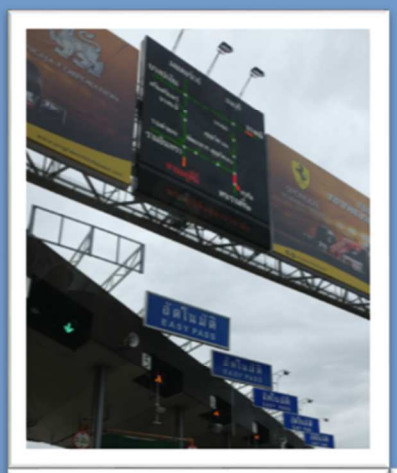
POLICY FRAMEWORK FOR THE USE AND DEPLOYMENT OF INTELLIGENT TRANSPORT SYSTEMS IN ASIA AND THE PACIFIC



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1

BACKGROUND

Dramatic advancements in Information and Communication Technology (ICT), such as smart mobile devices, wireless telecommunications, automated computer technologies and electronic automotive equipment, have revolutionized transport systems in recent years. Severe traffic problems (e.g. congestions, crashes and environmental pollutions) increase the necessity of applying these modern technologies in transport systems as a form of Intelligent Transport Systems (ITS). ITS have immense potential as a key enabler to cleaner, safer and more efficient transport systems in an innovative manner. This can contribute to reduce traffic crashes, travel time, travel costs and associated negative externalities by exchanging real-time traffic information, vehicle information and road conditions. ITS also assist travellers to determine the optimized trips by avoiding unnecessary journeys, congested routes, and selecting better coordination of transport modes. Further, ITS can meet ever-growing traveller's needs flexibly in terms of new mobility services, such as car sharing, bike sharing schemes or personal rapid transit. All these advantages can enhance the efficiency of traffic operations and services in the end.

ITS have come into spotlight for sustainable, efficient and competitive mobility in Asia and the Pacific. The Ministerial Conference on Transport held in Moscow, Russian Federation, in 2016 recognized the importance of ITS in transport systems, and new regional action programmes for 2017-2021 include the role of ITS for sustainable development, such as establishment of regional policy frameworks and tools of ITS, and application of ITS to road traffic crashes. It is expected that by harnessing state-of-the-art ITS technologies, the regional endeavour pursuing sustainable transport systems can be strengthened significantly.

Despite positive potential by ITS, low awareness, limited capacity and rule-of-thumb approaches to such technologies hinder the expandability of effective use and deployment of ITS in Asia and the Pacific. Given that some Asian countries (e.g. Japan, Republic of Korea and Singapore) are regarded as world leaders for ITS technologies, unmissable opportunities exist in the region that those countries can serve as good examples for less developed ITS countries, and thereby they can quickly learn and catch up the advancements. The full potential of ITS can only be

materialized when their uptake and deployment in the region evolves from current limited and fragmented to a continuous and seamless one. An integrated approach for ITS is accordingly required in the region in order to connect trans-Asian road networks in all member countries smoothly. Seamless trans-national ITS services, such as travel information, traffic management and route guidance, cannot be achieved by member countries alone. Furthermore, the concept of "smart city" and "autonomous vehicle" becomes popular in the Asia-Pacific region, which needs suitable preparedness with advanced ITS technologies. Given that the Asia-Pacific region is in a time of fast transition in transport systems, it is proper time to take a closer look for ITS developments and implementations in the region. In this context, as the first step, there is a need to establish regional policy framework in the drive towards utilizing successful practices from ITS leading countries, and harmonizing the policy directions, technology and application development and regulations relating to the use of ITS.

Transport systems form the backbone of the regional connectivity, which boosts international trades, exchanges of people and knowledge, and accessibility to rural and urban communities. While each country has different situations, it is noted that improved transport systems have been regarded as an enabler for successful sustainable development. With recognition of critical roles of ITS in promoting sustainable development, the policy framework is proposed in this report through the analysis of relevant literatures and fact-finding missions to five countries (i.e. China, Malaysia, Republic of Korea, Singapore and Viet Nam) of the region. Collected information is used to identify regional status of ITS, and eventually to develop policy recommendations for the development and implementation of ITS in Asia-Pacific region.

2

THE NEED FOR A POLICY FRAMEWORK IN ASIA AND THE PACIFIC

Although various efforts have been made to address traffic issues, the Asia-Pacific region still faces the following situations that are expected to grow:

- More than two billion inhabitants lived in urban areas in the region, which occupied about 55 per cent of urban population around the world in 2014.[1]

- 17 megacities (of world's 28 megacities that have a population more than 10 million people) are located in the region, and three most populous cities (Tokyo [37.8 million], Delhi [24.9 million], and Shanghai [23 million]) are also found in the region.[2]

- CO_2 emissions resulting from transport are steadily rising, which showed a 3.3 per cent increase between 2011 and 2012, reaching 2,146.5 million tons of CO_2.[3] 84 per cent of total amount of transport-related CO_2 emissions was produced by road transport.[4] Asia accounted for 19 per cent of total transport sector CO_2 emissions in 2006, but by 2030, this figure will increase to 31 per cent.[5]

- Much of the growth in non-OECD (Organization for Economic Cooperation and Development) transport energy use from 2012 to 2040 occurs in the emerging economies of non-OECD Asia, including China (2.7 per cent a year on average) and India (4.4 per cent a year on average).[6]

[1] Statistical Yearbook for Asia and the Pacific 2014 (ST/ESCAP/2704).
[2] Ibid.
[3] Statistical Yearbook for Asia and the Pacific 2014 (ST/ESCAP/2704).
[4] Ibid.
[5] Asian Development Bank, 2009. *Changing Course: A New Paradigm for Sustainable Urban Transport*. Publication Stock No. RPT090487. Manila, Philippines.
[6] U.S. Energy Information Administration, 2006. *International Energy Outlook 2016*. U.S. Department of Energy. Washington, D.C.

- Time losses and transport costs from road congestion imposes an economic cost of 2 per cent-5 per cent of gross domestic product in Asia every year.[7]

- More than 733,000 people were killed by road traffic crashes in the region in 2013, and the average fatality rate was higher than the worldwide average in 2013 (18.99 deaths and 17.4 deaths per 100,000 inhabitants, respectively).[8]

Traffic congestion has been growing in the region steadily as a result of increasing urbanization by population growth, rising use of vehicles and activity concentrations. Ever increasing traffic congestion has led to many detrimental issues, such as energy consumptions, economic losses, air pollutions and crashes. Road networks in many areas in Asia and the Pacific are operating at or near capacity throughout most periods of the day. There is also a continuous demand to mitigate greenhouse gas in the region. Given that transport is one of main contributors to produce CO_2 emissions, addressing transport emissions in Asia is essential for global greenhouse gas mitigation.

It is already acknowledged that coping with traffic congestions by constructing new infrastructure is no longer a valid option, because of financial, space and environmental reasons. ITS, in this regard, has received steady attentions worldwide as a tailor-made measure to address the challenges in cities. Many ITS applications have already shown substantial capabilities on safety, efficiency and smooth operation of transport systems at relatively modest cost.

As emphasized earlier, although in some Asian countries ITS have been implemented for more than two decades, the use and deployment of ITS is still fragmented and largely different across the Asia-Pacific region. The main reasons behind such a current situation are different awareness, technical capacity and a lack of effective cooperation. Despite diverse ITS solutions, mature technologies and local initiatives, this unevenness can lead to the uncoordinated and potentially inconsistent implementation of ITS in the region. This will eventually limit the benefits that can be delivered by the use of ITS. To fulfil the potential, it is important that ITS-related policies are established with clear goals and definable outputs. Regional coordination and cooperation should be also based on clear principles to ensure the optimized use of ITS through interoperable systems and applications tailored to regional conditions. The benefits from ITS interoperability can be maximized when ITS services are efficiently aligned with policies and directions.

In this regard, having an effective policy framework in place will accelerate progress of ITS deployment in the region. The framework could provide general policy recommendations for member countries and their development partners when formulating specific national master plans

[7] Asian Development Bank, 2010. *Sustainable Transport Initiative Operational Plan.* Publication Stock No. RPT102228. Manila, Philippines.
[8] World Health Organization, 2015. *Global Status Report on Road Safety 2015*. Geneva, Switzerland.

on ITS. It is also expected that the policy framework can support to build a truly integrated and user-friendly transport systems through ITS by facilitating broader collaboration and involvement of interested public agencies, research organizations, and private companies in the ITS area. This eventually support Sustainable Development Goals [9] —particularly Goal 11 (to make cities and human settlements inclusive, safe, resilient and sustainable), and target 11.2 (by 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons).

[9] Transforming Our World: The 2030 Agenda for Sustainable Development (A/RES/70/1).

3

OBJECTIVES OF THE POLICY FRAMEWORK

The policy framework aims to encourage the use and deployment of ITS in Asia and the Pacific. Although the boundary of policy framework is broad, this could help member States move advance ITS utilization by identifying applicable ITS services, providing considerations for implementation, establishing recommendations and action plans, proposing regulations and policies, and strengthening collaboration and networking among stakeholders. However, given that this report is the first endeavour dealing with the topic of policy framework for ITS, five distinct components will be provided with consideration of roles of policy framework. Note that even though ITS can be used in various areas of transport, this report focuses on the road transport. The details are as follows:

- Explore specific ITS applications currently in use in road transport in the Asia-Pacific region.
- Provide an overview of new trend of ITS technologies for road transport systems not only in the Asia-Pacific region but also around the world.
- Identify regional challenges and issues in ITS developments and implementations.
- Investigate general benefits of ITS applications that can be observed in the Asia-Pacific regions.
- Provide possible policy recommendations to enhance the use and deployment of ITS for road transport in the Asia-Pacific region.

The policy framework suggested in this report could contribute to lead the followings:

- Bring the attentions about the significant role of ITS in road transport systems in the Asia-Pacific region.
- Increase policy makers' understanding of ITS, including specific regional challenges, issues, benefits and applications.
- Trigger the ITS-related activities and initiatives with consistency of suggested policy recommendations in the Asia-Pacific region.

- Provide the policy recommendations that can be considered within national ITS plans and strategies in member countries, as well as guide the overall future ITS directions in the region.

Because the suggested policy framework is a ground work for the use and deployment of ITS in the region, continuous efforts are expected for the consistent uptake, implementation, integration and coordination of ITS services which promote interoperable and seamless transport services in the region. Also, various users' needs would be met by facilitating the efficient and rapid deployment of ITS driven by the perceived usefulness and benefits of ITS technologies.

4

ITS APPLICATIONS IN THE ASIA-PACIFIC REGION AND A NEW TREND OF ITS TECHNOLOGIES

ITS can provide smart and efficient transport mobility through various solutions. In response to the increasing demands, a wide array of ITS applications has been developed in both land transport and vehicle components, for example, real-time traffic information system, variable speed limits, lane departure warning system and adaptive cruise control. Also, because ITS can integrate transport modes, ITS applications (e.g. automatic fare collection system or multimodal trip planner) can increase the use of multimodal and intermodal transport systems.

Although there is a deluge of ITS applications to attain policy objectives, specific applications that are mostly used in the Asia-Pacific region exist. It is particularly meaningful to explore ITS applications currently in use in the region to understand the regional tendency determined by situations and user's demands, and also to increase the stakeholders' understanding of ITS solutions. Further, given that many attempts have been made to utilize new ICT in transport systems, providing a brief overview of new concept of ITS technologies could increase the awareness of latest trends to policy makers and related stakeholders. Additionally, this overview will be a primary indicator for policy recommendations by considering current and future ITS technologies which are one of major objectives in this report.

A. Most Used ITS Applications in Asia and the Pacific

ITS applications are technology-oriented, meaning that general policy makers are not easy to understand intuitionally. Although numerous applications have been developed around the globe, several applications are found which have been frequently used in the region. To increase policy makers' understanding, brief explanations and examples by each application are provided in layman's term with three major categories—"Advanced Traveller Information Systems (ATIS)", "Advanced Traffic Management Systems (ATMS)" and "Advanced Public Transport Systems (APTS)".

1. Advanced Traveller Information Systems

a) Real-time traffic information system

Real-time traffic information system keeps you updated with specific traffic information in given areas. Traffic information provided ranges from the route navigation to delay information caused by crashes, sever weather or road works. Technically, in order to provide traffic information, relevant data need to be collected, analysed and distributed to the public in real time. Various devices, such as surveillance cameras, fixed sensors, probe cars and mobile phones, are used to gather a number of data, and the Internet, radio, variable message signs and navigation devices are the major distributors of processed traffic information to the public. The primary goal of real-time traffic information system is to allow drivers to avoid traffic congestions by taking available detours, alternative transport modes or trip plans, which helps bring down total travel time and cost incurred by drivers. Ultimately, this can minimize the congestions for the entire transport networks as a whole.

Representatively, Japan started Vehicle Information and Communication System (VICS)[10] in 1996 which collects and processes traffic information through the VICS center. Key information for travel time, congestion and restriction is distributed to the user's navigation system and other on-board devices. VICS operates 24/7, and approximately 42 million units of vehicle navigation systems are compatible with real-time VICS traffic information. It is noted that proper route guidance by using VICS information is implemental to reduce CO_2 emissions and environmental burdens through better traffic flows and fuel consumptions.

b) Variable message sign

Variable Message Sign (VMS) is the most common application to distribute real time traffic information (e.g. traffic congestions, crashes, incidents and speed limit) in the region. VMS informs, warns or guides vehicles on specific roads in order to avoid traffic delays in advance and optimize the efficiency of traffic operations. Successful deployment of VMS involves several steps[11]—the type of traffic data is first investigated, VMS type is determined and proper corridor placement is selected. Finally, with the use of suitable communication scheme, dynamic messages are displayed on the selected VMS type.

Use of VMS is easily found in the region. For example, in 2005, a large VMS system was deployed in China.[12] Thailand also uses VMS as a traffic management tool.[13] Since 2014, Delhi,

[10] Society of Automotive Engineers of Japan, 2014. *Intelligent Transport Systems*. Japan.
[11] Wisconsin Department of Transportation, 2000. *Intelligent Transportation Systems (ITS) Design Manual*. Wisconsin, USA.
[12] Available from http://itsasia-pacific.com/about-its-asia-pacific/examples-of-its-deployment-by-countryarea/2005-vms-system-china/, accessed 2 February 2017.

India, have introduced VMS to alert motorists about traffic delays and guide commuters to use alternative routes at different intersections on major roads.[14] VMS is also prevalent in Australia's major roads and highways. They inform road users of a variety of information, for example, traffic hazards, incidents, lane closures, road works, route guidance, emergency information, real time congestion levels, variable speed limits, weather related traffic conditions and real-time destination travel times[15]. VMS helped increase travel speed in Australia by 13 per cent.[16]

c) Parking guidance and information system

Parking guidance and information system offers real-time information about available parking spots and route guidance to reach them through traffic monitoring systems and traffic information devices (e.g. VMS, the Internet and mobile applications). With the help of this system, users are easily aware of available parking spaces from the origin, which saves wandering time, cost, and eventually reduces congestions while looking for parking spots.

The Land Transport Authority of Singapore introduced Parking Guidance System (PGS) in 2008 with the aim to manage traffic demands. PSG collects information on unoccupied parking spaces from different parking locations across the city through central computer system, and displays the assembled information on electronic information panels.[17]

2. Advanced Traffic Management Systems

a) Adaptive signal control system

Adaptive signal control system allows relieving traffic congestions by clearing accumulated vehicle queues at specific intersections. In accordance with traffic predictions and patterns, this system adjusts traffic signal timings to reduce waiting times and optimize traffic flows. This adjustment offers significant advantages compared to conventional signal control that follows pre-programmed signal timing schedules. Traffic data are collected by traffic sensors, and then analyzed for determining proper signal timing, which is repeated by pre-designed time

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[13] Fukuda, T., A. Fukuda, K. Surasawadee, and P. Praditphet, 2004. *Preliminary Development of Intelligent Transportation System in Thailand.* The Sixth International Summer Symposium organized by Japan Society of Civil Engineers, Saitama University.
[14] Sharma, A., 2014. New system in offing to ease capital's traffic chaos, *India Today*. New Delhi, India. Available from http://indiatoday.intoday.in/story/new-system-to-ease-capitals-traffic-chaos/1/369171.html, accessed 2 May 2017.
[15] Department for Transport, Energy and Infrastructure, 2010. *Variable Message Signs.* K-Net Doc: 1585856. Version No.8, South Australia, Australia.
[16] Available from http://thinkinghighways.com/, accessed 3 April 2017.
[17] Siemens, undated. Singapore close-up, *City Climate Leadership Awards by C40 Siemens Cities.*

period for steady traffic flows.[18] Adaptive signal control system has shown to minimize the frequency of traffic congestions along with fuel consumptions.[19]

Japan, for example, adopted Public Transport Priority Systems in order to prioritize traffic signals for public transport in the network. Japan also introduced Fast Emergency Vehicle Pre-emption Systems which aims to curtail the time taken for emergency vehicles to reach the site of incident or hospital, as well as to prevent corollary traffic crashes by controlling traffic signals to prioritize emergency vehicles.[20] Similarly, Green Link Determining System[21] and Sydney Coordinated Adaptive Traffic System[22] are prominent as forms of adaptive signal control system in Singapore and Australia, respectively.

b) Automatic traffic enforcement system

Automatic traffic enforcement system is one of most effective approaches enforcing traffic laws for enhancing safety and efficiency with the help of monitoring cameras (e.g. red light cameras, speed cameras and parking enforcement cameras). Those cameras detect violation of traffic lights, speed limits and illegal parking. To be specific, cameras can recognize road activities by using detectors embedded into the road surface or radar technology. Digital pictures are taken whenever a vehicle fails to comply with traffic safety regulations[23]—driving within a speed limit or a red-light interval, or staying illegally at specific locations over a given time period. Automatic traffic enforcement systems can "*reduce fatalities and injuries by preventing and reducing traffic collisions and violations along with modifying aggressive drivers' behavior*"[24].

In the Republic of Korea, for example, as of 2012, 1,900 cameras for speeding, 1,800 cameras for signal violation, and 7,000 cameras for illegal parking were installed on the road of 106,000 km.[25] Reduced numbers for crashes and fatalities were observed from 2004 to 2006 by 20.3 per cent and 48.3 per cent, respectively, annually on average after the installations.[26] In Malaysia, new Automated Awareness Safety System is expected to begin in 2017 which manages the drivers by

[18] Federal Highway Administration, undated. *ASCT-Adaptive Signal Control Technologies.* U.S. Department of Transportation.
[19] Atkins North America Inc., 2013. *Adaptive Traffic Signal Control (ATSC)*. USA.
[20] Society of Automotive Engineers of Japan, 2014. *Intelligent Transport Systems*. Japan.
[21] Keong, C. K., 1993. The GLIDE system—Singapore's urban traffic control system*, Transport Review,* Vol. 13, Issue 4. (Published online 13 March 2007). Available from http://www.tandfonline.com/doi/abs/10.1080/01441649308716854?journalCode=ttrv20, accessed 2 March 2017.
[22] Government of New South Wales, 2011. *SCATS-Sydney Coordinated Adaptive Traffic System.* RTA/Pub. 11.401. Australia.
[23] Available from http://roadsafety.transport.nsw.gov.au/speeding/speedcameras/howdo_theywork.html, accessed 1 April 2017.
[24] Ibid
[25] The Korea Transport Institute, 2016. *ITS Developments in Korea, ITS Master Plan 2020*. Asia Leadership Program. Republic of Korea.
[26] Road Traffic Authority, 2008. *Research on ATES Effectiveness (I).* Republic of Korea.

suspending or cancelling the driving licenses who flout traffic rules, with an integration of the Automated Enforcement System using cameras.[27]

c) Road weather information system

Road weather information system provides comprehensive information on weather conditions related to road traffic[28], which could improve mobility, safety and productivity in transport systems. Environment sensor stations gather and transfer detailed meteorological data to automated warning systems, traffic operation centers, emergency operation centers, and road maintenance facilities using wireless or wired communication networks near real time.[29] The data collected is therefore used for traffic management, traveller's information, road maintenance, and emergency response that are subject to changing weather.

In China, the Nanjing Institute of Transportation Meteorology has constructed weather monitoring network system on the Shanghai-Nanjing Expressway, which provides real time weather monitoring information, weather disaster warning, and forecasting information to various information panels on the expressway.[30] New Zealand is also developing innovative weather solutions through its National Meteorological Service (MetService) in order to inform the impact of weather changes on road users and transport agencies.[31] MetService installed a solar-powered webcam and automated weather station to collect relevant information on major links in Dunedin Northern Motorway.[32]

d) Traffic incident management system

Traffic incident management system consists of a multi-disciplinary process—emergency detection, response, and clearance of traffic incidents—in order to preserve steady traffic flows and restore it as safely as possible.[33] This system is effective on reducing the duration required and impacts by traffic incidents for road users and crash victims, thereby minimizing consequent

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[27] Carvalho, M., 2017. Warning to traffic offenders, *The Star Malaysia*. Available from https://www.pressreader.com/malaysia/the-star-malaysia/20170118/281629599970477, accessed 1 May 2017.
[28] Available from http://www2.gnb.ca/content/gnb/en/departments/dti/highways_roads/content/transportation_systems/road_weather.html, accessed 1 May 2017.
[29] Federal Highway Administration, 2002. *An Introduction to Standards for Road Weather Information Systems (RWIS)*. U.S. Department of Transportation.
[30] Mingliang, Y., Y. Chengsong and P. Xinmin, 2009. Weather monitoring and forecasting services for provincial highways and railways in China, *World Meteorological Organization,* Vol. 58 (2). Available from https://public.wmo.int/en/bulletin/weather-monitoring-and-forecasting-services-provincial-highways-and-railways-china, accessed 11 April 2017.
[31] Available from http://metraweather.com/press/Road-weather-innovations-at-ITS-World-Congress-2016, accessed 1 May 2017.
[32] Ibid.
[33] Available from http://www.idot.illinois.gov/transportation-system/safety/roadway/traffic-incident-management, accessed 12 February 2017.

incidents. [34] This effort can not only reduce congestion costs but also lower social costs—medical and insurance costs—since it is rapidly responsive to traffic incidents.

Hong Kong, China, developed a Traffic and Incident Management System (TIMS) to seek for efficient management for traffic incidents, and also to disseminate relevant information to the users. [35] TIMS comprises various measures to attain its goals, such as automatic incident detection, traffic and transport contingency plans, traffic controls and surveillance systems.[36] Australia has deployed automatic crash notification system, which helps traffic incident management by detecting collisions and automatically notifying relevant information to a third party to initiate the emergency response by proper authorities.[37]

e) Ramp metering system

Ramp metering system is originally *"a strategy used to regulate the volume of vehicles entering a freeway at a given time thereby seeking optimal freeway operations*"[38]. Access to the highway is controlled by traffic signals powered by calculations using real-time data to decide the rate at which vehicles should enter the highway. Breaking up vehicle platoons, vehicles in the mainline do not need to reduce their speed in order to let others merge in the freeway. This system, therefore, eases highway congestions and increase the road capacity and safety.

Melbourne in Australia adopted a large ramp metering network along the entire inner-city M1 route that includes the CityLink Tollway, the WestGate Freeway and the Monash Freeway.[39] Similar ramp metering system is also found in Sydney to regulate the access to certain major roads. Taiwan Province of China has also established a ramp metering system since 1993.[40] Increasing a smoother and more reliable journey, Taipei deployed ramp metering systems to prevent congestions during peak hours, but public transport is an exception to bypass the traffic control imposed by ramp meters.[41]

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[34] U.S. Department of Transportation, undated. *Intelligent Transportation Systems for Traffic Incident Management-Deployment Benefits and Lessons Learned*. Available from https://ntl.bts.gov/lib/jpodocs/brochure/14288.htm, accessed 14 February 2017.
[35] Department of Transport, 2017. *Traffic and Incident Management System*, Government of the Hong Kong Special Administrative Region. Available from http://www.td.gov.hk/en/transport_in_hong_kong/its/intelligent_transport_systems_strategy_review_and_/traffic_and_incident_management_system/index.html, accessed 1 May 2017.
[36] Ibid.
[37] Ponte, G., G. A. Ryan, and R. W. G. Anderson, 2013. *Automatic Crash Notification*. CASR Report Series, CASR124. Centre for Automotive Safety Research, The University of Adelaide, Australia. Available from http://casr.adelaide.edu.au/publications/list/?id=1434, accessed 1 May 2017.
[38] Federal Highway Administration, 2014. *Ramp Metering: A Proven Effective Strategy.* U.S. Department of Transportation.
[39] Vic Roads, 2013. *Appendix A: Freeway Ramp Signals – Information Bulletin,* Victoria, Australia.
[40] Available from http://www.freeway.gov.tw/Publish.aspx?cnid=87&p=78, accessed 12 February 2017.
[41] Shan, S., 2011. Buses exempt from ramp meters on freeway No. 5, *Taipei Times*. Available from http://www.taipeitimes.com/News/taiwan/archives/2011/08/01/2003509666, accessed 12 February 2017.

f) Electronic toll collection system

Electronic Toll Collection (ETC) system allows users not to have to stop and pay cash at a toll booth[42], rather uses cashless payments based on wireless communication between in-vehicle devices (on-board units) and toll gate receivers[43]. Automated electronic tolling system can mitigate traffic delays caused by manual payments near toll plazas; thus, traffic flows and road capacity are significantly improved, and associated secondary impacts, such as fuel consumptions and air pollutions, can be reduced.

Also, this application is used to manage traffic demands, called Electronic Road Pricing (EPR) system, which charges vehicles for using priced roads according to the level of congestions. Based on the "pay-as-you-use" principle, ERP rates vary for roads and time periods depending on local traffic conditions (i.e. higher rates are charged during the peak hours, but lower rates or no charges are levied at other times) in order to reduce traffic demands and traffic congestions in a given time period. Using alternative modes, such as bike, walk or public transport, is accordingly encouraged which is the ultimate objective of this system.

China deployed ETC nationwide, that is, 29 provinces adopted ETC with 98.8 per cent of mainline toll stations with ETC lanes and 89.2 per cent of ramp toll stations with ETC lanes[44]. The pilot projects for ETC have also been proposed for main national highways in India, for example in Chandigarh-Parwanoon NH-5 and Ahmedabad-Mumbai highway.[45] The Republic of Korea has particularly seen positive outcomes from the introduction of ETC lanes (called "Hi-Pass") since 2007. 53 per cent of highway users have been using the Hi-Pass system as of 2013.[46] It was found that there was a decline in 14.8mL of fuel consumption and 34.6g of CO_2 emissions, when a single vehicle run by gasoline used Hi-Pass lane.[47]

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[42] Asia-Pacific Telecommunity, 2016. *Working Document toward Revision of APT Report on "the Usage of Its in APT Countries".* Document No AWG620/TMP-44, 6-9 September, Bangkok, Thailand.
[43] Times Mobility Networks Co., Ltd, undated. *ETC Electronic Toll Collection System.* Available from https://www.timescar-rental.com/beginner/etc.html, accessed 13 April 2017.
[44] ResearchInChina, 2016. *China ETC (Electronic Toll Collection),* Industry Report 2015-2019. Available from http://www.researchinchina.com/Htmls/Report/2016/10213.html, accessed 13 April 2017.
[45] Rawal, T., and V. Devadas, 2015. Intelligent transportation system in India – a review, *Journal of Development Management and Communication.* Vol. 2, No. 3. Available from https://www.researchgate.net/publication/286928014, accessed 1 May 2017.
[46] Lee, K. 2013. *Korea Smart Card Status and Proposal*, IC Card Research and Development Center. Republic of Korea.
[47] ITS Korea, 2014. *2013 Modularization of Korea's development Experience: Establishment of Intelligent Transport Systems (ITS).* Ministry of Land, Infrastructure and Transport, Republic of Korea.

Singapore's Land Transport Authority implemented ERP system in 1998. The effectiveness has been proved in dealing with traffic congestions along with curbing air pollution.[48] Furthermore, the government of Singapore was able to accumulate $90 million worth of revenue from ERP in 2010.[49] Hong Kong, China also conducted pilot tests and feasibility study[50] on ERP but plans are still facing opposition by local councillors[51].

3. Advanced Public Transport Systems

a) Electronic fare payment system

Electronic fare payment system allows users of public transport to pay electronically by smart cards, which is also known as automatic fare collection system. This system uses three main techniques consisting of electronic communication, data processing and data storage. [52] Users simply touch the smart cards containing an integrated circuit chip every time they access the compatible transport modes. A pre-set amount of fare is then deducted from the smart cards. By using this system, various objectives of transport policies can be realized because of the increased user's convenience and comfortableness, and associated costs from manual fare collection would be reduced.

Many Asian countries have progressively adopted this system. For example, Australia uses Smartrider in Perth, GoCard in Brisbane, Myki in Melbourne, Metrocard in Adelaide and Opal in Sydney.[53] Other countries also have been benefitted from this system, such as Japan (Suica[54] and Pasmo[55]), Philippines (Beep[56]), and Republic of Korea (T-money[57] and EB[58]). Ever since smart cards were adopted in the Republic of Korea in 1996, the number of card users for public transport has been increasing. As of 2012, 95 per cent of public transport users carried smart cards for their commute.[59]

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[48] Singapore Technologies Electronics Limited, undated. *Electronic Road Pricing for Singapore.*
[49] Siemens, undated. Singapore close-up, *City Climate Leadership Awards by C40 Siemens Cities.*
[50] Department of Transport, 2017. *Feasibility Study on Electronic Road Pricing.* Government of the Hong Kong Special Administrative Region. Available from http://www.td.gov.hk/en/publications_and_press_releases/publications/free_publications/feasibility_study_on_electronic_road_pricing/, accessed 12 April 2017.
[51] Allen, A-Y., 2016. Electronic road pricing plan for Hong Kong's Central district slammed by local councillors, *South China Morning Post*. Available from http://www.scmp.com/news/hong-kong/health-environment/article/1922978/electronic-road-pricing-plan-hong-kongs-central, accessed 12 April 2017.
[52] Available from http://floridaapts.lctr.org/technology_electronic.html, accessed 12 April 2017.
[53] Available from http://thinkinghighways.com/, accessed 12 April 2017.
[54] Available from http://www.jreast.co.jp/e/pass/suica.html, accessed 3April 2017.
[55] Available from http://www.pasmo.co.jp/, accessed 3 April 2017.
[56] Available from http://www.beeptopay.com/, accessed 3 April 2017.
[57] Available from https://eng.koreasmartcard.com/en/aeb/main/main/readMain.dev , accessed 15 April 2017.
[58] Available from http://www.ebcard.co.kr/eb/co/companyOverviewEn.do, accessed 1 May 2017.
[59] ITS Korea, 2014. *2013 Modularization of Korea's Development Experience: Establishment of Intelligent Transport Systems (ITS).* Ministry of Land, Infrastructure and Transport, Republic of Korea.

b) Automatic vehicle location system

Automatic vehicle location system determines the geographical location of a vehicle by using global positioning system in real time. Transport operators use this system to create direct communications between the traffic operation center and vehicles[60], which supports to manage fleet performance, route selection, schedule control and emergency response. Because this system provides the real-time location of vehicles, it can evaluate the performances of vehicles and drivers, and also can be integrated with other ITS applications, such as electronic fare payment system and automated passenger information system.

As an example, when Singapore adopted the smart card system in 2002, the Vehicle Location System (VLS) was part of the system to track the location of buses and analyze their movement to determine adaptive fares for the passenger.[61] In the Islamic Republic of Iran, a case exists to track the stolen vehicles by using VLS in the police center.[62]

c) Automated passenger information system

Automated passenger information system (also called as "bus information system") provides real time passenger information, which primarily includes arrival and departure time, and location information obtained from automatic vehicle location system. By providing real time information of public transport to travellers, the system increases user's convenience to conduct their journey confidently, including taking any necessary steps in the event of delays. The possible passengers can receive the processed information through the Internet, mobile applications, and information terminals at stations. With this system, users' boarding schedules can be adjusted flexibly by monitoring the real-time location of bus, and thereby, users' satisfaction would be significantly improved.[63]

[60] Available from https://www.ssatp.org/sites/ssatp/files/publications/Toolkits/ITS%20Toolkit%20content/its-technologies/automatic-vehicle-monitoring/automatic-vehicle-location.html, accessed 24 March 2017.
[61] Asia Pacific Smart Card Association, 2002. *Contactless Smart Card Schemes in the Asia Pacific Region.* Hong Kong, China.
[62] Mahdavifar, S. A., G. R. Sotudeh, and K. Heydari, 2009. *Automatic Vehicle Location Systems*, World Academy of Science, Engineering and Technology 54.
[63] Caulfield, B., and M. O'Mahony, 2003. *Real Time Passenger Information: The Benefits and Costs*, Association for European Transport. Available from http://abstracts.aetransport.org/paper/download/id/1546, accessed 1 May 2017.

Many cases are found in Asia. Viet Nam is one of the countries where implemented this system. As of 2015, information terminals were installed at 24 bus stops.[64] In Thailand, similar applications called "Trafy" and "TVIS" based on traffic-related information has been developed by National Electronics and Computer Technology Center.[65] The Republic of Korea adopted this system in 72 local cities, and an increase of bus passengers by 21.4 per cent was noticed in 2011.[66]

B. New Generation of ITS Technologies in Transport Systems

The advent of new technologies, such as Artificial Intelligence, Internet of Things (IoT) and big data analytics, affects ITS technologies in transport systems. To provide basic backgrounds for new ITS technologies, three representative concepts, "connected vehicles and cooperative ITS", "autonomous vehicles" and "smart city", are discussed in this section. Note that although some of concepts are now being implemented or developed in the Asia-Pacific region, most concepts are still in their infancy in most countries of the region. To share the concepts, status and features, the scope of exploration in this section is extended from the region to the globe.

U.S. Department of Transportation (USDOT)'s National Highway Traffic Safety Administration (NHTSA) has defined vehicle automation into five levels[67]. The higher level means the more automated vehicle.

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

- Function-specific Automation (Level 1): Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.

- Combined Function Automation (Level 2): This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centring.

[64] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II), Final Report –Summary.*
[65] Ibid.
[66] The Korea Transport Institute, 2016. *ITS Developments in Korea, ITS Master Plan 2020*. Asia Leadership Program, Republic of Korea.
[67] Available from http://autocaat.org/Technologies/Automated_and_Connected_Vehicles/, accessed 8 April 2017.

- Limited Self-Driving Automation (Level 3): Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The second-generation Google car is an example of limited self-driving automation.
- Full Self-Driving Automation (Level 4): The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. The third-generation Google car is an example of full self-driving automation. Vehicles with level 4 automation may also be referred to autonomous vehicles.

From the hierarchy, level 3 ("cooperative ITS and connected vehicles" in the report) and level 4 ("autonomous vehicles" in the report) are discussed with concepts and proper cases.

1. Connected vehicles and cooperative ITS

Connected vehicles and Cooperative ITS (C-ITS) are based on Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Everything (V2X) technologies which might be considered as part of level 3 in NHTSA definition.

a) Connected vehicles

According to the USDOT, connected vehicle technology will enable "*cars, buses, trucks, trains, roads and other infrastructure, and our smartphones and other devices to "talk" to one another"* [68] . By using V2V technologies and wireless communications, such as DSRC (Dedicated Short-Range Communications), cellular, Wi-Fi or satellite, vehicles on roads can acknowledge other vehicles' information by communicating with each other. Drivers are capable of reacting promptly to unexpected situations through notifications or alerts for bad road conditions, sudden stops ahead, or out of sight for driving. Applications with connected vehicle technologies are a large set of types, encompassing mainly safety (e.g. red light violation warning and forward collision warning), mobility (e.g. dynamic speed harmonization and cooperative adaptive cruise control), environment (e.g. dynamic eco-routing and eco-approach/departure at signalization intersections), and weather (e.g. weather response traffic information).[69]

[68] Available from https://www.its.dot.gov/research_areas/connected_vehicle.htm, accessed 8 April 2017.
[69] Available from

Because a number of benefits are expected through vigorous development of connected vehicle technologies, a report[70] from the USDOT summarized the followings representatively:

1. *"Improved safety, mobility, system efficiency, and access to resources for disadvantaged groups, and reduced negative environmental impacts such as vehicle emissions, the need for physical expansion, and noise."*

2. *"Increased opportunities to partner with non-government groups, such as private industry and universities."*

3. *"Real-time and real-world data to help with transportation planning and transportation system operations."*

4. *"Demonstrations of connected vehicle environments that fit into real-world environments of today."*

5. *"Reduced fatalities through weather-related, safety, infrastructure-based, and other applications."*

Diverse research and business developments for connected vehicles are currently being made by leading ITS countries in Europe, the United States of America (USA), and some Asian countries. For example, the USA already launched a pilot safety study (Safety Pilot Model Deployment[71]) led by the USDOT and NTHSA with nearly 2,800 vehicles testing V2V applications in 2012. 27 roadside units along with 75 miles of roadway were also installed in this study to test the V2I applications for traffic signal timing and emergency vehicles. In addition, the USDOT has selected three sites to test connected vehicle technologies to improve vehicle and pedestrian safety as well as traffic flow. This has been made through the Phase 1 of Connected Vehicle Pilot Deployment Program within up to 50 months. $178.8 billion in societal benefits annually are expected if connected vehicle safety applications are deployed across the entire U.S. vehicle fleet[72]. On top of that, Connected Vehicle Reference Implementation Architecture (CVRIA) has been established in the USA. CVRIA provides *"the basis for identifying the key interfaces across the connected vehicle environment which will support further analysis to identify and prioritize standards development activities"* [73].

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https://www.its.dot.gov/pilots/cv_pilot_apps.htm, accessed 8 April 2017.

[70] Research and Innovative Technology Administration, undated. *Guide to Federal ITS Research-Including Connected Vehicles.* FHWA-JPO-13-049. U.S. Department of Transportation.

[71] Available from https://www.its.dot.gov/research_archives/safety/safety_pilot_plan.htm, accessed 9 April 2017.

[72] Cronin, B., undated. *Connected Vehicle Benefits.* Research, ITS Joint Program Office, U.S. Department of Transportation.

[73] Available from http://local.iteris.com/cvria/, accessed 1 May 2017.

In Europe, the European Automotive Telecom Alliance (EATA) presented next roadmap for testing connected driving functionalities, including pilot projects and the on-going regulatory talks. The start in 2017 will take place in five EU countries (i.e. Belgium, France, Germany, the Netherlands and Spain), and other European countries are expected to join the project at a later stage. Another EATA's project (called CONCORDA) targets to enhance the functionalities (automated highway chauffeur, truck platooning and automated collision avoidance) for existing pilot projects.[74] In Asia and the Pacific, Australia has proved to be a leader in connected vehicles with the Cooperative Intelligent Transport Initiative[75], one of the world's first large scale test projects of V2V and V2I communications in heavy vehicles. Based in the region of Illawarra, the trial takes place on 42 km of crash prone road going from Port Kembla to Hume Highway, New South Wales.[76]

Noticeably, collaborative work has been initiated for connected vehicles around the globe; for example, the EU, USA and Japan set up the forum ("EU/US/JP Task Force") on connected vehicles to exchange experience and information. Lists of applications which require the use of communications for both V2V and V2I have been created by the European Telecommunications Standards Institute "Basic Set of Applications" and CVRIA, led by the United States Intelligent Transport Systems Joint Program Office[77]. In addition, a joint task force of the World Road Association-PIARC and the International Federation Automotive Engineering Societies have developed a report ("The Connected Vehicle"[78]) exploring the perspectives on a commercial and public sector, and discussing issues and implementation factors. Lastly, according to the analysis from the Groupe Spéciale Mobile Association[79], the market size for connected vehicles is expected to increase dramatically—the global connected vehicle market will be worth €39 billion in 2018, up from €13 billion in 2012.

b) Cooperative-ITS

Modern transport systems become more complex since it needs to respond sensitively to users' various demands. With many independent systems working together in the same

[74] Available from http://www.acea.be/press-releases/article/connected-and-automated-driving-eata-presents-deployment-roadmap-submits-pr, accessed 2 May 2017.
[75] Available from http://roadsafety.transport.nsw.gov.au/research/roadsafetytechnology/cits/citi/index.html, accessed 20 April 2017.
[76] Transport and Infrastructure Council, 2016. *National Policy Framework for Land Transport Technology: Action Plan 2016-2019.* Australia.
[77] Available from http://local.iteris.com/cvria/, accessed 14 March 2017.
[78] Technical Committee B.2 Road Network Operations, 2012. *The Connected Vehicle*. PIARC Ref: 2012R02EN. Available from http://www.piarc.org/en/order-library/13731-en-The%20connected%20vehicle.htm, accessed 1 May 2017.
[79] Groupe Spéciale Mobile Association, 2013. *Connected Car Forecast: Global Connected Car Market to Grow Threefold Within Five Years.* London, U.K.

environment, some describe it as a "Complex Adaptive System of Systems"[80]. This complexity should be tackled by new approaches which are more adapted for the constant evolution of technology. An innovative form of ITS is needed accordingly as to manage effectively and control the ever-growing complex systems.

An ideal form is represented as the "Concept of Operations"[81]. This concept proposes a modular and open design of ITS applications that can be connected easily in order to create a fully connected ITS network.[82] In this concept, interoperability is essential so as to turn ITS applications into a multi-purpose platform capable of tasks repurposing. Currently, most existing ITS are working in silos. Even though one ITS application is an integrated system by itself with various technologies, each ITS application is not easy to be integrated to other ITS applications. The one way to combine them is through the control center which has a limitation to respond quickly to external needs (e.g. disaster or emergency events). Standardization is a prerequisite to achieve full interoperability among ITS applications, which will improve resiliency against user's demands.

To surmount the limitation of previous ITS concept, C-ITS was developed as an advanced stage of ITS where a mobile communication-based ITS is utilized based on V2V and V2I technologies. It is expected that future ITS applications will rely on these V2V and V2I in a context of multimodal and multinational environment. These technologies rely on three major components—vehicular on-board units, infrastructure roadside units, and central managerial system. In the very near future, the digital connectivity with these components will be realized which is the domain of C-ITS.[83]

Figure 4.1 illustrates the basic concept of C-ITS with comparison of current ITS. In C-ITS, each vehicle communicates with each other and infrastructure by V2V and V2I technologies, respectively, while limited traffic information is collected and distributed in current ITS. All necessary information is shared with vehicles which can respond quickly to unexpected events on roads. Based on the recent study, experiments on potential impact of using such technologies showed positive benefits in reducing crashes and fatalities on roads.[84] C-ITS takes transport systems a step further as it takes advantage of the latest enhancements and additional services implied by the connection of systems together.

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

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

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

[83] Ibid.

[84] ITS Korea, 2014. *Establishment of ITS*. ISBN 979-11-5545-112-0 94320. Ministry of Land, Infrastructure and Transport, Republic of Korea.

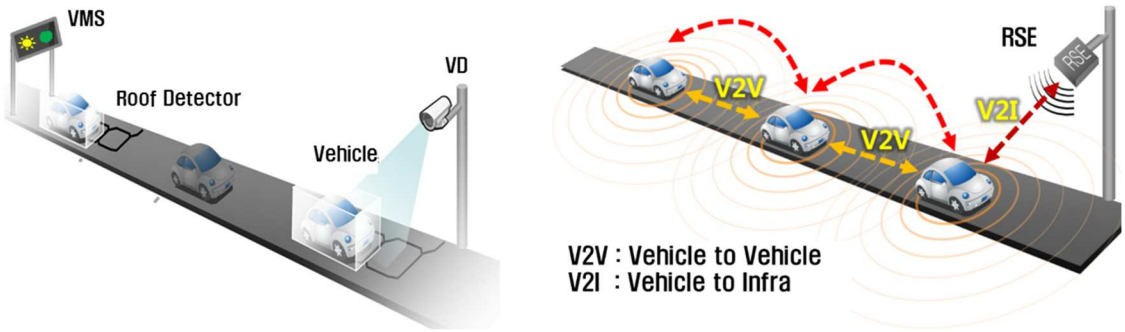

Figure 4.1 The comparison of conventional ITS (left) and cooperative ITS (right)[85]

Some European countries, Asian countries and the USA already set up the plan to implement C-ITS by authorities' guidelines as part of transport strategies for the future. For example, in Europe, projects are being set up to prepare the commercialization of the C-ITS (Cooperative systems for Sustainable Mobility and Energy Efficiency [COSMO][86] and Compass4D[87] from 2013 to 2016) and plan to reach an agreement that the C-ITS will be in place by 2015 through the consortium with vehicle manufacturers (Car-2-Car Consortium[88]). As for Japan, concept of C-ITS is also being thoroughly verified with regional trials concerning Smartway, Advanced Safety Vehicles (ASV) and Driving Safety Support Systems (DSSS), along with the launch of nationwide projects (ITS Spot[89]). The Republic of Korea is also a leading contributor in the development of ITS technologies adopting regularly "National ITS Master Plan" in order to proceed the evolutive ITS phases.[90] China is on the way to determine opportunities in implementing C-ITS, with Cooperative system for Highway Ramp Safety in Beijing-Tianjin Expressway (2012), for example, and Technology Development on Vehicle and Road Cooperation (2011-2015).[91]

2. Autonomous Vehicles

Latest enhancements in ICT have offered unprecedented advantages to the society. Transport systems have also drastic changes in terms of ITS applications. These changes, already embodied by the rise of concepts for C-ITS and connected vehicles, will drive us toward a new generation of autonomous vehicles.

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[85] Ministry of Land, Infrastructure and Transport, undated. *ITS National Plan 2020 (2nd ver.),* Republic of Korea.
[86] Franco, G., undated. Cooperative systems for sustainable mobility and energy efficiency. *Competitiveness and Innovation Framework Programme 2007-2013.*
Available from http://ec.europa.eu/transport/sites/transport/files/themes/its/events/doc/2012-06-07-workshop/1.4-ict-psp-predeployment-cosmo.pdf, accessed 24 April 2017.
[87] Available from http://www.compass4d.eu/, accessed 2 March 2017.
[88] Available from https://www.car-2-car.org/index.php?id=5, accessed 2 March 2017.
[89] Available from http://www.mlit.go.jp/kokusai/itf/kokusai_itf_000006.html, accessed 4 April 2017.
[90] ITS Korea, 2016. *Annual Report 2015.* Republic of Korea.
[91] Available from http://itsasia-pacific.com/pdf/WangXiaojing.pdf, accessed 25 March 2017.

Autonomous vehicles frequently refer to self-driving or driverless cars able to travel without human interventions, which is the highest level with fully automated systems. Technically, autonomous vehicles use the satellite positioning system and diverse sensors (i.e. radar, ultrasonic, infrared, laser, etc.) to detect the surrounding environment. Identified information is interpreted to find appropriate paths considering obstacles and traffic signage by using wireless networks, digital maps, automated controls in vehicles, and communication with smart infrastructure and the control center. So far, autonomous vehicles have existed mainly as prototypes; however, recently autonomous vehicles start being commercially available and cities are amending the legislations to permit driverless driving on roads.

While only a few countries, leaders in ITS, are working to develop such vehicles, some European and American cities have already made a noteworthy progress. For example, in Europe, research projects on autonomous driving, called City Alternative Transport and CityMobil[92], were initiated. Germany introduced the concept of automated driving as an objective for 2020 in the Round Table organized by the Transport and Digital Infrastructure. The United of Kingdom invested £33 million for the "driverless car" trials in four cities in 2014[93] and completed the regulatory review (called "the pathway to driverless cars"[94]) in 2015.

Some Asian and Pacific countries are also active in preparing autonomous vehicles. For example, Japan has already set up an "Autopilot System Study Group" [95] in 2012 to study automated driving on expressways. In addition, an automated driving system programme was selected in 2014 as part of "Cross-Ministerial Strategic Innovation Promotion Program"[96] for the purpose of developing new technologies to avoid crashes and alleviate congestions. The Land Transport Authority in Singapore established the first test site for self-driving vehicle technologies and mobility concept in 2015.[97] In Australia, vehicles with relatively prominent level of automation, including self-parking systems or traffic jam assistance, are already commercially available.[98] Australia's first driverless shuttle bus, "IntelliBus", has been trialled in Perth, with a possible carriage of 11 people and maximum speed of 45km/h in controlled environments. [99] South Australia had the first on-road trials of driverless cars in 2015 and driverless shuttle buses

[92] ERTRAC Task Force, 2015. *Automated Driving Roadmap—Status: Final for Publication.* Belgium.
[93] United Kingdom Parliament, undated. *Evidence Check: "Driverless cars".* Government Statement.
[94] United Kingdom Department of Transport, 2015. *Driverless Vehicles: Connected And Autonomous Technologies And Road Safety.* Available from https://www.gov.uk/government/publications/driverless-cars-in-the-uk-a-regulatory-review, accessed 7 March 2017.
[95] Yamamoto, T., 2014. *Automated Driving Activities in Japan.* ITS Policy and Program Office, Ministry of Land, Infrastructure, Transport and Tourism.
[96] Ibid.
[97] Land Transport Authority, 2017. *Joint Release by the Land Transport Authority (LTA) & MOT - Self-driving Vehicles Will Transform Singapore's Transport Landscape*. Singapore. Available from https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=e6dc5dff-8892-4f7f-9a3e-c89d29c0642c, accessed 3 March 2017.
[98] Transport and Infrastructure Council, 2016. *National Policy Framework for Land Transport Technology: Action Plan 2016-2019.* Australia.
[99] Available from http://thinkinghighways.com/, accessed 1 April 2017.

were trialed in Perth.[100] For the military purpose, remotely controlled or unmanned aerial vehicles (UAVs) have been developed, and their use for civilian purposes (e.g. special emergency and agriculture) has been growing in recent years. New Zealand has some world-leading companies producing UAVs; for example, in the maritime area, autonomous submersible vehicle, such as surveying submarines, are operating.[101]

Because autonomous vehicles are technology-intensive, many private automobile manufacturers and Internet-oriented technology companies such as Google Inc. and Baidu, Inc. are also actively driving toward research and development. Tesla's Model S and Google's self-driving cars are next-generation smart vehicles capable of driving without human interventions. Chinese car manufacturer is also participating in the development of autonomous vehicles like Chang'An Automobile. Different tests of autonomous vehicles have been running from Chongqing to Beijing on several expressway sections[102].

3. Smart City

Growing urbanization is a global phenomenon and cities rethink how to welcome this migration toward urban areas as to enable people to live in a sustainable city with adequate infrastructure and services. Redesigning infrastructure is essential to adapt the city to the evolving social needs and growing economic competition. Citizens also have higher expectations of their quality of life and it is the role of public authority to ensure efficient transport systems and seamless connectivity, and meet environmental challenges through technology enhancements and capabilities.

Deployment of ITS to a global scale has most likely propagated promising opportunities to transform socioeconomic lifestyle. A report pointed out that *"ITS is not only an innovative transport technology. It is a new way of living, a new business approach, and overall, a new culture for all players. Every portion of the transport sector of the future will be a receiver and a sender of information. Mega-cities will no longer be about how much to expand infrastructure to serve the continuous increase in population, but rather how to make the most use of the existing infrastructure to better serve more people"*[103]. With combination of ITS technologies and new advancement of IoT, the concept of smart city has emerged and now is gaining a momentum around the globe. Future applications in cities are expected to be more integrated and

[100] Ibid.
[101] Ministry of Transport, 2014. *Intelligent Transport Systems Technology Action Plan 2014-18: Transport in the Digital Age.* New Zealand.
[102] Wang, X., 2016. ITS development and deployment in China. *EGM on Asian Highway.* Intelligent Transportation Systems Center. Available from http://www.unescap.org/sites/default/files/3.1%20China_Mr.%20Xiaojing%20Wang.pdf, accessed 3 February 2017.
[103] United Nations Economic Commission for Europe, 2012. *Intelligent Transport Systems (ITS) for Sustainable Mobility*. Geneva, Switzerland.

interconnected. Transport infrastructure regarded in silos will be ended, and rather, cities' structure, sources of energy and various transport modes need to be considered all together.

Although there are different definitions depending on the aspect of what should be aimed for the future of the city, two directions pointed out by the World Bank[104] are usually referred as a target of smart city:

1. *"A technology-intensive city, with sensors everywhere and highly efficient public services, thanks to information that is gathered in real time by thousands of interconnected devices. (For example, trash cans have sensors that indicate when they are full, and trash collectors follow a specific route based on this information.). All buildings are "intelligent", with smart meters and energy saving systems, and transport is painless."*

2. *"A city that cultivates a better relationship between citizens and governments—leveraged by available technology. They rely on feedback from citizens to help improve service delivery, and creating mechanisms to gather this information. For example, Citizens are more active in managing their neighborhoods. Open government data is used by civil society to co-create smartphone applications (or an SMS service), e.g. to report a full trash can, and trash collectors can accommodate their routes based on this information."*

In recent years, smart city is often included as one of visions which target to achieve in a city. The concept of smart city does not compete with the efforts already done to improve economic, environmental and social sustainability; instead, smart city can support these progresses already underway. Although each city has different emphases according to the future goals, benefitting from smart technologies (i.e. ICT) is the core concept of smart city. In a technical term, information is collected from the sensor dotted in various places of city, communicated through wireless networks, shared with relevant agencies and analyzed to understand and take proper actions in a city.[105] Not only the city gains full situational awareness, it can also prevent traffic and climate situations in advance, anticipate tasks based on modelled patterns, and eventually, optimize the asset operations.[106] In terms of transport systems, contrary to traditional cities, transforming to smart cities brings more benefits by digitalization, centralization and interconnectedness. Representatively, the movements of each vehicle including public transport systems can be monitored and controlled in a coordinated way. Also, environment-friendly transport modes, such as electric vehicles, autonomous vehicles and personal rapid transit, can be operated with combination of intelligent traffic signal operations and smart infrastructure.[107] After all, eco-friendly transport environment is materialized with the reduction of associated negative externalities in smart cities.

[104] Available from http://www.worldbank.org/en/topic/ict/brief/smart-cities, accessed 4 April 2017.
[105] Available from http://readinessguide.smartcitiescouncil.com/, accessed 2 April 2017.
[106] Ibid.
[107] National Agency for Administrative City Construction, 2016. *Implementation Plan for Smart City in Sejong.*

A variety of activities have been noticed around the globe. For example, In the United Kingdom, the Smart London Plan[108], has been established by the Greater London Authority aiming for *"using the creative power of new technologies to serve London and improve Londoners' lives"*. Collaborative work is being done to support this plan and related summits are organized to share experiences and relevant information to better implement a digital city. In the USA, USDOT has leveraged about $350 million in public and private funds for smart city and advanced transport technologies. Smart City Challenge[109] was launched that requested mid-sized cities to develop ideas for being smart cities including using data, applications and technologies in December 2015. The Challenge induced 78 applicant cities, and USDOT committed up to $40 million to one winning city.

In Asia, a summit called Smart Cities Asia[110] is organized by the Knowledge Group from Malaysia, bringing together different stakeholders to discuss themes around the development of smart cities in the region. Main themes include smart development, smart ICT, smart mobility, smart citizens, smart energy, smart water and waste management. Singapore has also embarked a new phase of transformation of "Smart Nation", developing their own vision of the city for the future. Singapore Smart Mobility 2030[111] is the ITS strategic plan developed by the Intelligent Transportation Society Singapore together with the Land Transport Authority. This plan is targeting to produce a more comprehensive and sustainable ITS ecosystem in Singapore until 2030. The major areas are to improve quality of transport information, to enhance travel experience with smarter interactivity, to improve environment safety and to enable greener mobility. The Republic of Korea has been interested in establishing smart cities for over ten years. By IESE Business School's Cities in Motion index (the Smartest Cities)[112], the capital of the Republic of Korea, Seoul, ranked 8th around the globe and 1st in Asia. Under the master plan for ubiquitous city from 2009 to 2013 (previous concept for smart city), around $20 million was invested from the government. In August 2016, the Republic of Korea chose the smart city projects as one of nine major national strategies, and around $300 million is planning to invest to the development of smart city for five years (2017-2021).[113] Major components of smart city relating to transport are smart parking, smart crosswalk, smart mobility and smart infrastructure.

[108] Greater London Authority, 2017. *Smart London Plan*.
[109] Available from https://www.transportation.gov/smartcity, accessed 2 April 2017.
[110] Available from http://www.smartcitiesasia.com/, accessed 2 April 2017.
[111] Land Transport Authority, 2014. *Smart Mobility 2030-ITS Strategic Plan for Singapore*. Singapore.
[112] IESE Business School, 2016. *IESE Cities in Motion Index*. Madrid, Spain.
[113] National Assembly Research Service, 2016. *Issue and Point*. 1236th. Republic of Korea.

5

REGIONAL ITS CHALLENGES AND ISSUES

A. Common Challenges and Issues

Although the Asia-Pacific region has large disparities among member countries resulting from the differences of territory, landscape, climate and economy, common challenges and issues related to ITS can be identified. Ensure that common ITS-related challenges and issues extracted in this section are only focused on the Asia-Pacific region. All problems were sought based on relevant existing documents, and fact-finding missions in China, Malaysia, the Republic of Korea, Singapore and Viet Nam. Table 5.1 elaborates the summary of common challenges and issues identified in this study.

Table 5.1 Common ITS challenges and issues for the Asia-Pacific region

Category	Common Problems
Organizational Mechanism	▪ Lack of proper cooperation and collaboration - Weak public leadership by governments and ministries - Absence of private sector's participation due to low profits - Uncoordinated partnership among various ITS stakeholders (including official development assistance donors, societies, universities, etc.) ▪ Lack of holistic strategies, master plans and frameworks - Unclearness of short/medium/long term objectives and plans by authorities - Disorganized strategies on a project-by-project basis - No unified ITS standards and architecture - Loosely defined roles for the public and private
Implementation Structure	▪ Premature operations - Lack of centralized ITS center or discordant operational cooperation among ITS centers - Lack of skilled workers for ITS operations - Fragmented ITS services (standalone services) - Absence of prioritized orders for ITS implementations - Low understanding of related technologies and trends ▪ Unsecured funding sources - Priority for transport infrastructure investments - Uneven financial situations and shortage of available national budgets
Other Common Elements Hindering ITS Implementations	▪ Local characteristics - Different infrastructure patterns, transport facilities, and land territories - Scattered policy directions and implementations across the country ▪ Transport habits - Different mode share patterns with preferred transport mode - Various user's preference for ITS services

Note: This table is created by Transport Division based on relevant sources[114] and fact-finding missions.

[114] Asian Development Bank, 2013. *Bhutan Transport 2040 Integrated Strategic Vision.* Manila, Philippines; Japan International Cooperation Agency, 2016. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report–Summary*; Asian Development Bank, 2016. *Safety and Intelligent Transport Systems Development in the People's Republic of China.* Manila, Philippines; National Transport Development Policy Committee, 2014. *Moving India to 2032.* India Transport Report. Published on behalf of the Planning Commission, India; United Nations Economic and Social Commission for Asia and the Pacific, 2015. *Intelligent Transportation Systems for Sustainable Development in Asia and the Pacific.* Working Paper by the Information and Communications Technology and Disaster Risk Reduction Division. Bangkok, Thailand.

1. Organizational mechanism

Successful ITS implementations require various entities' participations encompassing public and private sectors, as well as harmonization from different stakeholders (including relevant official development assistance donors, societies and universities). However, improper cooperation and collaboration are noted as a frequent problem hindering the spread of ITS roll-outs in the region.

First, territorial public organizations like governments and ministries are not always taking the lead to create a dynamic environment for cooperation and collaboration in the Asia-Pacific region. A report underlined this issue in Mongolia that hesitant government decision concerning the funding could result in delay for the ITS implementation.[115] Similar observation was noted in Cambodia that the lack of authority's leadership on funding may cause the problem in facility maintenance. [116] This might be because ITS, by its very nature, have been led by private sectors since many areas within ITS boundaries are technology-oriented where the government has a limitation for direct controls. [117]

At the same time, it is occasionally acknowledged that there is a lack of wills from public entities to provide future strategies, direction and partnership settings, supportive regulatory environment and architecture. Without the public's leadership and coordination among different entities and stakeholders, ITS roll-outs should face the restrictions, and can be delivered in an uncoordinated way. Moreover, given that private sectors are interested in ITS developments only when the financial profits can be returned, the lack of the public sector's leadership cause the absence of harmonized participations from both public and private sides. For example, although ITS services in Mongolia are even fragmented because of the inefficiency of associated institutional cooperation and collaboration. [118] Such situation eventually interferes the constant ITS developments and implementations in the region. This issue has also been pointed out in China for new ITS technologies where "*stakeholders from the industry are waiting for the Government to take the lead in creating a market for V2I and V2V services*"[119].

[115] Asian Development Bank, 2016. *Mongolia: Intelligent Transport Systems-Development for Mongolia.* Technical Assistance Report. Manila, Philippines.
[116] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary.*
[117] Ministry of Transport, 2014. *Intelligent Transport Systems Technology Action Plan 2014-18: Transport in the Digital Age.* New Zealand.
[118] Asian Development Bank, 2016. *Mongolia: Intelligent Transport Systems-Development for Mongolia.* Technical Assistance Report. Manila, Philippines.
[119] Asian Development Bank, 2016. *Safety and Intelligent Transport Systems-Development in the People's Republic of China*. Manila, Philippines.

Second, many countries show the weakness of establishing ITS strategies, master plans and frameworks. At a country scale, it is essential to define short, medium, and long-term objectives and plans while keeping in mind to have a coherent overarching ITS vision. Yet, a number of countries in the region are only in the initial stage of ITS developments, meaning that their long-term strategies and plans have not yet built up. For example, in Mongolia, it is noted that ITS *"is fragmented as it does not have a national ITS policy, ITS architecture and standards plan, or any strategic investment plan (including a technology and project road map and implementation plan); resulting in inefficiency as it lacks associated institutional cooperation"*[120]. Pakistan also has not developed the ITS master plan.[121] On the other hand, a few countries in the region have been actively working on national ITS strategies, master plans and frameworks. Representatively, Singapore established the ITS strategic plan through "Smart Mobility 2030"—"*a plan that consolidates perspectives from both the authority and the industry, paving the way for a more comprehensive and sustainable ITS ecosystem in Singapore in the coming years till 2030*"[122]—which underlines ITS visions and key strategies for the long term. The Republic of Korea established "3rd ITS Master Plan 2020" in 2012 (the 1st ITS Master Plan was established in 1997), and "Introduction Plan for C-ITS" in 2013, respectively.[123] In Malaysia, the ITS master plan was set up in 2003 and currently "Malaysian ITS Blueprint" is in progress.[124] As for China, 12th 5-Year Plan for Highway and Water Transportation Technology Development (2011-2015) was issued in 2011, and 13th 5-Year Plan for the next 5 years has been issued in 2016.[125]

In addition, it was noted that ITS implementations in the region have been conducted on a project-by-project basis. Many ITS projects are designed locally and isolatedly without organized direction under national ITS strategies and plans. One case in India exemplifies this issue that *"much of the thinking on transport in India has been project-centric, done within single-mode silos"*[126]. This project-by-project based approach also results in inconstant use of standards and architectures. ITS standards contribute to ensure the interoperability that different

[120] Asian Development Bank, 2016. *Mongolia: Intelligent Transport Systems-Development for Mongolia.* Technical Assistance Report. Manila, Philippines.
[121] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary*.
[122] Land Transport Authority and Intelligent Transport Society Singapore, 2014. *ITS Strategic Plan for Singapore: Smart Mobility 2030*. Singapore.
[123] The Korea Transport Institute, 2016. *ITS Developments in Korea: ITS Master Plan 2020*. Asia Leadership Program. Republic of Korea.
[124] Highway Planning Unit, 2016. *Intelligent Transport System (ITS) blueprint workshop.* Ministry of Works, Malaysia. Available from http://www.myforesight.my/2016/02/04/intelligent-transport-system-its-blueprint-workshop-highway-planning-unit-ministry-of-works/, accessed 12 March 2017.
[125] Research Institute of Highway, undated. *Current Development Status of Perspectives of ITS in China,* Ministry of Transport, China.
[126] National Transport Development Policy Committee, 2014. *Moving India to 2032.* India Transport Report. Published on behalf of the Planning Commission, India.

ITS products, processes and services supplied can be mutually compatible.[127] Accordingly, without ITS standards, efficient interactions among ITS applications and compliances with new technologies cannot be facilitated. Given that the constant technological evolution is being made in the transport sector, the lack of ITS standards could be a profound problem. As emphasized in a report concerning the process of data for ITS purpose, "*it is important to standardize data entry forms and procedures to maintain quality and consistency of data*"[128], standards under national ITS strategies and plans are essential part. With a same reason, the architecture which define the functions of ITS components are found only in a few countries that also is another fatal challenge for rolling out the ITS services. ITS leading countries in Asia already have architectures, e.g. the Japanese ITS System Architecture was completed in 1999[129], whereas many countries of the region still do not have those architectures. As noted from the ITS Technical Note of the World Bank[130], an ITS architecture is an extremely essential part for incorporating the introduction and ongoing development of ITS in a systematic and consistent way. Not even technical perspective, the lack of ITS architecture could bring vague definitions of roles between public and private stakeholders to deliver and manage ITS facilities and services.[131]

2. Implementation structure

Although most of countries in the Asia-Pacific region are aware of the importance of ITS and various attempts have been noticed, the way to implement ITS has not well-organized which results in several regional common issues.

First, current ITS operations are not well cohesive and integrated in many countries of the region. For ITS operations, the centralized ITS center is a prerequisite. However, it is found that there are no centralized ITS centers or a lack of cooperation and communication between local ITS centers which is needed to share information and data to provide streamlined services. This issue accordingly leads to fragmented and uncoordinated ITS services, as observed in Malaysia and Viet Nam where coordination between organizations has been pointed out as a problem.[132]

Knowledge deficit for ITS implementations is another common issue. One misconception was permeated in Asian countries that ITS require costly systems which can be adopted only in developed countries. However, given that ITS have been perceived as a cost-effective solution[133],

[127] Available from https://www.cencenelec.eu/research/tools/ImportanceENs/Pages/default.aspx, accessed 25 April 2017.
[128] Asian Development Bank, 2016. *Safety and Intelligent Transport Systems Development in the People's Republic of China*. Manila, Philippines.
[129] Yokota, T., and R. J. Weiland, 2004. *ITS System Architecture for Developing Countries.* Technical Note 5. World Bank, Washington, D.C., USA.
[130] Ibid.
[131] Smadi, M., 2008. *Intelligent Transportation Systems (ITS): architecture, deployment, and advances*. Upper Great Plains Transportation Institute. Transportation Seminar Series.
[132] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report–Summary.*
[133] Michigan Department of Transportation, 2015. *Costs and Benefits of MDOT Intelligent Transportation System Deployments*. RC-1631, USA.

this misconception is a result of low understanding and lack of proper knowledge by policy makers. It is also found that ITS facilities have not been properly operated and maintained in the region. The insufficiency of skilled workers or trained engineers is one main reason that produces system under-used and faulty. The case in Karachi, Pakistan, exemplifies this issue that although traffic surveillance system, i.e. closed-circuit television (CCTV), was installed in the city, CCTVs were poorly maintained or not very utilized. [134]

Another observation is that disordered implementations are interrupting the expandability of ITS in many countries. Without proper operational management, each ITS service can be implemented in silos. This could result in inoperability between systems in the future, while data from one ITS service could be useful for another one so as to turn ITS into a multi-purpose platform capable of tasks repurposing. For example, while smart card systems are widely adopted in many countries, interoperability issues arise among cities within the country because such systems were introduced without proper supervision and plans. Now this hinders users from traveling with one card across the country, and also the integration and exchange of data from multiple sources are difficult to support management systems.

Second, ITS in many countries are suffering from the funding shortage. It is widely perceived that ITS are not often the priority in developing or less developed countries because of high desire for transport infrastructure investments. Even if there are transport issues that can be resolved by ITS applications, governmental restrictions may happen in some cases by unstable financial situations. Decision makers might recognize the need for investments once they are certain about benefits from functional ITS applications. To supplement the financial shortage on ITS, various types of supports are noticed in the region. For example, Japan International Cooperation Agency (JICA) supported to develop ITS-related plans or build facilities.[135] Korea International Cooperation Agency (KOICA) as well provided financial supports for ITS projects through the official development assistance programme. The Korea's Partnership with the Philippines (2012-2015) is an example, in which Korea will provide *"[…] support planning of Manila's logistics systems and establish efficient transport traffic management solutions by linking the different modes of transport and adopting Intelligent Transport Systems*"[136].

[134] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report–Summary.*
[135] Available from https://www.jica.go.jp/english/our_work/social_environmental/id/asia/southeast/category_c.html, accessed 12 April 2017.
[136] Korea International Cooperation Agency, 2012. *Country Partnership Strategy for the Republic of the Philippines 2012-2015*.

3. Other common elements hindering ITS implementations

Many indirect factors are additionally found in the region that cause the bottleneck for the spread of ITS. Indeed, because the Asia-Pacific region has peculiarities, such as different religious backgrounds, cultures, languages, natures, economic scales, income levels and political solidarity, human and social dimensions are diverse in the region[137]. In the same vein, each country has a distinct feature on transport infrastructure design and types of facilities, which require tailored policy directions. This localized singularity in transport systems impedes far-reaching ITS implementations in the end. For example, Malaysia has severe flooding that can be tackled by creating a transport system to pre-empt circulation condition, and improve traffic and resiliency against flooding. The Stormwater Management And Road (SMART) tunnel in Kuala Lumpur is an example of such adaptive system through its managing of storm water and peak hour traffic volume, while India requires large-scaled transport networks that are able to connect remote areas to more urban localizations.[138]

Another common factor for slow ITS adoption is related to transport tendency from the user's perspective. Because of the surge of vehicle ownership and available mode choices, various types of user's aspects appear according to traffic conditions. One example for increasing vehicle ownership is the Thimphu of Bhutan where the ownership was increased to 1.4 household vehicles on average as of 2015.[139] Even within a country, each region has different mode shares by user's preference—that is, more use of public transport is pursued in transit-oriented areas, while the private car might be more preferred in rural areas or poor transit-designed areas. For example, although several cities in East Asia has been developing railway and subway systems, ridership is still low because of inappropriate fares or poor service qualities.[140]

Furthermore, users have diverse needs for ITS services. For example, one might prefer having real-time traffic information en route to avoid traffic congestions, whereas another might need an electronic toll collection system to reduce the waiting time in a queue. As another example, taxi applications gain the popularity in more than 300 cities in China with more than 100 million service orders per day[141], while Seoul, Republic of Korea, continuously expands the coverage of bus information systems. Accordingly, the different user's favours on specific transport modes and ITS services require the localization of ITS implementations which needs to be guided by specific national ITS specifications and architectures. In a current situation that national and regional ITS directions are rarely found, different user's aspects could be one of elements that hinder the expandability of ITS roll-outs in the Asia-Pacific region.

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[137] Available from http://www.fao.org/docrep/w4388e/w4388e03.htm, accessed 23 April 2017.
[138] National Transport Development Policy Committee, 2014. *Moving India to 2032.* India Transport Report. Published on behalf of the Planning Commission, India.
[139] Ministry of Information and Communication, 2015. *Intelligent Transport Systems (ITS) Feasibility Study and Preparation of a Comprehensive ITS Action Plan for Thimphu City,* Royal Government of Bhutan.
[140] World Bank, 2004. *Appendix ITS Applications Around the World.* Washington, D.C., USA.
[141] Available from http://www.chinadaily.com.cn/business/2015-10/08/content_22127724.htm, accessed 12 February. 2017.

B. Country-specific Challenges and Issues for the Spread of ITS

In addition to common problems, country-specific challenges and issues need to be explored from sample countries in order to enhance the understanding for current situation of ITS in the Asia-Pacific region. In total, 12 countries have been investigated from relevant sources and fact-finding missions (in China, Malaysia, the Republic of Korea, Singapore and Viet Nam).

For the balanced understanding, the tri-level group is categorized by the status of ITS developments, and countries are selected from each group evenly. The first category is for the well-developed countries of ITS, such as Japan, Republic of Korea and Singapore where many investments and/or developments of ITS have already been made in these countries on the basis of national ITS plans or architecture. The second group of countries is those that are trying to catch up with the advancement of ITS and increase in investments in this area. The last category is for the countries which are just aware of the importance of ITS in their countries, but a small portion of developments or investments has been pursued so far. Most less developed countries of the region might belong to this category.

Table 5.2 shows the summary of country-specific problems identified from the region. Note that this summary is only associated with particular issues that have been found in publicly available sources and fact-finding missions in a given country.

Table 5.2 Country-specific challenges and issues

Countries	Summary of Problems
Bhutan[142]	▪ Fragmented transport network and unplanned space allocations ▪ Undeveloped public transport systems ▪ No legal documents for ITS purpose
Cambodia[143]	▪ Lack of public transport service ▪ Inadequate fundamental traffic operations (e.g. traffic signal) ▪ Prevalence of traffic violations in the city
China[144]	▪ ITS data security ▪ Legal and regulatory issues related to ITS ▪ Predicting future capabilities and deployment of ITS services

[142] Ministry of Information and Communication, 2015. *Intelligent Transport Systems (ITS) Feasibility Study and Preparation of a Comprehensive ITS Action Plan for Thimphu City,* Royal Government of Bhutan.
[143] Japan International Cooperation Agency. 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II). Final Report –Summary.*
[144] Asian Development Bank, 2016. *Safety and Intelligent Transport Systems Development in the People's Republic of China*. Manila, Philippines.

Table 5.2 Country-specific challenges and issues (Continue)

Countries	Summary of Problems
India[145]	▪ Maintenance is not pre-emptive but more rehabilitative ▪ Lack of definite guidelines and regulations for physical implementation ▪ Lack of holistic approach for transport systems
Japan[146]	▪ Promoting research and development for ITS, including private sectors ▪ Needs for appropriate maintenance and renewal of transport infrastructure
Republic of Korea[147]	▪ Disconnected flow of information among transport systems ▪ Segmentation among ITS stakeholders ▪ Needs for more organized process for ITS deployments and management ▪ Shortage of ITS experts on operations and management ▪ Slow adoption for new technologies by inefficient research and development
Malaysia[148]	▪ Insufficient cooperation among ITS stakeholders ▪ Lack of harmonization and integration of ITS technologies ▪ Limited collection and provision of information ▪ Shortage of expertise and knowledge, and national budgets ▪ Private sector's hesitance on ITS developments ▪ Lack of ITS-related research works
Mongolia[149]	▪ Low operational efficiency of ITS ▪ Limited application of ITS in the region ▪ Lack of coherent overarching ITS frameworks ▪ Inappropriate update of ITS plans by responding the demand

[145] Mallik, S., 2014. Intelligent Transportation System, *International Journal of Civil Engineering Research.* Vol. 5, No. 4, pp.367-372. Available from http://www.ripublication.com/ijcer.htm, accessed 23 April 2017; Rawal, T., and V. Devadas, 2015. ITS in India – A review, *Journal of Development Management and Communication.* Vol. 2, No. 3; European Business and Technology Center, 2012. *Snapshot Intelligent Transport Systems in India.* 120913_SNA. New Delhi, India; National Transport Development Policy Committee, 2014. *Moving India to 2032.* India Transport Report. Published on behalf of the Planning Commission, India.

[146] Ministry of Land, Infrastructure, Transport and Tourism, 2015. Utilizing ICT and promoting technology research and development, *White Paper on Land, Infrastructure, Transport and Tourism in Japan 2015*. pp.308-317.

[147] ITS Korea, 2016. *Annual Report 2015*. Republic of Korea; ITS Korea, 2014. *2013 Modularization of Korea's Development Experience: Establishment of Intelligent Transport Systems (ITS).* Ministry of Land, Infrastructure and Transport, Republic of Korea.

[148] Road Engineering Association of Malaysia, 2007. *ITS Strategic Plan for Malaysia. A Way Forward*; Highway Planning Unit, 2007. *Development of ITS System Architecture for Malaysia*. Final Report, Ministry of Works, Malaysia; Highway Planning Unit, 2004. *ITS for Highway*. Final Report, Ministry of Works, Malaysia.

[149] Asian Development Bank, 2016. *Mongolia: Intelligent Transport Systems-Development for Mongolia*. Technical Assistance Report. Manila, Philippines.

Table 5.2 Country-specific challenges and issues (Continue)

Countries	Summary of Problems
Pakistan[150]	▪ Basic ITS equipment (e.g. CCTV, traffic signal) implemented ▪ Lack of integrated ITS center ▪ Absence of ITS master plan, standard and architecture
Singapore[151]	▪ Need more data standards and protocols, and compatibility with international standards ▪ Need more collaboration with private sectors. ▪ Emerging privacy issues from ITS information. ▪ Uncertainty of users' benefits from advanced ITS technologies. ▪ Different types of rules and interfaces among ITS applications. ▪ Need a balanced ITS developments for various transport modes
Thailand[152]	▪ Limited supports from policy maker's low understanding ▪ Lack of proper collaborations with stakeholders ▪ Lack of integration of traffic-related information from organizations ▪ Incapability of ITS center based on numerical data, not real-time data
Viet Nam[153]	▪ Uncoordinated basic ITS equipment and traffic planning ▪ Shortage of national ITS standards and available national budgets ▪ Lack of harmonization and integration among ITS facilities (e.g. different information formats, facility design and technical standards) ▪ Disharmonized ITS implementations on a project-by-project basis ▪ ITS service provider-driven approach, not from users

Note: This table is created by Transport Division based on relevant sources and fact-finding missions.

[150] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary.*
[151] Chin, K. K., and G. Ong, 2015. *Smart Mobility 2030-ITS Strategic Plan for Singapore.* LTA Singapore-Journeys.
[152] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary.*
[153] Ibid.

1. Bhutan

Bhutan is in a period of transition to a rapid emerging economy.[154] Given that Bhutan still has a lack of transport infrastructure[155], some issues in the transport sector hinder ITS utilization which noticed from relevant sources.

First, transport networks in Bhutan are fragmented and space allocations in a city are not planned effectively which causes severe traffic congestions. An example can be found in Thimphu where on-street parking occupies from 1/3 to 1/2 of road spaces in a city center.[156] Second, a quality of public transport services and its coordination are poor. Because of underperforming public transport services in a city, around 50 per cent of travel demands is addressed by taxis in Thimphu, and also high automobile usages are encouraged.[157] Third, a report[158] about ITS feasibility study for Thimphu pointed out the barriers for ITS developments—high initial investments, complex implementation process, technological complexity, uncertainty for costs, benefits and public acceptance, protection of privacy, security and legal issues, high data requirement, and legal document requirements. In particular, key stakeholders recognized that no legal documents for ITS purpose would primarily interfere ITS implementations.

2. Cambodia

The development of ITS is still nascent in Cambodia because it still benefits from a growing economy. Basic ITS equipment such as traffic signals and CCTVs are being operated.

For problems regarding ITS developments, first, weather condition in Cambodia is particular since Cambodia is affected by flooding depending on the season during the year. This situation influences traffic conditions that need special treatments and strategies. Second, a lack of public transport services produces traffic congestions in major cities, such as Phnom Penh. [159] This shortage of services increases the use of private vehicles and motorcycles which have worsened traffic conditions resulting in an increasing number of crashes. Third, although traffic signal is managed by the government, traffic signal is not actuated in city centers according to the traffic situation.[160] Fourth, traffic violations, such as illegal on-street parking, signal jumping and

[154] Ministry of Information and Communication, 2015. *Intelligent Transport Systems (ITS) Feasibility Study and Preparation of a Comprehensive ITS Action Plan for Thimphu City,* Royal Government of Bhutan.
[155] Ministry of Information and Communications, undated. *Current status of national transport policies, systems and projects in Bhutan,* Workshop on Sustainable and Inclusive Transport Policy/Systems. Royal Government of Bhutan.
[156] Ibid.
[157] Ministry of Information and Communication, 2015. *Intelligent Transport Systems (ITS) Feasibility Study and Preparation of a Comprehensive ITS Action Plan for Thimphu City,* Royal Government of Bhutan.
[158] Ibid.
[159] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary.*
[160] Ibid.

jaywalking, are prevalent in urban areas. Particularly, the monitoring system (i.e. CCTV) that can watch violations is separately managed by the Ministry of Interior and EZECOM[161], which might weaken the efficiency of surveillance.

3. China

With the largest population of the world, the number of traffic issues in China are proportionally increased. To suppress this increment, China is actively adopting new technologies, and now one of the countries which have advanced ITS technologies. As of now, nine ITS service fields exist with 47 services and 179 sub-services, and for transport systems, 36 cities have adopted bus intelligent application systems, 30 cities have adopted taxi service management information systems, and 110 cities have initiated bus one-card demonstration projects.[162]

Even though China has shown a great advancement in ITS developments in recent years, some challenges are identified through relevant documents and meetings with the ITS public sector. First, legal and regulatory issues are part of ITS challenges because the legislation usually falls behind the fast ITS developments.[163] Without proper legal and regulatory frameworks, ITS services might not be provided productively. Second, although efforts from the Ministries have been made, managing information security in the transport sector becomes a challenge in China, which is also one of the core themes of the national information security strategy.[164] Third, considering the geographical location of China, communications with neighbouring countries are necessary for ITS interoperability, but few opportunities are found. The lack of ITS standards among Asian countries reinforces this issue. Fourth, because China has huge land size and population, there are different ITS demands from local and province governments, lack of harmonization among different public agencies, and technical issues to exchange information across the country. Lastly, considering various service demands from users and capabilities of ITS services, there is a challenge in coordinating each ITS service properly.[165]

[161] Ibid.
[162] China Academy of Transportation Sciences, 2017. Conference materials (discussion materials) from fact-finding mission in China, unpublished.
[163] Asian Development Bank, 2016. *Safety and Intelligent Transport Systems Development in the People's Republic of China*. Manila, Philippines.
[164] Ibid.
[165] Ibid.

4. India

Transport systems in India have been under intense pressure from skyrocketing population, growing economy, urban migration and increasing demands. ITS as a traffic management tool have gained great interests to mitigate traffic issues in India. Nonetheless, some challenges can be underlined that need to be considered.

First, the maintenance of transport infrastructure is not pre-emptive but more rehabilitative, although maintenance should be conducted regularly in a timely manner.[166] This lack of well-maintenance for infrastructure could bring the inefficiency of ITS services and inappropriate conditions for ITS deployments. Second, good guidelines and regulations are an essential prerequisite for effective ITS roll-outs considering the harmonization with the entire system of transport, but few guidelines and regulations are found in India that could block the physical implementation of ITS.[167] Third, the institutional governance for transport systems is already outdated, which brings silo decisions.[168] The lack of holistic approach from the institutional governance's perspective makes poor multimodal coordination and connectivity, and inefficient city-wide traffic operations[169], which weaken the ITS benefits. In addition, this difficulty would bring incompatibility issue for the integration of ITS applications with international ITS architecture.

5. Japan

With an aging population that cannot support industries anymore, Japan faces new challenges to respond global competitions. For the sustainable growth, Japan are still promoting ITS initiatives as effective measures for traffic safety, traffic congestions and disaster management, in accordance with the goal to be the World's Most Advanced ITS Nation as declared in 2013.[170] Although Japan is rightfully considered as one of global leaders in ITS at an advanced stage of ITS evolutions, the country still faces problems to push forward ITS developments.

First, private sector investments in ITS research and development need to be encouraged.[171] Because ITS are technology-intensive and fast-growing with new emerging technologies, technological research and development, especially from the private sector, can incorporate new trend of technologies to ITS developments in a timely manner. IT Strategic Headquarters, Japan,

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[166] National Transport Development Policy Committee, 2014. *Moving India to 2032.* India Transport Report. Published on behalf of the Planning Commission, India.
[167] European Business and Technology Center, 2012. *Snapshot Intelligent Transport Systems in India*. 120913_SNA. New Delhi, India.
[168] National Transport Development Policy Committee, 2014. *Moving India to 2032.* India Transport Report. Published on behalf of the Planning Commission, India.
[169] European Business and Technology Center, 2012. *Snapshot Intelligent Transport Systems in India.* 120913_SNA. New Delhi, India.
[170] Ministry of Land, Infrastructure, Transport and Tourism, 2015. Utilizing ICT and promoting technology research and development, *White Paper on Land, Infrastructure, Transport and Tourism in Japan 2015.* pp.308-317.
[171] Ibid.

in this sense, endorsed the "Public-Private Partnership-Based ITS Concept and Roadmap" in 2014.[172] Second, although ITS are widespread in Japan, some local areas still have problems with maintaining transport infrastructure which might prevent ITS.[173] Proper maintenance and renewal of transport infrastructure could lead to maximize the benefits from ITS deployments.

6. Malaysia

Increasing economic activities and rising population are adding pressure to transport systems in Malaysia, moreover in urban areas, resulting in significant traffic congestion issues. ITS are not an unknown subject in the country. The Ministry of Works has decided to use ITS for better management and operations of the existing transport infrastructure.[174] Based on the Master Plan established in 2003[175], several applications are implemented as of 2017. Yet, because Malaysia is in the stage of driving ITS developments, some problems are noted in various areas.

First, institutional weakness among stakeholders in ITS deployments is one challenge in Malaysia because this restricts an optimal use of ITS applications.[176] Few discussions among various transport services (e.g. ITS and traffic safety) might strengthen this weakness. Second, harmonization and integration of ITS technologies are needed to provide coordinated services to users.[177] The separate operations of ITS would limit the collection and provision of traffic information, such that benefits from ITS services become weakened. Third, national budgets for ITS are limited, and ITS expertise and knowledge are not sufficiently enough to expedite ITS developments in Malaysia. One reason for this might be the hesitance of private sectors in ITS industries. Limited budgets also affect ITS-related research works, which could eventually block ITS advancements in the country.

7. Mongolia

The government of Mongolia emphasizes various ICT initiatives (e.g. E-Mongolia National Program, E-Government Master Plan and Smart Government Project) for the transformation to knowledge society.[178] However, Mongolia faces many challenges from large land size, low density in rural areas and densely populated urban areas to make the country more integrated,

[172] Ibid.
[173] Ibid.
[174] Highway Planning Unit, 2007. *Development of ITS System Architecture for Malaysia*. Final Report. Ministry of Works, Malaysia.
[175] Highway Planning Unit, 2007. *ITS in Malaysia*. Ministry of Works, Malaysia.
[176] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary (February 2015).*
[177] Ibid.
[178] Asian Development Bank, 2016. *Mongolia: Intelligent Transport Systems-Development for Mongolia*. Technical Assistance Report. Manila, Philippines.

inclusive and efficient. These features are even more challenging when it comes to the transport sector, including ITS developments and implementations.

First, because ITS deployments are at an early stage in this country, operational efficiency for ITS is low as a result of improper operations and maintenance.[179] Second, the coverage of ITS services is limited. For example, regional roads do not have ITS services, except to monitor regional bus operations.[180] Third, most ITS developments are pursued on a project-by-project basis, resulting from the lack of overarching ITS frameworks.[181] This problem would generate the improper coordination among ITS stakeholders, and inconsistent and fragmented ITS services to users. Therefore, the plan of ITS roll-outs for near-, medium-, and long-term is necessary for the transport services across the country.[182] Fourth, although there was a piece of ITS plans, those have not been properly updated to match the demand[183], which eventually leads to low quality of ITS services.

8. Pakistan

Pakistan is experiencing increasing travel demands in recent years, which results in severe traffic congestions and crashes. Although to mitigate traffic issues, ITS technologies were adopted in this country, the development is still considered at an early stage. Three major issues are found in this situation.

First, only basic ITS equipment is employed throughout the country (mainly, CCTVs and traffic signals).[184] Even though continuous expansion and upgrade are necessary in order to fully operate these systems, poor maintenance are observed that could deteriorate equipment.[185] Second, the integrated ITS center is missing in Pakistan.[186] Without integrated ITS center, ITS applications are only able to be operated as a standalone system which conducts limited functions—for example, CCTV is only used for security monitoring. Traffic operational treatments cannot be expected with combination of traffic signal controls, although traffic incidents are found through CCTV monitoring. Third, an ITS master plan has not been developed in the country.[187] ITS standard and architecture are not exceptions. Without master plan, standard and architecture, each ITS application would be introduced individually in an uncoordinated manner, which ultimately hinders the continuous service to users.

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[179] Ibid.
[180] Ibid.
[181] Ibid.
[182] Ibid.
[183] Ibid.
[184] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary.*
[185] Ibid.
[186] Ibid.
[187] Ibid.

9. Republic of Korea

The Republic of Korea is regarded as one of leading countries for ITS technologies around the globe. The country is also progressing numerous ITS projects based on the national ITS master plan ("3rd ITS Master Plan 2020 in the Vehicle and Road Areas"[188]), and moving towards a new generation of ITS technologies. However, from its rapid economic growth and fast ITS developments, some limitations are identified.

First, cooperation among ITS stakeholders is still weak, including both private and public entities. While large corporations focus on integrating information technology into ITS, small or mid-sized enterprises focus on productions of ITS products.[189] These two different efforts without overall national guidelines might weaken the utilization of ITS technologies. Also, inefficient cooperation between the private and public makes a limited flow of information among transport systems. Second, more organized process for ITS deployments and management is necessary.[190] Although there are already lots of investments for ITS in the Republic of Korea, inefficient process for deploying ITS interferes from maximizing benefits from those investments. Third, ironically, it is noted that there is a shortage of ITS experts on operations and management.[191] The local traffic operations centers suffer from finding experts to effectively manage the centers in order to utilize ITS information. Lastly, new ITS technologies are growing quickly around the globe, but the activities of technological research and development do not catch them promptly for rapid ITS evolutions.[192] To respond user's ever-growing demands, proper adoptions for new technologies are encouraged.

10. Singapore

Singapore is well known as one of global leaders for ITS initiatives. Since ITS's important role was acknowledged in 1995, the Land Transport Authority has constantly adopted ITS technologies to manage traffic issues and provide pleasant travel experiences to users. With the first ITS Master Plan in 2006, a variety of ITS applications have been implemented in Singapore, just to name a few, "Parking Guidance System", "e-TrafficScan", "Green Man+" and "Green Link Determining System".[193] Although ITS are quite advanced in this country, some issues are found that block sustaining ITS services.

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[188] Ministry of Land, Infrastructure and Transport, 2012. *ITS Master Plan 2020 in the Vehicle and Road Areas*, 11-1611000-002332-01. Republic of Korea.
[189] ITS Korea, 2014. *2013 Modularization of Korea's Development Experience: Establishment of Intelligent Transport Systems (ITS)*. Ministry of Land, Infrastructure and Transport, Republic of Korea.
[190] Ministry of Land, Infrastructure and Transport, 2012. *ITS Master Plan 2020 in the Vehicle and Road Areas*, 11-1611000-002332-01. Republic of Korea.
[191] Ibid.
[192] Ibid.
[193] ITS Thailand, 2015. Road Safety and Traffic Management in Thailand. *The VI International Congress Road Traffic Russia*.

First, new ITS solutions are necessary to respond to increasing travel demands and the lack of available physical spaces.[194] Singapore currently faces major constraints in space, growing population and travel demands which affect environmental problems in the end. Second, data standards and protocols need to be more developed to ensure the efficacy and interoperability of ITS ecosystem.[195] The adoption of ITS standards and protocols would facilitate more ITS solutions and bring benefits to users. It is also pointed out that Singapore ITS standards need to be compatible with international standards. Third, close partnerships between public and private sectors need to be established.[196] This collaboration could reinforce the promotion of ITS awareness and expertise. Fourth, because ITS services require much information than other facilities, privacy issues have arisen recently which needs proper regulations. Besides, different types of rules and interfaces among ITS applications are another issue from this complexity. Fifth, although Singapore has advanced ITS developments, there is an uncertainty about the benefits for some ITS applications. To expand ITS services, this doubt needs to be resolved by relevant studies. Lastly, considering the density of transport modes in the country, balanced ITS roll-outs for various transport modes, such as public transports, taxis, individual vehicles, bicycles and walking, should be planned and conducted.

11. Thailand

Thailand is a fast-growing country with a world-renowned mega city, Bangkok. Due to the emerging demand for individual vehicles and relatively poor transport infrastructure, traffic congestions and crashes are still long-pending troubles in Thailand. ITS have been developed in the last few years to tackle traffic issues prevalent in the country. Although six ITS applications have been implemented with Thailand ITS Master Plan 2013-207[197], it is noted that current ITS are limited and need to be improved.

First, policy maker's understanding is still low to provide constant supports on ITS developments. Second, collaborations and cooperation are essential for the successful ITS deployments, but proper coordination with public authorities, private sectors and academia are limited in Thailand.[198] Third, traffic-related information with ITS technologies is not efficiently integrated from each organization.[199] This interoperability prevents users from receiving integrated traffic information which is more effective to relieve traffic issues. Fourth, collected information does

[194] Ibid.
[195] Japan International Cooperation Agency, 2015. *Data Collection Survey for Intelligent Transport Systems (Phase-II) Final Report –Summary.*
[196] Ibid.
[197] Ibid.
[198] ITS Thailand, 2015. Road Safety and Traffic Management in Thailand. *The VI International Congress Road Traffic Russia*.
[199] Japan International Cooperation Agency, *Data Collection Survey for Intelligent Transport Systems (Phase-II)* Final Report –Summary (February 2015). Country: Thailand.

not reflect actual situation in a real-time basis because numerical data which has been used so far is restricted to provide reliable information by ITS applications.[200]

12. Viet Nam

Viet Nam has growing economy and population that brings many traffic issues. Hanoi, for example, individual vehicles, taxis and motorcycles are mixed, and severe traffic congestions and crashes are generated by uncoordinated traffic signals and traffic violations. To suppress the problems, ITS have been introduced, and a few major applications are currently implemented in the country. As an ITS-developing country, Viet Nam's ITS roll-outs have issues that need to be tackled in the long run.

First, basic ITS equipment and traffic planning are not well-coordinated.[201] Although ITS applications are found easily in Hanoi, their effects are not maximized because of improper traffic planning to support them. Second, national ITS standards and available national budgets are not enough to develop own ITS technologies and policies. Also, the lack of national ITS architecture which is currently in progress worsens this situation. Third, because ITS facilities including regional traffic information centers have been developed by different international donors, different information formats, facility design and technical standards are another challenge within this country. This is because there are few discussions among different ITS developers and donors. This restricts the exchange of information among ITS applications and provision of seamless services for users. Fourth, in line with third issue, there are compatibility issues from disharmonized ITS implementations on a project-by-project basis. Electronic toll collection system is a representative example in Viet Nam. Similarly, different approaches of ITS deployments are applied between national roads and city/urban roads. Lastly, ITS services are developed by the government and donors in Viet Nam; thus, user's demands are not properly reflected in the course of decision making. Although offering diverse ITS services would be beneficial to users and society, provider-cantered approaches might bring excessive or erroneous supply that makes some ITS facilities useless or inefficient.

[200] Ibid.
[201] Ibid.

6

ITS BENEFITS IN ASIA AND THE PACIFIC

The role of ITS is determined on the basis of issues from traffic congestions. By offering the opportunity with ITS technologies through real-time control and communications, transport mobility can be improved which contributes the achievement of transport policy goals. Although it is widely perceived that ITS can provide more efficient, safer and greener transport services in a community, showing tangible benefits are meaningful to enhance the awareness of policy makers for ITS utilization. Accordingly, specific ITS benefits in the region need to be identified with supporting cases.

Table 6.1 describes the summary of ITS benefits from the viewpoints of authority and operator, user, and society. Note that the benefits discussed here are only learned from relevant sources focused on the Asia-Pacific region.

Table 6.1 ITS benefits in the Asia-Pacific region

Viewpoint	Observed Benefits
User	▪ Reduced trip uncertainty - Deliver real-time traffic/public transport information - Broadcast weather conditions - Warn in advance dangerous roads and incidents ▪ Increased travel convenience - Assist the driver in the driving process - Integrate multimodal/intermodal transport services - Provide better accessibility and connection ▪ Reduced travel time and cost - Guide optimal travel routes and parking areas - Support fuel efficient driving
Authority and Operator	▪ Better traffic safety - Increase traffic monitoring - Curtail the time taken for emergency vehicles - Enhance the efficiency of law enforcement ▪ Improved traffic management - Monitor real-time traffic conditions - Maintain the equilibrium between users and road/public transport/parking capacities - Provide better coordination of transport networks and modes
Society	▪ Minimized environmental issues - Reduce individual's trip frequencies - Decrease traffic congestions - Reduce fuel consumptions ▪ Lower social costs - Mitigate traffic crash-related costs - Rise trust and use of public transport ▪ Maximized economic opportunities - Provide transport services in remote areas - Increase trade activities - Create new transport industries

Note: This table is created by Transport Division based on previous sources[202].

[202] Ministry of Information and Communication, 2015. *Intelligent Transport Systems (ITS) Feasibility Study and Preparation of a Comprehensive ITS Action Plan for Thimphu City,* Royal Government of Bhutan; United Nations Economic and Social Commission for Asia and the Pacific, 2015. *Intelligent Transportation Systems for Sustainable Development in Asia and the Pacific.* Working Paper by the Information and Communications Technology and Disaster Risk Reduction Division. Bangkok, Thailand; Asian Development Bank, 2016. *Safety and Intelligent Transport Systems Development in the People's Republic of China.* Manila, Philippines; Ministry of Land, Infrastructure, Transport and Tourism, 2015. Utilizing ICT and promoting technology research and development, *White Paper on Land, Infrastructure, Transport and Tourism in Japan 2015.* pp.308-317; Centre for Strategic and

First and foremost, from the user's perspective, ITS can mitigate the uncertainty along the trip by providing estimated traffic time, road conditions, locations of public transport, weather, and incidents (e.g. crashes, road work and so on). Real-time information collected from various sources, such as mobile devices, vehicles, roadside equipment and related agencies, is processed and disseminated to users in a timely manner. For instance, warning users for incidents in specific areas or severe weather anticipated can offer the affordability that travelers might avoid risky situations. Precisely, the ITS-Spot system (using V2X technologies) in Japan, travel data such as time, location, speed and behavioral data is collected through 1,600 probe devices communicating with cars and a central system.[203] The ITS-Spot system provides the dynamic route guidance and safe driving support to users.[204] In the Osaka-Kobe area of Japan, the introduction of dynamic message signs provided traffic time savings on an average of 9.8 minutes per vehicle during the periods of congestion and up to 38 minutes per vehicle during incident congestion.[205] A pilot project in Bengaluru and Hyderabad in India also targets to obtain real-time traffic information (images) in major intersections and connector roads. Real-time images are available 24/7 on the internet portal. An internet advisory information system and short message service system help motorists access updated information for traffic congestions and limited access by ongoing maintenance or construction activities.[206]

ITS increase user's convenience during traveling by offering technical assistance, and better connected and coordinated transport services. With the advancement of automatic vehicle components, drivers can be partly free of the burden in the driving process. Collision avoidance system for example is an automobile technology that uses radar, camera and laser to detect a threatening crash and either warn the driver or can act autonomously. Based on a study[207] in Australia, a forward collision avoidance system could reduce 16 per cent of all fatalities, and a land departure warning system could bring 7 per cent of reduction in all fatalities. Telling travellers real-time operational status of transport modes also encourages the use of multimode by offering easy transfer, improved connection and better accessibility. In Singapore, the Contactless e-Purse Application Standard (CEPAS)[208] encourages the use of multiple modes which provides

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Policy Studies, 2014. *Review to Formulate a Roadmap and Draft National Masterplan for a Sustainable Land Transportation System for Brunei Darussalam, Vol. 5, Executive Summary,* Brunei Darussalam.

[203] Ministry of Land, Infrastructure, Transport and Tourism, undated. *Vehicle-Infrastructure Cooperative Infrastructure Cooperative System and Probe Data in Japan*. Japan.

[204] Available from http://www.mlit.go.jp/kokusai/itf/kokusai_itf_000006.html, accessed 12 April 2017.

[205] Abe, S. 1998. *Evaluation of Route Comparison Information Boards on Hanshin Expressway.* Paper presented at the 5th World Congress Conference on ITS. October 12-16, Republic of Korea.

[206] Rawal, T., and V. Devadas, 2015. Intelligent transportation system in India – a review, *Journal of Development Management and Communication*. Vol. 2, No. 3. Available from https://www.researchgate.net/publication/286928014, accessed 1 May 2017.

[207] Anderson, R. W. G., T. P. Hutchinson, B. Linke, and G. Ponte, 2011. *Analysis of Crash Data to Estimate the Benefits of Emerging Vehicle Technology.* CASR Report Series, CASR094. Centre for Automotive Safety Research, The University of Adelaide, Australia.

[208] Available from https://www.imda.gov.sg/industry-development/infrastructure/ict-standards-and-frameworks/specification-for-contactless-e-purse-application-cepas, accessed 1 May 2017.

"*significant step closer towards giving consumers the convenience of having a single card for making transit, motoring and retail payments instead of using multiple cards for different payments*" [209]. CEPAS allows users to make transfers without incurring additional boarding charge which consolidated with a distance-based fare system in 2010 to provide a more integrated and equitable fare structure regardless of the number of transfers they make.[210] In Nagoya, Japan, a personal integrated travel assistance system was tested to see its feasibility. The results showed approximately 20 per cent fewer carbon dioxide emissions by switching the mode from individual vehicles to public transport, walking or bicycles.[211]

An efficient and responsive transport service through ITS is another enabler to reduce travel time and cost. Optimized route and parking guidance based on up-to-date information help users avoid traffic delays and associated costs including fuel consumptions. Many cases exist in the region. For example, in Delhi, India, Advanced Parking Management System was adopted in some parking facilities to manage the parking demand effectively.[212] A Parking Guidance System in Singapore is another example to reduce travel time and costs in search for available parking spots by displaying available spaces on 30 electronic information panels across the city.[213] In Japan, it was found that after several road tests, the Dynamic Route Guidance System in the Vehicle Information and Communication System (VICS, the forefront of ITS in Japan) showed 15 per cent reduction of travel time.[214]

Second, from the authority and operator's side, the most valuable benefit from ITS is the improved traffic management in specific areas. Data collected through ITS could help authorities and operators understand and manage traffic flows in the most efficient way. That is, by operating traffic management center, real-time traffic situations are monitored for the whole transport networks through various surveillance equipment, such as closed-circuit televisions (CCTVs), detectors and mobile devices. The trial deployment of STREAMS Motorway Management system in Melbourne, Australia in 2007 showed 30 per cent reduction in traffic incidents, 42 per cent reduction in travel times during peak hours and 11 per cent reduction in emissions.[215] Besides, the centralized management system can contribute to maintain the balanced demand from users and

[209] Available from https://www.epscepashub.sg/cepashub-eservice/MainPage.aspx, accessed 1 May 2017.
[210] Available from https://www.mot.gov.sg/About-MOT/Land-Transport/Public-Transport/Fares---Payment-Systems/, accessed 1 May 2017.
[211] Usui, T., 2008. Development and validation of Internet-based personalized travel assistance system for mobility management. *Paper presented at the 15th ITS Word Congress.* November 16-20, New York, USA.
[212] Rawal, T., and V. Devadas, 2015. Intelligent transportation system in India – a review, *Journal of Development Management and Communication.* Vol. 2, No. 3. Available from https://www.researchgate.net/publication/286928014, accessed 1 May 2017.
[213] Siemens, undated. Singapore close-up, *City Climate Leadership Awards by C40 Siemens Cities.*
[214] Available from http://www.itscosts.its.dot.gov/ITS/benecost.nsf/ID/F9CBEF32DFA26C20852569610051E2AE?OpenDocument&Query=BApp, accessed 23 April 2017.
[215] Available from http://www.itsinternational.com/sections/cost-benefit-analysis/features/integrating-traffic-systems-improves-management-and-control/, accessed 24 April 2017.

supply on infrastructure capacity, as well as coordinate transport modes and networks. One example for the former is the Electronic Road Pricing (ERP) system in Singapore. The ERP programme has controlled the demand by charging fees on drivers to maintain target speeds of 45 to 65 kilometres per hour on expressways, and 20 to 30 kilometres per hour on arterials.[216] For the latter, a homogenous system through a well-coordinated transport services and networks gains time and monetary values. An example can be found in Seoul, Republic of Korea, where collected data was analyzed to increase the usage of night-time bus through proposing ideal bus routes that fitted more needs with right interval times and bus locations, as well as give necessary information to authorities to enhance the efficiency of transport services. [217]

Increased traffic safety is another asset provided by ITS for authorities and operators. For example, some ITS technologies help reduce the crashes, and by ITS tools, emergency vehicles can arrive a certain crash site in time, thereby, preventing secondary impacts. A report about cooperative ITS in China estimated that the Automatic Crash Notification system which can automatically call emergency services when a collision occurs could reduce the fatality by about 5 per cent.[218] Other applications like Adaptive Signal Control system can also prevent corollary traffic fatalities and injuries through changing the signal dynamically. Singapore's Green Link Determining system controls all traffic lights by adjusting green time in an adaptive manner based on demands from motorists and pedestrians. This eventually can minimize the delays by vehicles and provide more crossing time to disabled and elderly.[219] A fully adaptive traffic system in Australia, called Sydney Coordinated Adaptive Traffic System, has shown the reduction of road crashes from 15 to 50 per cent with the use of detection, ramp metering, incident management, variable message signs and dynamic speed limits.[220] Automated law enforcement offers another benefit as it regulates speed limits and prevents dangerous driver's behaviours (e.g. red-light running). One before-and-after study in the Republic of Korea proved the effectiveness of Automatic Traffic Enforcement systems which monitor speeding, illegal parking, and traffic sign violations. Comparing the same location after the installation, the number of crashes were reduced by 29.1-32.5 per cent, and the number of deaths by 51.8-59.5 per cent during a year period.[221] In Hong Kong, China (where 195 sites with red light cameras and 125 locations with speed enforcement cameras exist as of 2016), after red light cameras and speed enforcement cameras were installed, the number of red light violations were reduced by about 43-55 per cent, and there

[216] Federal Highway Administration, 2010. *Reducing Congestion and Funding Transportation Using Road Pricing In Europe and Singapore.* U.S. Department of Transportation.
[217] Available from http://www.venturesquare.net/529875
[218] Asian Development Bank, 2016. *Safety and Intelligent Transport Systems Development in the People's Republic of China*. Manila, Philippines.
[219] Available from http://www.onemotoring.com.sg/publish/onemotoring/en/on_the_roads/traffic_management/intelligent_transport_systems/glide.html, accessed 2 February 2017.
[220] Available from http://thinkinghighways.com/, accessed 5 April 2017.
[221] Korea Transportation Safety Authority, 2006. *Evaluation of Automatic Traffic Enforcement Systems*. Republic of Korea.

was a 40 per cent reduction in the number of traffic crashes.[222] For emergency vehicles, an Emergency Vehicle Priority system in Queensland, Australia, providing green lights for emergency vehicles to respond the incidents improved travel times by to 20 per cent with no measurable impacts on congestions.[223]

Lastly, from the society's viewpoint, the application of ITS in traffic operations and management can offer three major benefits—environmental issues, social costs and economic activities. Enhanced multimodal connectivity and optimized traffic flows by ITS can minimize individual's trips and traffic congestions along with fuel consumptions. Given that most traffic issues are generated by traffic congestions, shortened travel time and increased use of public transport can contribute to mitigate related environmental issues. For example, it was noted in Indonesia that about 20 per cent of traffic congestion could be avoided by the delivery of traffic information offered by ITS projects.[224] Jeju, Republic of Korea, showed the 31.9 per cent reduction for traffic delays by the introduction of ITS which generated 42.4 per cent decrease in energy consumption, while Gwacheon had 56.4 per cent reduction for traffic delays with 11.8 per cent reduction in energy consumption.[225] By appropriate route guidance from VICS in Japan, CO2 emissions in 2010 were reduced by roughly 2.4 million tons.[226]

Applying ITS also encourages the use of car sharing or public transport systems which contributes to lower pollution and decrease carbon footprint for the society. Although quantitative studies about impacts by car sharing (e.g. reduction of emissions or vehicle kilometers traveled) are rarely found in the region[227], car sharing continues to grow (e.g. China is expected to grow by about 80 per cent annually with total car sharing vehicles reaching 16,000 by 2018 if the government supports the industry[228]), and provides environmental benefits to the society. It is found that the progressive adoption of integrated electronic fare collection systems in urban areas

[222] Government of the Hong Kong Special Administrative Region, 2017. *Traffic and Incident Management System*, Department of Transport. Available from http://www.td.gov.hk/en/transport_in_hong_kong/its/intelligent_transport_systems_strategy_review_and_/traffic_and_incident_management_system/index.html, accessed 1 May 2017.

[223] Transport and Infrastructure Council, 2016. *National Policy Framework for Land Transport Technology: Action Plan 2016-2019.* INFRA-2991. Canberra, Australia.

[224] Omron Social Solutions Co., Ltd., Omron Asia Pacific PTE Ltd., West Nippon Expressway Company Limited, The Institute of Behavioral Sciences, and Japan Research Institute for Social Systems, 2015. *Study on the Intelligent Transport System (ITS) in Makassar, the Republic of Indonesia.* Final Report, Study on Economic Partnership Projects in Developing Countries in FY2014. Ministry of Economy, Trade and Industry, Ernst & Young ShinNihon LLC, Japan External Trade Organization.

[225] Lee, S-H., D-S Oh, J-H Seo, J-Y Yoon, C-H Choi and S-C Yoon, 2014. *Establishment of Intelligent Transport Systems (ITS),* ITS Korea, Ministry of Land, Infrastructure and Transport, Republic of Korea.

[226] Society of Automotive Engineers of Japan, 2014. *Intelligent Transport Systems*. Japan.

[227] Barth, M., S. A. Shaheen, T. Fukuda and A. Fukuda, 2006. Carsharing and station cars in Asia, *Transportation Research Record: Journal of the Transportation Research Board,* No. 1986, Transportation Research Board of the National Academies, Washington, D.C., pp.106-115.

[228] Zeng, H., 2014. Car-sharing grows in China as an alternative to vehicle ownership. *The City Fix*. Available from http://thecityfix.com/blog/car-sharing-china-alternate-vehicle-ownership-car-congestion-peer-to-peer-growing-government-support-heshuang-zeng/, accessed 15 April 2017.

of Australia improved boarding time and reliability (e.g. Smartrider in Perth, GoCard in Brisbane, Myki in Melbourne and Opal in Sydney)[229], which might contribute to change the mode from individual vehicles to public transport systems that will bring good impacts to the environment eventually.

Because ITS are responsive to traffic crashes and multimodal usages, it can lower the associated social costs for the whole nation. For example, speed limit enforcement helped Guizhou province in China reduce their number of crashes to 79.33 per cent, with a decrease of 39.3 per cent in deaths and 57.61 per cent of injuries from 2005 to 2006.[230] ITS can be also seen as a contributing factor to economic opportunities, in that enhanced transport mobility provides better transport services with increased seamless connectivity, and thereby economic, social and trade activities. ITS projects in Makassar and Jakarta, Indonesia showed the annual savings for 32,848 Yen[231] per year for a logistics vehicle, 43,684 Yen per year for a taxi and 11,649 Yen per year for a general vehicle. These economic effects per the vehicle are higher compared to 24,000 Yen per year of the application usage fee for a logistics vehicle and a taxi and 1,200 Yen per year of the application usage fee for a general vehicle.[232] In terms of freight transport, a study showed that automated Electronic Supply Chain Manifest in Taiwan Province of China, for example, could handle 70 per cent of the paperwork required for international air cargo shipments by improving freight delivery, logistics and services which are essential for regional economic integration and activities. [233] A tracking and wireless communication technology using a global navigation satellite system is used in Australia to remotely where, how and when heavy vehicles are being operated.[234] This system offers enhanced productivity and efficiency for transport operators and at the same time reduces the number of trucks on the road which is an asset to the society. Another aspect of economic opportunities by ITS is creating new transport industries, as it would encourage the private sector to get involved in the development of new technologies for transport issues. One representative example is private car sharing business in Southeast Asia like "GrabTaxi" which widely permeates across Malaysia, Singapore, Thailand, Viet Nam, Indonesia

[229] Available from http://thinkinghighways.com/, accessed 23 April 2017.
[230] Wang, X., 2016. ITS development and deployment in China. *EGM on Asian Highway.* Intelligent Transportation Systems Center. Available from http://www.unescap.org/sites/default/files/3.1%20China_Mr.%20Xiaojing%20Wang.pdf, accessed 3 February 2017.
[231] Because this study is for the economic partnership which was led by Japanese experts, the document uses Yen as a currency.
[232] Omron Social Solutions Co., Ltd., Omron Asia Pacific PTE Ltd., West Nippon Expressway Company Limited, The Institute of Behavioral Sciences, and Japan Research Institute for Social Systems, 2015. *Study on the Intelligent Transport System (ITS) in Makassar, the Republic of Indonesia.* Final Report, Study on Economic Partnership Projects in Developing Countries in FY2014. Ministry of Economy, Trade and Industry, Ernst & Young ShinNihon LLC, Japan External Trade Organization.
[233]Available from http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/F4AC01F06DFF3631852573E60052D307?OpenDocument&Query=Home, accessed 5 April 2017.
[234] Available from http://thinkinghighways.com/, accessed 2 February 2017.

and the Philippines. As of 2015, GrabTaxi's application for smartphones had been downloaded 4.8 million times[235] and an investment of $100 million was decided over the next few years[236].

[235] Purnell, N., and R. Carew, 2015. *Singapore's GrabTaxi rides high with over $200 million investment*. The Wall Street Journal. July 1.
[236] Tegos, M., 2015. *GrabTaxi CEO reveals huge recruitment drive at new $100M R&D center*. TechinAsia. April 8.

7

POLICY RECOMMENDATIONS FOR THE ASIA-PACIFIC REGION

Because member States are already aware of the potentials of ITS in resolving traffic issues, various local initiatives exist but with a limited scope. Further work to enhance ITS deployments in the Asia-Pacific region should take into account this existing basis in each country and also emerging technologies. As it is already known that ITS are not only technical but also organizational and institutional nature, ITS can be optimally used when they are deployed with the strategic policy framework. The regional guidance for the work of ITS roll-outs by UNESCAP, in that sense, should be a pragmatic approach with clear policy goals and directions. In addition, an integrated approach should be pursued with consideration of a variety of fast-growing ITS features, including new technologies, policy necessity, multimodal demand, public-private dialogue and so on. With this integrated approach, it is eventually envisaged that the regional cooperation on an Asian and Pacific level would be encouraged to provide a coordinated use of ITS that allows for continuous services for the users in the region.

Based on lessons learned from extensive literature reviews and fact-finding missions, this Chapter provides a feasible policy framework focusing on recommendations that could overcome the slow and fragmented uptake and deployment of ITS in the Asia-Pacific region.

A. Considerations for Proposing the Policy Framework by UNESCAP

1. UNESCAP's roles in transport

As a regional development arm of the United Nations for the Asia-Pacific region, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) has 53 member States and 9 associate members. The implementation of the 2030 Agenda for Sustainable Development and the achievement of the Sustainable Development Goals are the priority

activities by UNESCAP for attaining inclusive and sustainable economic and social development in the region.

UNESCAP supports member States to overcome the regional challenges by offering results oriented projects, technical assistance and capacity building. The smaller and often left out voices of the region such as the least developed countries, the small island States and landlocked States, are also of strong interest in participation for UNESCAP. In addition, UNESCAP promotes rigorous analysis and peer learning in the area of work, translates these findings into policy dialogues and recommendations, and provides development practices, knowledge sharing and technical assistance to member States in the implementation of these recommendations. UNESCAP uses its convening power to bring countries together to address issues through regional cooperation—that is, issues that all or a group of countries in the region face, for which it is necessary to learn from each other, issues that benefit from regional or multi-country involvement, issues that are transboundary in nature, or that would benefit from collaborative inter-country approaches, and issues that are of a sensitive or emerging nature and require further advocacy and negotiation.

Enhancing regional connectivity by transport is essential in the Asia-Pacific region, in that trade activities within the region reach only more than half of ones in Europe and North America. However, two different bottlenecks are observed for the transport connectivity across the region—that is, poor quality transport infrastructure and non-physical barriers. For the former, there is a need for better intraregional transport systems through regional initiatives for improved infrastructure within member States. UNESCAP also makes an effort on strengthening the connectivity, utilizing existing infrastructure and enhancing the level of integration among different transport modes by supporting the development of an intermodal regional network, including the networks of the Asian Highway, Trans-Asian Railway and Dry Ports. For the latter, UNESCAP tackles non-physical hindrances to cross-border and transit transport of vehicles, goods and people through regional facilitation frameworks, facilitation agreements, models, standards and tools. Besides, UNESCAP contributes in developing transport logistics policies, improving the skills of logistics service providers and transport professionals.

In addition to enhancing the transport connectivity, UNESCAP helps improve rural connectivity, mobility, ITS and road safety to provide positive impact of connectivity to the environment and society. UNESCAP is also aware of benefits using ICT for the sustainable transport as a form of ITS, and helps publicize the potentials of ITS for transport challenges in fast growing areas in the region. As an intergovernmental platform, UNESCAP supports its member States in terms of transport in building national capacities, developing policies and programmes, regulatory and institutional frameworks, and partnerships and agreements, and reviewing progress in achieving the internationally agreed development goals and targets adopted at global and regional conferences.

Considering UNESCAP's roles in the region, possible policy framework would play a key role to enhance ITS developments and implementations.

2. Guiding principles for ITS policy recommendations in the region

As the first endeavour to develop the policy framework by UNESCAP, defining clear principles that govern the extent and features of policy recommendations for the framework would be useful to give them more practicality and usefulness.

The guiding principles are as follows:

- Be considerate: Given that each country has different circumstances, taking account of the diversity of Asian and Pacific countries is necessary for ITS utilization, as well as each member country's expectations should be met effectively.

- Be multi-sectoral: Because ITS are not only technical but also organizational and institutional in nature, proposed policy recommendations should consider diverse aspects of these features of ITS.

- Be compatible: Considering that numerous ITS initiatives and plans are found in many countries in the region, UNESCAP's recommendations for ITS enhancements should be harmonized and in sync with local attempts, not ostracize them.

- Be cohesive: UNESCAP has its mandates, roles and visions. UNESCAP sets up Regional Action Programmes for next five years to attain the 2030 Agenda for Sustainable Development. The ITS policy recommendations from UNESCAP should be reconciled with them under this boundary.

- Be effective: Given that recent traffic issues become more transboundary and complicated, UNESCAP's recommendations should be practical, feasible, and fruitful in order to guide regional actions for ITS roll-outs effectively.

- Be unique: Considering that UNESCAP provides particular functions as the largest intergovernmental platform in the region, policy recommendations from UNESCAP should be distinctive that only UNESCAP can propose to enhance ITS roll-outs in the Asia-Pacific region.

Complying with these principles will make the ITS policy recommendations proposed in this report more persuasive, thereby, encouraging the follow-up actions from member countries and UNESCAP.

B. Details of Regional Policy Recommendations

A set of recommendations are proposed with consideration of status, challenges, benefits and technological trends identified in previous Chapters, roles of UNESCAP and guiding principles for ITS policy recommendations. Two areas are chosen as a priory for policy recommendations to enhance ITS deployments in the Asia-Pacific region.

1. Regulatory framework for the use of ITS in the Asia-Pacific region

A rule and regulation for ITS is a statement or procedure broadly governing the compliance implementation, operations and management standards and requirements relating to ITS services. Although rules and regulations are prerequisite for efficient and seamless ITS services in the region, many challenges are noticed from literature reviews and fact-finding missions. Representative examples of challenges are listed as follows:

- Increasing legal and regulatory issues related to ITS
- Complicated regulatory environment by various ITS stakeholders
- Different types of rules, regulations and laws for ITS implementation
- Lack of guidelines or frameworks associated with legal and regulatory issues for ITS
- Limited attentions and capacity in Asia and the Pacific
- Lack of intergovernmental leadership and regional cooperation

Given that advanced forms of ITS (i.e. C-ITS and autonomous vehicles) have been already considered in several cities of the region, more regulatory issues are expected to arise with complicated dynamics. The lack of good regional guidelines or frameworks about regulatory issues, in this regard, poses an obstacle to ITS roll-outs in the region. The main bottleneck for such challenges is low awareness, understanding and capacity of rules, regulations and laws for ITS. In order to facilitate efficient seamless movements of people and freight crossing in the borders with ITS technologies, even in countries where proper ITS policies and plans exists, related rules, regulations and laws for the use of ITS require being taken into account and harmonized for the consistent ITS services in the Asia-Pacific region.

The primary objective of this regulatory framework is to foster the integrated approach by government to the development and adoption of ITS-related rules, regulations and laws, as well as to increase the private sectors' attentions on such matters. This framework mainly will:

- Analyse and produce an overview of status of rules, regulations and laws to make a regulatory framework for implementing ITS services in both developed and less-developed ITS countries.
- Explore new ITS technologies with a view for recognizing potential regulatory issues that needs suitable regional cooperation and preparedness.
- Provide a set of regulatory recommendations that member States can refer to tackle regulatory issues for ITS services.
- Propose relevant policy recommendations along with a regulatory framework that can help adopt and utilize the regulatory recommendations properly.
- Guide the consistent implementation, integration and uptake of ITS from the regulatory perspective across member countries.

The regulatory framework will be disseminated to stakeholders involved in ITS and will ensure that efforts dealing with regulatory issues would not be duplicated but harmonized by stakeholders and governments. Strategic positioning of each member country for regulatory issues is expected from this framework which is also valuable to increase the streamlined ITS services among countries.

2. Strategic framework for traffic management center in the Asia-Pacific region

Traffic management centers (TMCs) serve as a control tower for major roads in a city and highway networks. TMCs monitor traffic signals, roads, intersections, incidents and any other issues that interfere smooth traffic flows. Traffic management plans and strategies are proactively implemented through TMCs to decrease traffic congestion and coordinate other authorities during incidents, emergencies or recurrent delays. Further, TMCs play a significant role to operate and manage various ITS applications, such as real-time traffic information system, parking guidance and information system, adaptive signal control system, automatic traffic enforcement system, traffic incident management system and automatic vehicle location system.

Despite such important role of TMCs, many relevant challenges are found in the region as listed below:

- Increasing usable information and data from various ITS sources
- Limited aggregation and provision of ITS information and data by TMCs
- Lack of harmonization and integration of ITS applications
- Segregated connection among TMCs
- Lack of overarching frameworks and/or policies for TMCs
- Shortage of expertise and experiences on TMCs
- Necessity of strategic process for operations and management with TMCs

As emphasized above, new ITS technologies are ever-growing which require more functions and roles from TMCs. For instance, in smart cities, innumerable information and data would be collected from various kinds of devices, processed and disseminated to the users through the TMC. All activities in a city, including each vehicle's movement, need to be monitored and controlled by the TMC to enhance energy efficiency, safety and dwellers' quality of life. To be prepared for upcoming needs and overcome regional challenges identified in this report, the regional strategic framework for TMC is suggested that can include, but not limited to, the following components:

- Identification of current status and necessary functions, roles and supporting policies for TMCs with consideration of regional transport features.
- Guidance of effective roles and responsibilities for associated agencies to conduct strategic operations and management by TMCs.
- Provision of detailed types of ITS applications (including potential applications newly developed) that can be incorporated with TMCs.
- Considerations of technical and/or non-technical harmonization of information and data distributed through TMCs.
- Recommendations of regional policies and plans to establish integrated TMCs for seamless ITS services.

The ultimate goal of this strategic framework is to surmount the imbalanced development of TMCs in the Asia-Pacific region, and to provide concordant, integrated and structured guidelines relating to TMCs. Further, suitable preparedness is pursued in response to rising needs produced by new ITS technologies.

8

CONCLUSIONS

ITS have been constantly evolving with a fast pace of technology innovations. Numerous ITS solutions and tools are developed with a deluge of data sources, information and techniques. It is well acknowledged that ITS can contribute to optimize transport infrastructure and provide pleasant journey services to users. ITS have been implemented to enhance the mobility, and efficiency of system, thereby attaining the goals of transport policies. Further, in recent years, a new trend for ITS developments, such as big data, open access, connected vehicles, and autonomous vehicles, grabs the attentions. With an increasing number of ITS-related national or local initiatives, demands for new mobility services and applications are continuously growing in the Asia-Pacific region.

However, although adopting ITS technologies is getting widespread in the Asia-Pacific region to resolve traffic issues, a policy gap among member States still remains which results in fragmented and inconsistent services to users. Given that technologies are getting smarter and ITS services become diverse, prompt actions are required to respond to current ITS issues and newly coming changes in transport ecosystem from the policy perspective.

As the first endeavour for ITS from UNESCAP, the policy framework was proposed through understanding of ITS developments in the Asia-Pacific region. To be specific, first, this report broadly explored specific ITS applications for road transport currently in use in the region. Second, an overview of new trend of technologies for transport systems around the globe was provided. Third, regional challenges and issues in ITS developments and implementations were extensively examined by reviewing the literature and fact-finding missions (China, Malaysia, Republic of Korea, Singapore and Viet Nam). Fourth, general benefits from ITS applications that can be frequently observed in the region were identified. Lastly, considering identified problems, benefits and new technologies for transport systems, possible policy recommendations to enhance the use and deployment of ITS for road transport were provided on the basis of proposed guiding principles.

Even though ITS are not the panacea for relieving all traffic issues, ITS have been regarded as one of the most effective tools with reasonable costs. Countries and their cities in the region would benefit from being strategically positioned to take advantage of well-established ITS policies. Although the policy framework proposed from this report cannot cover all matters that need to be considered for the region, this would be the good trigger to open the door for further discussions and activities to benefit from ITS technologies across Asia and the Pacific. In addition, because ITS can be applied to all areas of transport including maritime and railway, based on the proposed policy framework, more studies need to be considered encompassing all areas of transport. Nevertheless, being able to have access to ITS benefits and potentials through the policy framework would serve as a huge step forward in the contribution of sustainable transport towards sustainable development goals.

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