods

Another applicable domain for ITS services is in Commercial Vehicle Operation Systems (CVO) and the management of hazardous materials[57]. The latter service domain is principally served by vehicle-tracking using GPS technology and two-way communication of vehicles ferrying hazardous materials. These technologies minimize the social costs and risks of transporting

[53] http://data.gov.in/, accessed February 2015.
[54] http://data.gov.sg/common/search.aspx?theme=05, accessed February 2015.
[55] See for example: http://blogs.law.harvard.edu/vrm/projects/), accessed February 2015.
[56] See presentation by Juwan Yoo, "Seoul Bus Iphone APP": http://www.internationaltransportforum.org/2010/pdf/Yoo.pdf, accessed February 2015.
[57] US Department of Transportation, RITA, <http://www.itsoverview.its.dot.gov/EMS.asp>, accessed February 2015.

dangerous materials by helping to reduce time on the road, optimize fuel consumption, and avoid the risk of accidents for drivers and other road users.

For the management of large commercial fleets, ITS contributes to reducing logistical processing time in activities such as multiple transportation movements (loading and unloading)[58]. Such systems may contribute to lowering the costs for operators, with vehicles spending less time on the road, thereby enhancing public safety and environmental protection. ICT may enable multi-purpose stations for trucks (weigh, traffic counts, axle number, traffic centres for security and emergency response). GPS is also being used for tracking trucks by customs and border authorities in transit regime (especially for transit countries), to remotely monitor trucks while these are crossing the country from one border point to another.

D. Designing Master Plans and Formulating Standards

Different approaches exist in establishing ITS initiatives and implementing ITS architectures at national level. Leaders such as Japan and the Republic of Korea have developed comprehensive ITS master plans that identify service and technological gaps, and set the groundwork for co-ordination and control of various ITS initiatives. In addition, the outcome statements of a master plan allow the articulation of governance objectives and principles. Each local authority can establish its own ITS plan in accordance with the national plan, providing for a systematic approach. When ITS master plans are designed at a local level without consideration of the national master plan, projects may turn out scattered and eventually present problems of compatibility and inter-operability, spending may also be duplicated.

The scope of an ITS master plan may be drawn up to include basic principles, objectives, a roadmap for ITS development, the design of collaborative private–public partnership types, and a dedicated ITS organization. The Singapore Land Transport Authority, in collaboration with ITS Singapore, developed the Singapore ITS Master Plan 2.0 “Smart Mobility 2030”[59] in 2014, to respond to changing needs and to provide for strategic leadership, guidance and support in facilitating “a connected transport community”. ITS development has succeeded in Singapore, thanks in part to the public–private basis for collaboration. The Authority attracted the participation of many citizens in innovative solutions for commuters that drew on their own experiences with local transportation.

Beyond the important role played by national master plans, ITS development is also greatly enhanced by the usage of common standards. The leading countries in ITS development have established collaborative partnerships across regions that rest on common ITS standards. In Europe, ITS standards are set by the European Telecommunications Standards Institute (ETSI) and the Comité Européen de Normalisation (CEN). In 2009, the European Commission Directorate General on the Information Society (DG INFSO; now DG Connect) of the European Commission and the Research and Innovative Technology Administration (RITA) of the United

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[58] Ministry of Land, ITS Korea, ITS terminology dictionary (2010) <http://terms.naver.com/entry.nhn?docId=2071446&cid=41543&categoryId=41543>

[59] Smart mobility 2030, ITS strategic plan for Singapore, available at : http://www.lta.gov.sg/content/dam/ltaweb/corp/RoadsMotoring/files/SmartMobility2030.pdf

States Department of Transportation exchanged a memorandum of understanding on feasible economies of scale and decreasing development costs. As a result, ITS standardization has proceeded through a series of detailed collaborative tasks[60]. Associations such as ITS America and ITS Japan are part of the collaborative strategy that produces ITS forms and protocols. In particular, the Japanese Department of Transportation established agreements with RITA and DG INFSO in 2010 and 2011 respectively. Japan also has its own ITS standardization committee, deputed to work on supporting international standards and interfacing with ITS Japan.

The International Organization for Standardization (ISO) set up a technical committee devoted to ITS standards (ISO/TC 204) in 1992 that currently comprises 26 participating countries and 27 observing countries[61]. Twelve working groups focus on such topics as ITS architecture, database technology and electronic toll collection, among others[62]. This work is mostly led by developed countries. The work on ITS architecture aims at establishing a system architecture based on sharing roles and responsibilities among different institutions in order to develop a single set of guidelines for ITS services and infrastructure[63].

The proliferation of ITS projects has inevitably led to problems of compatibility and inter-operability within and across countries. Most countries have attempted to standardize their architecture in formulating national ITS strategy or developing ITS infrastructure for different urban areas. The adoption of consistent ITS architecture within each country typically reflects the extent of its holistic thinking about ITS implementation in relation with its national interests and its level of commitment to adoption. Countries tend to standardize ITS architecture in order to enhance systematic planning and effectiveness in resource management. Such architectural thinking helps in setting differential roles for ITS applications and boosting inter-operability among systems. It also minimizes duplication in service development and increases the replicability of various services through enhanced compatibility.

Developing ITS technical and service standards at national level are important for Asian countries. Having such standards in a national ITS strategy can ensure the sustainability, compatibility and capacity to expand ITS services and so contribute to cost management and boost operational efficiency. One key challenge in ITS adoption relates to national capacities to coordinate various stakeholders in the public and private sectors, effectively balancing multiple objectives and interests in ITS deployment. A national standardized process framed by ISO may

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[60] Research on standardization of ITS in-vehicle system, Japan Automobile Research Institute, 2012.03, Available at: http://www.piarc.or.kr/05_board/board_04.htm?Item=board7&mode=download&File=%5B%C0%CF%BA%BB%5DITS+%C2%F7%B7%AE+%C5%BE%C0%E7+%BD%C3%BD%BA%C5%DB%C0%C7+%C7%A5%C1%D8%C8%AD%BF%A1+%B0%FC%C7%D1+%C1%B6%BB%E7+%BF%AC%B1%B8.pdf, accessed February 2015.

[61] ITS Standardization Activities of ISO/TC204, 2011, 2014.

[62] ISO/TC 204 Intelligent transport systems: http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=54706, accessed February 2015.

[63] Ibid.

help in accelerate ITS deployment, since it draws on ITS standards in each participating country. Close collaborative partnerships between ITS standardization groups and local urban policy decision-makers serve to close the conceptual gaps that can impede effective ITS implementation.

Box 6: European plan for deploying ITS

The European Union (EU) has established an action plan for deploying ITS through a collaborative system based on five different themes[64]: (1) optimal use of road, traffic, and travel data; (2) continuous traffic and freight management; (3) road safety and security; (4) integration of vehicles into transport infrastructure; and (5) data protection and liability in terms of European ITS coordination. Through working to meet goals in those areas, developers have designed an open platform architecture for embedding devices in vehicles, begun to collaborate on a standardized data form for individual assessment of journey times, and worked out standardized reference terms for all EU Member States. In particular, those terms comprise detailed definitions of technology, specifications and standardization processes with detailed instructions.

E. Partnership Models for ITS Development

One critical challenge at an early stage of ITS implementation is formulating an executable financing plan with sustainable collaborative partnerships. Government-led approaches often face difficulties in financial planning, since the level of investment required for infrastructure is sometimes beyond local resource levels. Also, ITS funding obviously needs to be sustainable and predictable, which is not always compatible with local political developments. Most ITS projects in China, for example, depend heavily on public funding, although local authorities seek to attract private investors from outside the public sector, relying on a Build-Transfer (BT) model to mitigate financial risks[65]. Indian mega-cities (known as tier-1 cities) such as New Delhi, Mumbai, Bangalore and Chennai have their own authority to promote ITS. However, the smaller cities of Indore, Pune and other tier-2 cities currently lack the technical and financial capacity to develop ITS infrastructure. They have recently turned to the Ministry of Urban Development for support with ITS pilot projects, through a earmarked fund called the Sustainable Urban Transport Project[66].

Official development assistance (ODA) is also a common collaborative mechanism among newcomers to ITS services. Japan is a leading practitioner of this particular partnership form, which it uses for a wide range of ITS development assistance. This includes support for

[64] Commission of the European Communities, Action Plan for the Development of Intelligent Transport Systems in Europe, 2008, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52008DC0886, accessed February 2015.

[65] China Monthly Business Information 46th, 2013. 07, available at: http://china.korcham.net/Service/News/appl/MonthlyReportList.asp, accessed February 2015.

[66] Ministry of Land, Infrastructure and Transport, Republic of Korea: Study on the strategy of ITS promotion and export, 2013, available at: http://www.prism.go.kr/homepage/researchCommon/downloadResearchAttachFile.do?work_key=001&file_type=CPR&seq_no=001&pdf_conv_yn=Y&research_id=1613000-201300091, accessed February 2015.

drawing-up the Manila ITS master plan, the Sri Lankan national tollgate system and development of a toll road network. Viet Nam has established an ODA partnership with Japan to set up national ITS initiatives, while Danang city has signed an agreement with the Japan International Cooperation Agency (JICA) to improve the city's traffic system by offering intelligent parking and public transport.

Besides funding aspects, ITS projects are most likely to succeed when they have the backing, even the technical involvement, of major private-sector players. The automobile industry has been committed over the long term to work with Governments and regulators on the safety of drivers, vehicle occupants and pedestrians. In all ITS leading countries, major automobile manufacturers have participated in research and business development projects and envision the commercialization of in-car and other ITS services (e.g., in Europe, the United States and Japan). All of them have incrementally worked towards increasing the successful commercialization rate of ITS initiatives through private-sector engagement and financial interest.

Active industry engagement and collaboration has been understood in Europe as being central to the commercial validation of new ITS products and services. Some projects run at a pan-European level, while other research and business development initiatives stand independently in individual European countries. Fiat, Volvo and BMW are among the active participants in networked partnership with competing private-sector partners. This could prove an advantage in growing European ITS absorptive capacity. Along with European automobile manufacturers, Japanese automobile companies are mostly active in the development of a road-to-vehicle collaboration system (such as V2X). Nissan, Toyota, Honda, Mercedes-Benz and Volkswagen are collaborating in the "ITS Safety 2010" project with Japanese public agencies responsible for testing road-to-vehicle collaboration systems in various road conditions. The United States Department of Transportation has collaborated with three major automobile manufacturers (General Motors, Ford and Chrysler) on vehicle-to-road collaboration systems since the early 1990s. As part of a strategic research and development plan supported by the Federal Government, six different cities including Dallas, Minneapolis, Orlando and San Francisco have been announced as "Field Operation Test" cities for testing technological feasibility and measuring impact of services in trials running between 2010 and 2014[67].

While the scope for ITS adoption varies across different Asian nations, a trend has emerged regarding transfer of technological knowledge, often related to funding from ITS leaders to adopters. Such leaders as Japan and Korea are focusing on ATMS, ATIS, APTS and CVO. They aim at creating a range of ITS applications by primarily addressing safety and environmental issues, increasingly by incorporating artificial intelligence. At the same time, adopting nations, mostly in South East Asia, are often simply focusing on building an ITS-supported infrastructure to resolve traffic congestion.

Countries where the uptake of ITS has occurred relatively recently are developing operations to control traffic by using CCTV and through providing information services about road use. Their

[67] Republic of Korea, Ministry of Land, op. cit.

services currently operate in limited areas; usually in large or capital cities. In such countries, ITS tend to be bankrolled by international financial institutions such as the World Bank or by donor nations such as the Republic of Korea and Japan. Both financing support and technology transfer from ITS leaders represent sources of capacity development for adopters, who ultimately aim at closing gaps with the leaders. For example, the Republic of Korea has formed a consortium with ITS Korea, KOTRA and the Export-Import Bank of Korea to promote ITS in Asia. This private–public partnership has provided ITS infrastructure development for ETCS, ITS-supported highways and cashless bus ticketing systems (CBTS) in Malaysia (see lead 4), Viet Nam and China. Korean firms currently operate 66 projects in 23 different countries, with total estimated sales of USD 8 million in 2014[68]. JICA currently backs international market entry for Japanese ITS companies in various parts of Asia through ODA funding. Other recent ITS adopting countries are further undertaking forms of liaison with more developed national partners by organizing joint international seminars, formulating their own master plans and conducting feasibility studies.

Box 7: Partnering to develop a cashless system in Malaysia

In 2010, Malaysia launched a project to increase the efficiency of bus route operations and to simplify the calculation of bus ticket charges. The Malaysian Government held that the Seoul cashless bus ticketing system was the best in its field, together with its significant social and economic impacts. Korea Smart Card Co., Ltd. became their partner and LG CNS Co., Ltd. undertook the system development. Rapid KL, one of the largest transportation companies in Kuala Lumpur, designed and fitted out transit card readers, driver consoles and multifunctional devices for selling and charging transit cards in 1,091 buses. In effect, the scheme saw an increase in daily usage of about 20,000 passengers per month (on top of an existing load of 250,000), resulting in a marked drop in congestion and carbon emissions[69].

In conclusion, new technologies and ways of collecting and processing data are already demonstrating their potential for crucial impact on driving safety, reduction in fuel consumption and efficient communication between vehicles, infrastructure and traffic centres. A challenge emerges, however, in the need to standardize policies regarding communication devices and frequency allotment. In the near future, driverless car technologies are likely to attract the most attention in the paradigm shift to transportation systems based on information and communication technology that work equitably for minority population groups like the elderly and disabled. The demand for advanced traffic management systems that promote vehicle safety support and autonomous driving, among other features, will rise as societies develop[70]. Government, police authorities and the private sector will together need to create innovative

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[68] "Government, turn its eyes to overseas for construction orders", Ezyeconomy, 2014.03 <http://www.ezyeconomy.com/news/articleView.html?idxno=52819>

[69] See Intelligent Transport Society of Korea: Study on the strategy of ITS promotion and export – final report, May 2014. Available at: http://bit.ly/1BYaiWC, accessed February 2015.

[70] Korea Institute of Science and Technology Evaluation and Planning, Direction of ITS Improvement for Human and Environment, 2012.06, available at: http://attfile.konetic.or.kr/konetic/xml/market/51A2A1220933.pdf, accessed February 2015.

partnerships in developing new infrastructure for high-quality traffic information and an efficient accident response system.

IV. Regional cooperation for ITS

Despite the promise of benefits and potential from early developments, ITS enjoy policy promotion in only a handful of ESCAP Member States. Countries with national ITS associations currently include China, India, Japan, Malaysia, the Republic of Korea, Singapore and Thailand[71].

Furthermore, Asian countries struggle with a lack of guidelines for ITS implementation, with the absence of ITS regulation, or with the lack of a regional ITS data repository, as well as with high sunk and ongoing implementation costs[72]. The current trends in ITS policy and regulation mainly concern financial support, standardization, capacity development and master planning at a central level[73].

The private sector association that ITS in Asia-Pacific currently only promotes is networking and offers planners the opportunity for cooperatively resolving common ITS problems through its hosting of the ITS Asia-Pacific Forum. International organizations, including international financing institutions appear to be taking a piecemeal approach or pursuing cooperation on a small scale. In the absence of interregional coordination and cooperation in Asia and the Pacific, aggravated by insufficient academic input, ITS integration will remain challenging for this region.

In this context, the following section identifies a set of areas for action for Asia-Pacific countries to support ITS development. In doing so, it highlights some of the synergies that can be tapped through regional undertakings and regional cooperation.

A. The Asia-Pacific information superhighway and fibre optic cables for ITS

The Asia-Pacific Information Superhighway initiative[74] supported by ESCAP, calls for the deployment of fibre optic cables along major road networks as an option to build a connectivity space in Asia-Pacific. Rolling out fibre optics along highways will not only contribute to connecting large urban centres with high transmission capacities, but will also contribute to ensuring that high capacity transmission means are available for future ITS systems development along these highways. Future ITS services may increasingly need fibre for traffic data aggregation and rapid high-volume transmission to regional or national data centres where big data will be stored and processed. The Asia-Pacific Information Superhighway initiative of ESCAP could therefore provide the scope to support ITS and promote interconnectivity between

[71] ITS Asia-Pacific, ITS Guideline for Sustainable Transport in the Asia-Pacific Region, 2013, available at: http://www.its-jp.org/english/files/2013/12/2013.12.5_Final_ITS-Guideline.pdf, accessed February 2015.
[72] Ibid.
[73] Ibid.
[74] Asian Information Superhighway: seamless connectivity for sustainable development in Asia and the Pacific, note by the ESCAP secretariat, 2014, http://www.unescap.org/sites/default/files/Item%202%20E.pdf, accessed February 2015.

countries by encouraging the systematic deployment of fibre along the roads of the Asian Highway Network Agreement.

B. Fostering a cadre of ITS experts through investment in ITS technologies

The rapid development of ITS has not yet brought an end to the high number of road deaths. ITS must increasingly prioritize passenger safety above traffic flow. Most leading ITS countries are investing on V2X technologies by focusing on commercialization of systems that will help improve road safety. Most Asian countries, apart from Japan, the Republic of Korea and Singapore, are late-adopters and should take advantage of assistance in developing their own ITS innovation capabilities and ability to foster ITS experts in both services and technologies. Policymakers should only undertake those forms of ITS development that fit with their sustainable funding model. Specifically, they should seek to win the commitment of Governments for long-run ITS initiatives. ITS can contribute economic growth and help cities become greener and more efficient. Policy initiatives should aim to foster a cadre of ITS experts who are able to understand the real contributions of ITS to sustainable development and to develop a diverse ITS ecosystem. As one source of innovation at national level, cooperation among research institutions and universities will play a critical role in educating future ITS experts. In this context, it is important to understand what are the right sets of skills that countries need in planning, building and operating ITS that correspond with national priorities. Good practices could be surveyed at the regional level for different levels of economic development. A regional dialogue should be fostered to support this exchange of information and practices. Regional training activities could be implemented to grow national capacities to design and operate ITS and to foster a regional ITS expert network.

C. Diversifying ITS services through allocating and improving frequency bandwidth and fibre optics

As interconnections among ITS services increase in density, issues with ITS frequency bandwidth allocation and the means of linking up wireless communication networks such as DSRC need to be resolved. Most ITS technologies to date have communicated in a one-way direction, for instance in having such forms of traffic infrastructure as CCTV to sense vehicle movement. As ITS moves towards bi-directional communication, the potential for ITS facilities to fail in transmitting messages grows because of interference caused by the crossing of ITS frequencies. Standardized frequencies may need to be allocated to a diverse set of ITS services. Furthermore, those standardized frequencies could drive the interconnectivity of ITS across highway systems and, eventually, facilitate cross-border inter-operability of systems, if frequency harmonization is coordinated at the regional level. In turn, that could help facilitate intraregional transport and trade, thereby contributing to regional integration objectives and sustainable development.

D. Developing a global ITS reference model and adopting relevant national master plans

Several Asian countries have developed ITS without making strong commitments to standards or strategy. Their lack of ITS standards is likely to result in lower levels of inter-operability and interconnectivity in ITS applications with their neighbours. Recent ITS adopters such as China and India, among other Asian States, have prioritised traffic-management in their ITS, but challenges in joining up and harmonizing ITS applications may arise in the future, if a strong focus on a global ITS architecture consistency is not embedded in the systems design at an early stage[75].

Most developing countries in the ESCAP region use the ITS reference model provided by the ISO in planning their ITS services. Aiming to boost their national economic competitiveness, countries tend to have recourse to functional reference architectural frameworks in setting out an integrated suite of ITS services that is governed by defined practices. Such frameworks cover various levels of ITS services that deal with different modes of transport including railways, buses and heavy-vehicle travel on roads. Each country should select standardized ITS services based on its current ITS technological capability and needs. Since most Asian countries are developing ITS systems for public transportation, they will be able to adopt standardized reference models for demand-responsive service and traffic control.

Countries that have relatively recently adopted ITS services should proceed incrementally to vehicle-oriented ITS services that include automated vehicle operation, collision avoidance, and vehicle information communication. Efforts to develop those relatively advanced ITS services would be facilitated if countries would adopt a global ITS service reference model. Policymakers should develop projects of interregional co-operation to develop and share a reference ITS service model. Such efforts would improve chances of success if a regional policy dialogue could be sustained via ESCAP or the Asia-Pacific ITS Forum acting as facilitator in sharing ITS service best practices. Meanwhile, countries can rely on the ISO standards to facilitate effective ITS service deployment.

International standards and ITS architecture frameworks need to be embedded in a holistic strategy in which ITS can evolve quickly. Such a strategy should help secure the alignment and connectivity of various ITS systems based on governmental cooperation, detailed principles and guidelines. A national ITS master plan should cover successive roll-out from the first phase of ITS implementation to the planning of emerging technologies and services, not only for leading countries but also for more recent adopters, as shown below[76].

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[75] Dibyendu Sengupta, Intelligent Transport Systems in India, 2014, EBTC, available at: http://ebtc.eu/index.php/sector/transport/transport-news/278-insight-intelligent-transport-systems-in-india, accessed February 2015.

[76] ITS Asia-Pacific, op. cit.

Basic components of ITS national plans are considered to be:

- Traffic status
- Outstanding issues to be resolved
- Issue-specific targets
- Means and technologies for achieving targets
- Implementation systems (planning proposals and implementation organizations) and capacity building
- Roadmap (a schedule for achieving targets)
- Updated plans and processes

Countries should use integrated road mapping to formulate a national master plan that directs the pace and nature of ITS implementation. Such plans should reflect the variation in scope of ITS implementation across different regions. National plans should reflect the guidelines provided by the ITS Asia-Pacific master plan[77]. Further, national plans should adopt standardized ITS architectural framework as per the models provided by the ISO to guide ITS implementation at national level. ESCAP could create a regional repository of national ITS master plans, for easier reference. ESCAP could also support exchanges of practices at the regional level and the designing of model master plans for the region, which could support ESCAP countries in elaborating their own ITS master plans.

E. Building ITS capacity through regional public–private partnership ecosystems

Developing countries may need to cooperate with private-sector partners who already have world-class experience in ITS implementation. One model of collaboration is establishing a test-bed region for validating advanced ITS services and technologies. The most important characteristic of such partnership ecosystems is that they are not one-off trials but undertake testing of a succession of long-term developments in the provision of new ITS services. Furthermore, cooperation with leading ITS countries through ODA, or grants and loans from international financing institutions as the World Bank and Asian Development Bank, may help countries build up their ITS capacity. Adopting countries present opportunities for ITS innovation, facilitated by technology transfer; established nations can also benefit from those opportunities. Liaison with regional companies or Government agencies that have their own human capital and flexible forms of access to market information has the potential to foster new strategic alliances or joint ventures. A new business model of sustainable public–private partnerships is needed in which both national and international companies partner with Governments. “Build–Operate–Transfer” and Project Financing represent two types of partnership capable of fostering sustainable ITS investment that can reduce financial pressure on Governments and municipalities. With the emergence in ESCAP of new regional actors in funding infrastructure for development, further work is necessary to identify ways to finance

[77] ITS Asia-Pacific, ITS Guideline for Sustainable Transport in the Asia-Pacific Region, 2013, available at: http://www.its-jp.org/english/files/2013/12/2013.12.5_Final_ITS-Guideline.pdf, accessed February 2015.

various types of ITS in developing countries. ESCAP could play a role in analysing this particular area of financing development.

F. Fostering open innovation through open data initiatives and collaboration

Big and open data are likely to play a key role in the creation of advanced ITS services. For example, real-time traffic data describing individual road-user actions and interactions can guide the development of new ITS services and applications. GPS information will enable drivers to navigate to urban services, accommodation and refilling points in an optimal manner, all the while receiving updates on traffic flow and local news. Such advantages, however, come with multiple issues of security and privacy for data users. Governments need to regulate the use of personal data by defining legal rights and to establish procedures for enforcing the law that can prevent the abuse of private information. Governments should also set limits on what is considered legitimate regarding collection, processing and use of data for fair personal purposes.

Policy needs to be directed by a detailed plan for governing the categorization of open data and defining the scope of open initiatives, drawing on best practices in Asia and Pacific and beyond. Infrastructure-related open data will be another growth engine for ITS service developments, complementing already-installed ITS infrastructure and attracting young regional entrepreneurs who want to build sustainable business models. Policies need to carefully balance the opening up of large quantities of data with the requirements to protect data privacy and safety. Good practices exist at the regional level and beyond. Regional organisations such as ESCAP can explore and promote such good practice and facilitate policy dialogue on this issue at the regional level.

Countries should pay more attention to developing sensible data security and privacy policies in light of the evolution of ITS towards C-ITS. Along with C-ITS, the IoT will represent another major paradigm shift in IT. Public discussions are continuing on how the IoT will impact future Internet governance, for example under the leadership of the European Commission in the European Union. In order to secure public endorsement of ITS based on big and open data and IoT, policymakers will need to address issues of privacy protection, security, safety, governance, inter-operability and standardization in order to develop a feasible regulatory framework. Regional exchanges of good practices and ensuing sets of guidelines could help additional countries in taking steps towards using big and open data for ITS.

G. The way forward

An emerging field for policymaking, ITS is in need of more systematic in-depth research. Rapid evolutions in information and communications technology are bound to create new applications in transport with potentially huge implications for sustainable development. One area of work that comes to mind, and for which technological progress will have to be monitored carefully is autonomous vehicles. Autonomous vehicles probably have the potential to revolutionise the transport sector, with many important policy implications, including at the regional level.

Further analysis should also be carried out to assess how much ITS can reduce congestion and pollution, and its direct contributions to sustainable development. Future areas for research at the regional level could also include the potential role of ITS in developing safer and more efficient rail systems, in improving journey efficiency and cross-border facilitation. ESCAP could also carry out further analysis on inter-modal interconnected transport systems, with a view to further facilitate trade in goods and the expansion of tourism in the region. Finally, ESCAP could conduct research on ITS applications in other modes of transport that may be more relevant to specific countries given their geographic situation. This includes inland waterways navigation, air traffic control, and maritime transport.

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